

Master Beekeeper Certification Mock Examination

365 Questions with Answer Key, Rationale and References · Southeastern United States

Ver. 2.3, October 2026 · Companion to the Master Beekeeper Certification Study Guide, Ver. 2.5

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This document is a result of organizing and researching many online resources, combined with study materials from conferences, reading lists, as well as presentations made by me to local groups and at State conferences. These references are listed in the companion document, the Master Beekeeper Certification Study Guide.

To assist in the creation of this Master Beekeeper Certification Mock Examination, A.I. has been used. A word of warning, while A.I. is great at organizing and managing information, it can make mistakes, sometimes convincingly. The core information contained here has been passed through A.I. multiple times to confirm the validity of the information however it is up to the reader to double check facts contained here. Additionally, science changes. What was once an accepted fact becomes dated and replaced by newer scientific discoveries. Accepted treatments change, approved treatments are replaced or outlawed. Therefore, the reader, as a prospective Master Beekeeper, should always perform due diligence to ascertain the validity of any information contained here.

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Edited and compiled by Larry Coble, Eastern Apicultural Society Master Beekeeper

How to Use This Mock Examination

This book combines the 365-question examination and its answer key into a single volume, arranged section by section. Each of the twenty sections is presented in two parts:

Part A — Questions. The section's questions exactly as they appear on the examination.

Part B — Answer Key. Beginning on a new page, the correct answer (or a model answer for short-answer items), the rationale and the references for the same questions.

Work through Part A as a self-test, writing your answers to the short-answer items on the lines provided, before turning to Part B. Then read every rationale, including those for the items you answered correctly: the rationale explains why each answer matters in practice and, for multiple-choice items, why the other options fail. Keeping Part B covered while you work Part A makes each section a complete practice test.

The companion Master Beekeeper Certification Study Guide (Ver. 2.5) teaches each section in the chapter of the same number, and the two books are kept in agreement: where a figure or a source changes, both are corrected together.

About the Examination

Instructions: This examination contains 365 questions across 20 domains of apicultural knowledge, in three formats:

(MC) Multiple Choice – select the single best answer

(TF) True/False

(SA) Short Answer – answer in a short paragraph; items may require more than one element for full credit

This examination sits above an intermediate exit examination. It assumes that the candidate already knows what a competent beekeeper does, and tests instead whether they understand why it works: the mechanisms behind the practices, the reasoning that connects an observation to a decision, and the quantitative steps that turn a measurement into an action. Several items require the candidate to distinguish among competing explanations rather than to name a single condition.

Questions are framed for United States practice. Region-specific items refer to the southeastern US and to its physiographic divisions — the coastal plain, the piedmont, the southern Appalachian Mountains and the Gulf coastal areas — rather than to individual states, since apiary law, registration requirements, and cottage food rules differ from state to state and must be checked locally.

Questions are numbered continuously 1–365. In this book the answer key for each section follows that section's questions, giving the correct answer, an explanatory rationale and references for every item.

Good luck.

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Section 1: Honey Bee Biology, Anatomy & Physiology (Q1–27)

Part A — Questions

1. **(MC)** The transition of a worker bee from in-hive tasks to foraging is regulated principally by:
 - **A)** Hormonal state interacting with colony demand, with vitellogenin falling and juvenile hormone rising, so that the age of first foraging shifts according to what the colony needs
 - **B)** Direct recruitment by returning foragers, who select individual house bees and lead them to the field, so the transition depends on how many foragers are currently active
 - **C)** An internal developmental clock that fixes first foraging at about three weeks of age, so the transition proceeds on the same schedule whatever the colony's population or forage
 - **D)** Cumulative flight-muscle development, so that a bee begins foraging once her thoracic muscles reach full mass, a threshold reached at a fixed age irrespective of hormonal state
2. **(SA)** Name the storage protein produced in the fat body whose level is high in nurse bees and in winter bees and low in foragers, and state two functions attributed to it.
3. **(MC)** Winter bees, sometimes called diutinus bees, differ from summer workers chiefly in that they:
 - **A)** Are the final brood cycle's drones, retained through the cold months because the colony draws on their body mass to help maintain the temperature of the winter cluster
 - **B)** Are ordinary summer workers that survive longer only because cold slows their metabolism, so their lifespan reverts to normal as soon as brood rearing resumes in spring
 - **C)** Are physiologically distinct, with enlarged fat bodies, high vitellogenin and low juvenile hormone, which together allow them to live for months rather than for weeks
 - **D)** Are reared from a distinct class of egg that the queen lays only in autumn, which develops into a separate long-lived form under the shortening photoperiod of late season
4. **(SA)** Explain how sex is determined in honey bees, and describe what happens to a fertilized egg that is homozygous at the sex-determining locus.
5. **(MC)** Caste determination in honey bees is best described as:
 - **A)** Genetic: queens develop from eggs fertilized by a distinct class of drone whose sperm carries the alleles that produce the queen phenotype in the resulting female larva
 - **B)** Positional: a larva placed in a cell hanging vertically develops as a queen, while the same larva in a horizontal cell develops as a worker regardless of how it is fed
 - **C)** Nutritional and developmental: queen and worker arise from identical fertilized eggs, and the quantity, composition and duration of larval feeding direct the two pathways
 - **D)** Thermal: queen cells are held two to three degrees warmer than worker cells, and the elevated temperature during pupation produces the queen's ovaries and larger body size
6. **(MC)** The wax glands of a worker bee are located on the:
 - **A)** Sternites of the abdomen as four pairs, reaching peak development at roughly twelve to eighteen days of age though the glands can be reactivated later when comb is needed

- **B)** Tergites of the abdomen as three pairs, developing at emergence and regressing permanently once the bee has completed her first week of comb-building work in the colony
- **C)** Pleural region of the thorax, adjacent to the wing bases, where the secreted scales are passed forward to the mandibles by the middle pair of legs during comb construction
- **D)** Base of the mandibles, alongside the glands producing brood food, which is why the same young bees both feed larvae and build comb during the same period of adult life

7. (SA) Name the glands that produce brood food, describe how they change with worker age, and state one condition that causes them to atrophy prematurely.

8. (MC) The proventriculus lies between the crop and the midgut and functions to:

- **A)** Secrete invertase into the nectar as it passes from the crop, beginning the conversion of sucrose to glucose and fructose before the load is delivered to a house bee
- **B)** Filter pollen grains and other particles out of the crop contents and pass them into the midgut, allowing relatively particle-free nectar to be carried and regurgitated
- **C)** Secrete the enzymes that digest pollen protein, so that the particles leaving the crop reach the midgut already partly digested and ready for absorption
- **D)** Concentrate the nectar by resorbing water into the hemolymph during the return flight, so that the load delivered to the colony is already partly ripened on arrival

9. (TF) Honey bees have an open circulatory system, and oxygen is carried to the tissues by a respiratory pigment dissolved in the hemolymph, which the dorsal vessel pumps through the body.

True / False

10. (MC) A worker honey bee possesses ten pairs of spiracles. The pair of particular diagnostic importance is:

- **A)** The three pairs on the propodeum, which regulate the airflow used in evaporative cooling and which become blocked by wax scales in heavily propolized colonies
- **B)** The second thoracic pair, which lies directly beneath the wing base and through which tracheal mites are drawn into the flight muscle when the bee begins to fly
- **C)** The first thoracic pair, which is the route by which *Acarapis woodi* enters young adult bees to colonize the prothoracic tracheae during the first days of adult life
- **D)** The final abdominal pair, through which *Nosema* spores are voided in the feces and by which the infection is transmitted to nestmates cleaning contaminated comb surfaces

11. (SA) Describe how a colony maintains brood nest temperature, naming both the warming and the cooling mechanisms, and state the temperature range maintained.

12. (MC) Queen mandibular pheromone is significant to colony management because it:

- **A)** Is distributed by contact and food sharing and inhibits queen rearing and worker ovary development, so that crowding, by lowering the amount received per bee, reduces queen cell building
- **B)** Is deposited by the queen directly onto each comb she walks across, so that a colony which has outgrown its combs no longer receives the signal across the whole of its brood nest
- **C)** Is emitted only during the queen's daily circuit of the brood nest, so that any interruption to her movement immediately halts all queen rearing throughout the colony

- **D)** Is produced in proportion to the colony's population, so that a large colony generates more of it and the increased concentration is itself the trigger for swarm preparation

13. (MC) Alarm pheromone released when a bee stings or is alarmed:

- **A)** Includes isopentyl acetate among its components, is released from glands associated with the sting apparatus, and marks the target so further defenders are recruited to that spot
- **B)** Consists chiefly of geraniol and citral released from the Nasonov gland, and is fanned into the air so that defenders can locate the source of a disturbance at the entrance
- **C)** Is released only by bees that have actually stung, so that a colony disturbed without any stings being delivered shows no escalation of its defensive response at all
- **D)** Is a single volatile compound produced in the mandibular glands of guard bees, which disperses rapidly and recruits defenders to the colony entrance rather than to the target

14. (SA) Explain the two mechanisms by which smoke calms a colony.

15. (MC) A queen's spermatheca:

- **A)** Produces the eggs themselves, which pass down the lateral oviducts and are fertilized only when the queen encounters a cell of the appropriate width during her laying circuit
- **B)** Stores sperm that is replenished on subsequent mating flights each spring, which is why a queen's fertility can recover after a season of producing patchy or drone-heavy brood
- **C)** Secretes queen mandibular pheromone, which is transferred to attendant workers during grooming and then distributed through the colony by contact and by food exchange
- **D)** Stores spermatozoa acquired during her mating flights, releasing sperm to fertilize eggs laid in worker-sized cells, and the stored supply must last her entire productive life

16. (TF) Worker bees possess ovarioles and can activate their ovaries, but in a queenright colony this is suppressed by the combined action of queen pheromone and open brood pheromone, and any worker-laid eggs are largely removed by other workers.

True / False

17. (MC) Which statement about drone reproductive biology is correct?

- **A)** Drones mate with the queen inside the hive shortly before she departs on her orientation flight, which is why a colony rearing a queen must also be rearing drones at that time
- **B)** Drones reach sexual maturity roughly twelve to sixteen days after emergence, fly to congregation areas on warm afternoons, and die upon mating; a queen mates with a dozen or more
- **C)** Drones mature within three days of emergence and mate repeatedly across successive flights, surviving each mating, which is why a single strong drone source can father many queens
- **D)** Drones deposit sperm on the comb near sealed queen cells, and the emerging virgin acquires it there, which is the reason drone brood is reared close to the queen cells

18. (SA) Explain why the workers in a single colony are not all full sisters, and give one colony-level advantage that results.

19. (MC) The principal sugar circulating in honey bee hemolymph is:

- **A)** Fructose bound to a specific hemolymph transport protein, which releases it at the thoracic muscles and accounts for the bee's tolerance of very high sugar loads

- **B)** Sucrose absorbed unchanged from the crop and transported intact to the flight muscles, where it is hydrolyzed at the point of use by muscle-bound invertase
- **C)** Glucose, maintained at a concentration comparable to vertebrate blood sugar and buffered by the fat body, which releases stored glycogen as flight demand increases
- **D)** Trehalose, a non-reducing disaccharide that can be carried at high concentration without damaging hemolymph proteins and is mobilized rapidly at the flight muscle

20. (MC) The rectum and rectal pads of the honey bee are significant because they:

- **A)** Complete the digestion of pollen after it leaves the ventriculus, which is why beebread that has not been properly acidified in the cell passes through largely unused by the bee
- **B)** Store nectar during transport, functioning as a secondary crop that allows a forager to carry a larger load than the honey stomach alone would otherwise permit
- **C)** Resorb water and salts from the fecal mass, permitting retention of feces during periods when bees cannot fly, which is why stores with a high indigestible fraction cause dysentery
- **D)** Secrete the peritrophic membrane that lines the gut, protecting the epithelium from abrasion by pollen grains and forming the barrier that *Nosema* must cross to infect

21. (SA) Name the two enzymes added to nectar by worker bees that are central to honey formation, and state what each does.

22. (TF) Honey bee color vision is trichromatic with sensitivity in the red, yellow and blue, so bees discriminate red flowers especially well while being insensitive to ultraviolet light.

True / False

23. (MC) Bee venom is dominated by which component, and what is its principal effect?

- **A)** Melittin, which makes up roughly half the venom's dry weight and is a membrane-disrupting peptide responsible for much of the immediate pain and the local tissue effect
- **B)** Phospholipase A2, which accounts for roughly half the dry weight and produces the immediate burning pain, while also being the principal allergen in sensitized individuals
- **C)** Hyaluronidase, which comprises most of the venom by mass and causes pain directly by degrading the connective tissue matrix at the site where the sting is delivered
- **D)** Formic acid, which constitutes the bulk of the venom and produces the characteristic burning sensation, with the peptide fraction contributing only the swelling that follows

24. (MC) Approximate developmental periods from egg to emergence are:

- **A)** Queen 14 days, worker 21 days, drone 26 days, with capping at roughly day 7 for the queen, day 9 for the worker and day 11 for the drone
- **B)** Queen 16 days, worker 21 days, drone 24 days, with capping at roughly day 8 for the queen, day 9 for the worker and day 10 for the drone
- **C)** Queen 21 days, worker 16 days, drone 24 days, with capping at roughly day 9 for the queen, day 8 for the worker and day 10 for the drone
- **D)** Queen 16 days, worker 24 days, drone 21 days, with capping at roughly day 8 for the queen, day 10 for the worker and day 9 for the drone

25. (SA) A colony has abundant capped honey but brood rearing has stopped in midsummer despite warm weather and a laying queen. Give the two most likely nutritional explanations and the observation that distinguishes them.

26. (MC) The corbicula, or pollen basket, and the associated pollen press function to:

- **A)** Compress pollen combed from the body and extrude it onto the concave outer surface of the hind tibia, where a stiff central hair and a little nectar hold the load in place
- **B)** Filter pollen out of the nectar carried in the crop and transfer it to the outer surface of the hind leg, which is why foragers return with both loads simultaneously
- **C)** Comb pollen from the body hairs and pack it directly into the cell, which is why corbicular loads are deposited dry and must be moistened by house bees before storage
- **D)** Moisten pollen with glandular secretion and compress it into the pellet, the secretion supplying the enzymes that later acidify the beebread once it is packed in the cell

27. (SA) Explain what beebread is, how it differs from freshly collected pollen, and why the distinction matters to a beekeeper assessing a colony.

Part B — Answer Key: Section 1

1. (MC) The transition of a worker bee from in-hive tasks to foraging is regulated principally by:

Answer: A) Hormonal state interacting with colony demand, with vitellogenin falling and juvenile hormone rising, so that the age of first foraging shifts according to what the colony needs

Rationale: Age polyethism is a flexible default rather than a fixed schedule. A colony that loses its foragers produces precocious foragers from young bees; a colony that loses its nurses can push foragers back into brood care. The hormonal correlates matter practically because anything that damages the physiological state of developing bees, such as heavy mite parasitism or poor nutrition, distorts this system and produces short-lived, poorly performing adults.

References: Winston, *The Biology of the Honey Bee*, Harvard Univ. Press, 1987; Robinson, *Annu. Rev. Entomol.* 37:637-665 (1992); Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

2. (SA) Name the storage protein produced in the fat body whose level is high in nurse bees and in winter bees and low in foragers, and state two functions attributed to it.

Model answer: Vitellogenin. Functions include serving as a protein and amino acid reserve drawn upon for brood food production, acting as an antioxidant that contributes to the extended lifespan of winter bees, supporting immune function, and contributing to the regulation of the transition to foraging through its interaction with juvenile hormone.

Rationale: Vitellogenin is the practical link between nutrition, mite damage and overwintering success. Bees reared under heavy Varroa pressure or with inadequate autumn pollen have depressed vitellogenin, which is why a colony can appear populous in early autumn and still fail to reach spring. Understanding the mechanism explains why the late-summer mite threshold is the decisive management point of the year.

References: Amdam et al., *Exp. Gerontol.* 39:767-773 (2004); Somerville, *Fat Bees Skinny Bees*, RIRDC Publication 05/054, 2005.

3. (MC) Winter bees, sometimes called diutinus bees, differ from summer workers chiefly in that they:

Answer: C) Are physiologically distinct, with enlarged fat bodies, high vitellogenin and low juvenile hormone, which together allow them to live for months rather than for weeks

Rationale: They are the same genotype in a different physiological state, produced when brood rearing declines and autumn pollen is abundant. Two conditions promote their production: a reduction in open brood, which removes the drain on vitellogenin reserves, and good late-season protein intake. In the southeastern US the corollary is important, because colonies that continue heavy brood rearing late, or that face a poor autumn pollen supply, produce physiologically summer-type bees that will not carry the colony through.

References: Mattila, Harris & Otis, *Insectes Soc.* 48:88-93 (2001); Amdam et al., *Exp. Gerontol.* 39:767-773 (2004).

4. (SA) Explain how sex is determined in honey bees, and describe what happens to a fertilized egg that is homozygous at the sex-determining locus.

Model answer: Honey bees use haplodiploidy governed by a single sex-determining locus. Unfertilized eggs are haploid and develop as drones. Fertilized eggs that are heterozygous at that locus develop as females, either workers or queens depending on larval nutrition. A fertilized egg that happens to be homozygous at the locus develops as a diploid drone, which nurse bees detect and cannibalize within hours of hatching, so the cell appears empty.

Rationale: This is the mechanism behind the spotty, so-called shot brood pattern seen with inbreeding: the queen is laying normally, the eggs hatch, and the larvae are removed too quickly for the beekeeper to see. The diagnostic clue is a scattered pattern with no disease signs, no odor, no ropiness and negligible mite counts. The remedy is unrelated genetics, not requeening from the same line.

References: Woyke, *J. Apic. Res.* 2:19-24 (1963); Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997.

5. (MC) Caste determination in honey bees is best described as:

Answer: C) Nutritional and developmental: queen and worker arise from identical fertilized eggs, and the quantity, composition and duration of larval feeding direct the two pathways

Rationale: The same genotype produces two very different phenotypes, which is why caste is a standard example of nutritionally driven developmental plasticity. The practical consequences run through queen rearing: larval age at grafting determines how long the larva receives queen-type feeding before development diverges, and queens started from larvae older than about three days are measurably inferior in ovariole number, spermatheca size and weight.

References: Winston, *The Biology of the Honey Bee*, Harvard Univ. Press, 1987; Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997.

6. (MC) The wax glands of a worker bee are located on the:

Answer: A) Sternites of the abdomen as four pairs, reaching peak development at roughly twelve to eighteen days of age though the glands can be reactivated later when comb is needed

Rationale: Wax production is energetically expensive and requires a warm cluster and abundant carbohydrate, which is why comb is drawn readily during a flow and poorly during a dearth. The reversibility of gland development explains why a colony can be induced to draw comb outside the normal window by heavy feeding, and why a package composed mainly of older bees is initially slow to build.

References: *Snodgrass, Anatomy of the Honey Bee, Cornell Univ. Press, 1956; Hepburn, Honeybees and Wax, Springer, 1986.*

7. (SA) Name the glands that produce brood food, describe how they change with worker age, and state one condition that causes them to atrophy prematurely.

Model answer: The hypopharyngeal glands, assisted by the mandibular glands. They enlarge over roughly the first week to ten days of adult life, when the bee is functioning as a nurse and producing brood food rich in protein, then regress as the bee shifts to foraging, at which point the secretion changes toward carbohydrate-processing enzymes such as invertase. Premature atrophy is caused by pollen deprivation, and also by *Vairimorpha* (*Nosema*) infection, heavy *Varroa* parasitism and some pesticide exposures.

Rationale: Gland development is therefore a physiological readout of colony nutrition, which is why a colony short of pollen cannot rear brood no matter how much honey it holds. The regression is reversible, so a colony deprived of nurses can bring foragers back into brood care.

References: *Crailsheim & Stolberg, J. Insect Physiol. 35:595-602 (1989); Somerville, Fat Bees Skinny Bees, RIRDC Publication 05/054, 2005.*

8. (MC) The proventriculus lies between the crop and the midgut and functions to:

Answer: B) Filter pollen grains and other particles out of the crop contents and pass them into the midgut, allowing relatively particle-free nectar to be carried and regurgitated

Rationale: This valve is what makes nectar transport possible: a forager can carry a crop load without digesting it. Its filtering action also means that pollen collected incidentally in nectar is removed before the nectar is passed to house bees, which is one reason honey contains relatively little pollen compared with the amount of foraging involved. The valve also meters how much of the crop load passes on to the midgut, which is how the forager fuels her own flight, but it secretes no digestive enzymes; digestion begins in the midgut.

References: *Snodgrass, Anatomy of the Honey Bee, Cornell Univ. Press, 1956; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

9. (TF) Honey bees have an open circulatory system, and oxygen is carried to the tissues by a respiratory pigment dissolved in the hemolymph, which the dorsal vessel pumps through the body.

Answer: False

Rationale: The circulatory system is indeed open and the dorsal vessel does circulate hemolymph, but hemolymph carries no oxygen-transport pigment. Oxygen reaches the tissues directly through the tracheae and air sacs supplied by the spiracles. Two practical points follow: tracheal mite damage acts locally on gas delivery rather than through a circulating deficit, and carbon dioxide narcosis is rapid and reversible, which is what makes it usable for anesthetizing queens.

References: Snodgrass, *Anatomy of the Honey Bee*, Cornell Univ. Press, 1956; Sammartaro, Gerson & Needham, *Annu. Rev. Entomol.* 45:519-548 (2000).

10. (MC) A worker honey bee possesses ten pairs of spiracles. The pair of particular diagnostic importance is:

Answer: C) The first thoracic pair, which is the route by which *Acarapis woodi* enters young adult bees to colonize the prothoracic tracheae during the first days of adult life

Rationale: Tracheal mites enter only during a narrow window in the first few days of adult life, which explains why transmission depends on close contact with very young bees and why colony age structure influences spread. It also explains why diagnosis requires dissection of the prothoracic trachea rather than external examination, and why finding *Acarapis* mites on the outside of a bee proves nothing, since two non-pathogenic external *Acarapis* species also occur.

References: Shimanuki & Knox, *Diagnosis of Honey Bee Diseases*, USDA Agriculture Handbook 690, 2000; Sammartaro, Gerson & Needham, *Annu. Rev. Entomol.* 45:519-548 (2000).

11. (SA) Describe how a colony maintains brood nest temperature, naming both the warming and the cooling mechanisms, and state the temperature range maintained.

Model answer: The brood nest is held at roughly 34 to 35 degrees C, about 93 to 96 degrees F. Warming is accomplished by workers contracting their flight muscles without moving the wings, generating heat that is transferred by pressing the thorax against cell cappings or by entering empty cells within the brood area and warming adjacent capped cells through the shared walls. Cooling is accomplished by collecting water, spreading it in thin films on comb surfaces and cell rims, and fanning to promote evaporation, together with fanning to move air through the hive and, at high loads, by surplus bees moving outside the hive.

Rationale: The narrowness of the range is what makes it examinable: brood reared even a degree below optimum yields adults with impaired learning and shortened lifespan, which is a practical argument for keeping cool-weather inspections brief and for never splitting a brood nest across boxes in cold weather.

References: Kleinhenz, Bujok, Fuchs & Tautz, *J. Exp. Biol.* 206:4217-4231 (2003); Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

12. (MC) Queen mandibular pheromone is significant to colony management because it:

Answer: A) Is distributed by contact and food sharing and inhibits queen rearing and worker ovary development, so that crowding, by lowering the amount received per bee, reduces queen cell building

Rationale: This mechanism is the biological bridge between congestion and swarming, and it explains why relieving crowding is genuine swarm control while cutting cells is not. It also explains supersedure in an aging or injured queen. A second queen signal, tarsal or footprint pheromone deposited as she walks the comb, contributes by inhibiting queen cup development on the comb face.

References: *Free, Pheromones of Social Bees, Chapman & Hall, 1987; Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

13. (MC) Alarm pheromone released when a bee stings or is alarmed:

Answer: A) Includes isopentyl acetate among its components, is released from glands associated with the sting apparatus, and marks the target so further defenders are recruited to that spot

Rationale: The practical consequences are immediate. A sting on clothing or a glove marks that spot and draws further stings, so the area should be smoked or the item removed. Crushing bees during manipulation releases the same signal, which is one reason careful handling and light smoke reduce defensive escalation. The banana-like odor is a useful field cue that a colony's tolerance has been exceeded.

References: *Free, Pheromones of Social Bees, Chapman & Hall, 1987; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

14. (SA) Explain the two mechanisms by which smoke calms a colony.

Model answer: Smoke masks and disrupts the perception of alarm pheromone, so the recruitment of defenders is interrupted. The traditional explanation is that smoke also triggers a feeding response in which bees engorge on honey, which occupies them and leaves them less able to flex the abdomen to sting; this is widely taught but has not been demonstrated experimentally. Cool white smoke applied lightly at the entrance and under the cover, then given a moment to act, is far more effective than a heavy volume, and hot or excessive smoke drives bees off the combs and can provoke rather than calm.

Rationale: A candidate should also note that smoke taints hive products if used heavily around supers, that fuel must be free of treated or painted material, and that in the pine landscapes of the southeastern US a smoldering smoker is a genuine wildfire hazard requiring careful extinguishing and transport.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammataro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

15. (MC) A queen's spermatheca:

Answer: D) Stores spermatozoa acquired during her mating flights, releasing sperm to fertilize eggs laid in worker-sized cells, and the stored supply must last her entire productive life

Rationale: Because the supply is finite and is never replenished, a queen who mated poorly, or whose stored sperm has been damaged, becomes a drone layer. Damage to stored sperm can be caused by temperature extremes during shipping with no visible sign in the queen, which is a leading suspected cause of early supersedure and of partial drone-laying in queens that appeared sound on arrival.

References: Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997; Pettis, Rice, Joselow, vanEngelsdorp & Chaimanee, *PLoS ONE* 11:e0147220 (2016).

16. (TF) Worker bees possess ovarioles and can activate their ovaries, but in a queenright colony this is suppressed by the combined action of queen pheromone and open brood pheromone, and any worker-laid eggs are largely removed by other workers.

Answer: True

Rationale: Both signals are required, which is why laying workers appear only after prolonged queenlessness with no young brood, and why giving repeated frames of open brood to a laying-worker colony can suppress the condition. The removal of worker-laid eggs by nestmates is why a beekeeper rarely sees worker-laid brood in a colony that has been queenless only a short time.

References: Hoover et al., *Naturwissenschaften* 90:477-480 (2003); Winston, *The Biology of the Honey Bee*, Harvard Univ. Press, 1987.

17. (MC) Which statement about drone reproductive biology is correct?

Answer: B) Drones reach sexual maturity roughly twelve to sixteen days after emergence, fly to congregation areas on warm afternoons, and die upon mating; a queen mates with a dozen or more

Rationale: The maturation interval matters to anyone rearing queens: drone mother colonies must be established well ahead of the mating window, since a drone needs about 24 days from egg to emergence plus roughly two more weeks to mature. Multiple mating is also why open-mated daughters do not reproduce a purchased queen's traits reliably.

References: Koeniger, Koeniger, Ellis & Connor, *Mating Biology of Honey Bees*, Wicwas, 2014; Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997.

18. (SA) Explain why the workers in a single colony are not all full sisters, and give one colony-level advantage that results.

Model answer: Because the queen mates with many drones and stores their sperm mixed together, her daughters comprise several patriline. Workers sharing the same father are full sisters, related by three quarters because they share the father's entire haploid genome, while workers with different fathers are half sisters related by one quarter. The resulting genetic diversity confers colony-level advantages including more precise thermoregulation, better disease resistance, more consistent foraging performance and greater overall productivity.

Rationale: The mechanism behind the thermoregulation advantage is that patriline differ in the temperature at which they begin fanning or clustering, so a diverse colony responds in a graded rather than an all-or-nothing way and holds the brood nest within a narrower band.

References: Mattila & Seeley, *Science* 317:362-364 (2007); Jones, Myerscough, Graham & Oldroyd, *Science* 305:402-404 (2004).

19. (MC) The principal sugar circulating in honey bee hemolymph is:

Answer: D) Trehalose, a non-reducing disaccharide that can be carried at high concentration without damaging hemolymph proteins and is mobilized rapidly at the flight muscle

Rationale: Trehalose depletion is the physiological definition of flight fuel exhaustion, which is why foragers caught out in a sudden cold snap or confined without food collapse abruptly. It also explains why a starving colony deteriorates so quickly once stores are exhausted: there is no substantial energy reserve outside the stored honey and the small amount circulating.

References: Blatt & Roces, *J. Exp. Biol.* 204:2709-2716 (2001); Goodman, *Form and Function in the Honey Bee*, IBRA, 2003.

20. (MC) The rectum and rectal pads of the honey bee are significant because they:

Answer: C) Resorb water and salts from the fecal mass, permitting retention of feces during periods when bees cannot fly, which is why stores with a high indigestible fraction cause dysentery

Rationale: In much of the southeastern US, prolonged confinement is uncommon because mild spells permit frequent cleansing flights, so dysentery there is more often traced to fermented feed, excess moisture or unsuitable stores than to confinement itself. The general principle remains: what the colony cannot digest must be retained, and retention capacity is finite.

References: Snodgrass, *Anatomy of the Honey Bee*, Cornell Univ. Press, 1956; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

21. (SA) Name the two enzymes added to nectar by worker bees that are central to honey formation, and state what each does.

Model answer: Invertase, also called sucrase or alpha-glucosidase, which hydrolyzes sucrose into glucose and fructose; and glucose oxidase, which acts on glucose to produce gluconic acid, contributing to honey's low pH, and hydrogen peroxide, which contributes to its antibacterial activity. Both originate in the hypopharyngeal glands of worker bees.

Rationale: Both enzymes are heat labile, which is why their activity is used as an indicator of heat abuse or age in honey, and why overheating honey during processing degrades a measurable quality parameter. Glucose oxidase also explains why diluted honey shows much greater peroxide activity than undiluted honey, since the reaction requires water.

References: White, in Crane (ed.), *Honey: A Comprehensive Survey*, Heinemann, 1975; Molan, *Bee World* 73:5-28 (1992).

22. (TF) Honey bee color vision is trichromatic with sensitivity in the red, yellow and blue, so bees discriminate red flowers especially well while being insensitive to ultraviolet light.

Answer: False

Rationale: The receptor set is reversed. Bees see ultraviolet, blue and green and are effectively red-blind. This is why many bee-pollinated flowers carry ultraviolet nectar guides invisible to us, and why deep red flowers such as trumpet creeper are generally bird rather than bee plants. Bees also detect the polarization pattern of skylight, which allows orientation when the sun itself is obscured.

References: Menzel & Backhaus, in *Vision and Visual Dysfunction* vol. 6, Macmillan, 1991; von Frisch, *The Dance Language and Orientation of Bees*, Harvard Univ. Press, 1967.

23. (MC) Bee venom is dominated by which component, and what is its principal effect?

Answer: A) Melittin, which makes up roughly half the venom's dry weight and is a membrane-disrupting peptide responsible for much of the immediate pain and the local tissue effect

Rationale: Phospholipase A2, at roughly a tenth of dry weight, is the principal allergen responsible for IgE-mediated reactions, which is a useful distinction: the component causing most of the pain is not the one causing most of the allergy. Hyaluronidase promotes spread of the venom through tissue.

Understanding the composition supports an accurate explanation of why a large local swelling is not the same thing as an allergic reaction.

References: Piek (ed.), *Venoms of the Hymenoptera*, Academic Press, 1986; Golden et al., *Ann. Allergy Asthma Immunol.* 118:28-54 (2017).

24. (MC) Approximate developmental periods from egg to emergence are:

Answer: B) Queen 16 days, worker 21 days, drone 24 days, with capping at roughly day 8 for the queen, day 9 for the worker and day 10 for the drone

Rationale: The capping dates matter as much as the emergence dates. Queen cell capping at about day 8 is why a swarm typically issues then and why a 7-day inspection interval is the standard during swarm season. The longer capped period of drone brood, roughly 14 to 15 days against 12 for workers, is why Varroa reproduces more successfully in drone cells and why drone brood trapping works.

References: Winston, *The Biology of the Honey Bee*, Harvard Univ. Press, 1987; Rosenkranz, Aumeier & Ziegelmann, *J. Invertebr. Pathol.* 103:S96-S119 (2010).

25. (SA) A colony has abundant capped honey but brood rearing has stopped in midsummer despite warm weather and a laying queen. Give the two most likely nutritional explanations and the observation that distinguishes them.

Model answer: Either a pollen dearth, in which the colony lacks the protein needed to produce brood food, or a pollen- and honey-bound brood nest, in which stored beebread and nectar have filled the cells the queen would otherwise use. The distinguishing observation is the amount of stored beebread and the availability of empty cells in the brood area: a dearth shows little or no stored pollen with empty, polished cells available, whereas a bound nest shows combs packed with beebread and nectar and no laying space.

Rationale: The two call for opposite responses. A dearth is addressed by pollen supplementation or by relocating to better forage; a bound nest is addressed by providing drawn comb or foundation for expansion and by moving filled frames out of the brood area. In the southeastern US the midsummer dearth makes the first common, while a heavy late-spring flow can produce the second.

References: Somerville, *Fat Bees Skinny Bees*, RIRDC Publication 05/054, 2005; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

26. (MC) The corbicula, or pollen basket, and the associated pollen press function to:

Answer: A) Compress pollen combed from the body and extrude it onto the concave outer surface of the hind tibia, where a stiff central hair and a little nectar hold the load in place

Rationale: Because the load is moistened with nectar to hold it together, corbicular pollen carries a moisture and sugar component, which matters to anyone operating a pollen trap: the product is perishable and must be dried or frozen promptly. It also explains why very dry, unmoistened pollen such as that of some wind-pollinated species is carried less efficiently.

References: *Snodgrass, Anatomy of the Honey Bee, Cornell Univ. Press, 1956; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

27. (SA) Explain what beebread is, how it differs from freshly collected pollen, and why the distinction matters to a beekeeper assessing a colony.

Model answer: Beebread is pollen that workers have packed into cells and mixed with honey and glandular secretions. The added material acidifies the mass and suppresses spoilage organisms, so beebread keeps far longer than fresh corbicular pollen, which ferments or molds within hours to days in warm humid conditions. It is the colony's stored protein reserve. The distinction matters because assessing stored beebread, rather than watching incoming pollen loads alone, tells the beekeeper whether the colony has a reserve to draw on when forage fails, which is precisely the question during a dearth.

Rationale: A colony with abundant honey and no beebread cannot rear brood, and a beekeeper who assesses only honey stores will misjudge that colony's condition entirely.

References: *Anderson et al., Mol. Ecol. 23:5904-5917 (2014); Somerville, Fat Bees Skinny Bees, RIRDC Publication 05/054, 2005.*

Section 2: Colony Behavior, Communication & Social Organization (Q28–48)

Part A — Questions

28. (MC) A forager returns from a source and performs a waggle run angled 45 degrees to the left of straight up on the vertical comb. This indicates that the source lies:

- **A)** Directly away from the sun at a distance encoded by the angle, with the waggle duration conveying the richness rather than the remoteness of the find
- **B)** 45 degrees to the right of the sun's direction, since the transposition from gravity to solar bearing reverses the handedness of the angle danced
- **C)** 45 degrees below the horizontal from the hive entrance, a bearing used only for sources located in tree canopy well above the level of the colony
- **D)** 45 degrees to the left of the sun's direction, with distance encoded in the duration of the waggle portion of the run rather than in the angle

29. (SA) Explain how bees maintain accurate dance direction over the course of a day, and what they do when the sun is obscured by cloud.

30. (MC) A tremble dance performed by a returning nectar forager most accurately signals that:

- **A)** The colony has become too warm, so the dance recruits water collectors and fanning bees in the same way that a waggle dance recruits foragers to a nectar source
- **B)** She experienced a long delay finding a receiver bee, so processing capacity is lagging behind collection; the dance recruits more receivers and dampens further waggle dancing
- **C)** She encountered a predator or a competitor at the source, so the dance warns nestmates away from that particular location while leaving other recruitment unaffected
- **D)** The source she visited has been exhausted or has become unprofitable, so the dance cancels the recruitment generated by her own earlier waggle dances for that location

31. (MC) A round dance rather than a waggle dance is performed when:

- **A)** The source is beyond about five kilometers, so that the waggle run would be too long to perform on the comb and a simplified signal conveys distance alone
- **B)** The source is very close to the hive, generally within roughly 50 to 100 meters, so that direction information is unnecessary and recruits simply search the vicinity
- **C)** The forager is recruiting water collectors rather than nectar foragers, since water sources are located by odor and require no directional information from the dancer
- **D)** The colony is preparing to swarm, and the dance is performed by scouts on the surface of the cluster to indicate that a candidate cavity is nearby and worth inspecting

32. (SA) Describe how scout bees from a clustered swarm reach a decision about a new nest site.

33. (MC) Guard bees distinguish nestmates from intruders principally by:

- **A)** Detection of queen mandibular pheromone carried on the returning bee's body, the concentration of which identifies which colony she belongs to as she lands

- **B)** An innate genetic label carried by every bee from a given queen, which is fixed at emergence and cannot be altered by diet, comb or the colony's forage conditions
- **C)** A learned chemical template based on cuticular hydrocarbons, which are strongly influenced by the comb the bees occupy and by the colony's forage and so drift with season
- **D)** Recognition of the individual bee, learned through repeated contact at the entrance, which is why guards challenge unfamiliar nestmates returning after a long absence

34. (SA) Explain why drifting between colonies in an apiary matters epidemiologically, and give three layout measures that reduce it.

35. (MC) Robbing escalates rapidly once it begins because:

- **A)** Successful robbers return and recruit more robbers while the target's defensive capacity falls as it loses bees, producing positive feedback that continues until it is stripped
- **B)** Robbing bees release Nasonov pheromone at the target entrance, which recruits still more robbers to that colony and marks it for the remainder of the dearth period each season
- **C)** The queen of the robbing colony directs the attack by sending out successive waves of foragers, which is why removing her interrupts the behavior within a day or two
- **D)** Alarm pheromone released by the defenders spreads through the apiary and recruits bees from every colony present, which is why robbing always becomes apiary-wide

36. (SA) Distinguish hygienic behavior from Varroa sensitive hygiene, and describe how each is assessed.

37. (TF) Propolis deposited as a lining inside the nest cavity has been shown to reduce the baseline expression of immune-related genes in workers, consistent with the idea that an antimicrobial nest envelope substitutes for costly individual immune investment.

True / False

38. (MC) Tooting and quacking heard within a hive indicate that:

- **A)** The queen is signaling the colony to abscond, which is why the sound is heard most often in colonies under heavy pest pressure or in colonies that have been disturbed
- **B)** Two mated queens are present in the colony following an incomplete supersedure, and the exchange precedes the fight that will determine which of them is retained
- **C)** The colony has become queenless and is producing emergency cells, the sound arising from workers piping over the cells they are constructing on the comb face
- **D)** Virgin queens are present, typically a free virgin tooting and mature virgins still in their cells quacking, which normally means a primary swarm has already issued

39. (MC) Water collection by a colony is regulated principally by:

- **A)** Ambient humidity measured at the entrance by guard bees, who recruit water collectors whenever the outside air is dry enough for evaporative cooling to be effective
- **B)** Feedback from how readily hive bees accept water from returning collectors, so a collector unloaded quickly returns for more while one that is refused ceases collecting
- **C)** Direct signaling from the queen, whose reduced laying rate under heat stress is detected by attendants and communicated to foragers as a demand for cooling water
- **D)** A fixed proportion of the foraging force permanently assigned to water collection, which is why colonies maintain water gathering even when no cooling demand exists

40. (SA) A colony has become noticeably more defensive over several weeks with no change in weather or handling. List the possible causes you would investigate, in the order you would check them.

41. (MC) Trophallaxis, the mouth-to-mouth exchange of food between bees, is significant because it:

- **A)** Serves mainly to redistribute stores during dearth, so that the exchange is rare during a flow and becomes frequent only when incoming nectar has stopped
- **B)** Occurs only between nurse bees and larvae, and is the route by which brood food is delivered, which is why it ceases entirely in a colony without open brood
- **C)** Transfers digestive enzymes from older to younger bees, which is why a colony deprived of its foragers cannot process incoming nectar until a new cohort has fully matured
- **D)** Distributes food, water and pheromonal information rapidly through the colony, so that material given to a few bees spreads to a large share of the colony within hours and throughout it within a day or two

42. (TF) A large beard of bees on the front of a hive on a hot, humid evening is a reliable early sign of imminent swarming, and the colony should be examined for queen cells the next day.

True / False

43. (MC) Undertaking behavior in a colony is best described as:

- **A)** A specialized duty of the oldest foragers, who carry corpses well away from the hive on their final flights and frequently do not return from them
- **B)** A response to physical stillness, so that any immobile object in the hive, including an anesthetized but living bee, is carried out by the same mechanism
- **C)** A task performed by a relatively small subset of middle-aged workers, triggered largely by chemical changes in the corpse rather than by immobility alone
- **D)** A task shared equally by all adult bees, with each worker removing whatever debris she encounters, which is why removal rate scales directly with colony population

44. (SA) Describe the differences between orientation flights and robbing at a hive entrance, giving at least four observable distinctions.

45. (MC) The vibration or shaking signal, in which a worker grasps a nestmate and vibrates her body, is best characterized as:

- **A)** A directional signal indicating the location of a new nest site, performed on the surface of a swarm cluster and distinguished from the waggle dance by its vertical run
- **B)** A specific inhibitory signal that halts waggle dancing for one particular source, delivered by foragers who have found that source depleted, crowded or dangerous on arrival
- **C)** A nonspecific activating signal that raises the receiver's activity level and her likelihood of engaging in whatever task is in demand, with its rate rising before swarm departure
- **D)** A signal produced only by the queen, and only in the days before a swarm issues, by which she prepares the colony for her departure and her reduced feeding

46. (MC) A colony that has been queenless for several days but still has young larvae will typically show:

- **A)** Multiple eggs placed on the walls of cells rather than centered at the base, together with drone brood raised in worker cells and a conspicuous absence of any laying queen

- **B)** Single centered eggs in worker cells but with all resulting brood capped as drones, together with a calm demeanor and a normal, evenly distributed brood pattern
- **C)** A rising roar, agitated bees running on the combs, absence of eggs with progressively older youngest brood, emergency cells on the comb face and often increased defensiveness
- **D)** A solid worker brood pattern with all stages present, reduced foraging activity, and queen cups along the bottom bars that have been polished but not yet provisioned

47. (TF) Colonies with African-derived genetics differ from European-derived colonies in measurable behavioral parameters, including a lower threshold for defensive response, more bees responding, longer pursuit distances, more sustained arousal, and markedly higher rates of swarming and absconding.

True / False

48. (SA) Explain what absconding is, how it differs from swarming, and list four conditions that commonly trigger it in the southeastern US.

Part B — Answer Key: Section 2

28. (MC) A forager returns from a source and performs a waggle run angled 45 degrees to the left of straight up on the vertical comb. This indicates that the source lies:

Answer: D) 45 degrees to the left of the sun's direction, with distance encoded in the duration of the waggle portion of the run rather than in the angle

Rationale: Straight up on the comb is transposed to the direction of the sun's azimuth, and both the magnitude and the handedness of the angle are preserved. Distance is encoded in the length of the waggle portion, with longer runs meaning greater distance. Dance vigor conveys the quality of the source, and odor carried on the dancer's body helps recruits identify the flower on arrival.

References: *von Frisch, The Dance Language and Orientation of Bees, Harvard Univ. Press, 1967; Seeley, The Wisdom of the Hive, Harvard Univ. Press, 1995.*

29. (SA) Explain how bees maintain accurate dance direction over the course of a day, and what they do when the sun is obscured by cloud.

Model answer: Bees use the sun's azimuth as their reference and compensate for its movement across the sky using an internal circadian clock, so a bee confined for a period and released later still orients correctly relative to the source, and dances performed in the dark hive shift appropriately as time passes. When the sun is obscured, bees infer its position from the pattern of polarized light in patches of blue sky, detected by specialized ommatidia in the dorsal rim of the compound eye, and they also use landmarks and the overall light gradient.

Rationale: Time compensation runs continuously rather than being recomputed from a fresh look at the sky, which is why scouts dancing on an overnight cluster keep their dance angles correct for the sun's movement; when the swarm lifts off the next morning it is guided by an informed minority of scouts that streak through the cloud toward the chosen cavity.

References: von Frisch, *The Dance Language and Orientation of Bees*, Harvard Univ. Press, 1967; Rossel & Wehner, *Nature* 323:128-131 (1986).

30. (MC) A tremble dance performed by a returning nectar forager most accurately signals that:

Answer: B) She experienced a long delay finding a receiver bee, so processing capacity is lagging behind collection; the dance recruits more receivers and dampens further waggle dancing

Rationale: The principal trigger is unloading delay, not source quality, although crowding at the source can also elicit the dance. Recognizing tremble dancing in a colony during a strong flow is a useful field cue that the colony needs more space for storage and ripening, since the bottleneck is not what the foragers can find but what the house bees can process and where they can put it.

References: Seeley, *Behav. Ecol. Sociobiol.* 31:375-383 (1992); Seeley, *The Wisdom of the Hive*, Harvard Univ. Press, 1995.

31. (MC) A round dance rather than a waggle dance is performed when:

Answer: B) The source is very close to the hive, generally within roughly 50 to 100 meters, so that direction information is unnecessary and recruits simply search the vicinity

Rationale: The two dances grade into one another through intermediate forms as distance increases. The practical corollary is that open feeding or a spill near the apiary produces intense, undirected local searching, which is one of the mechanisms by which careless feeding triggers robbing during a dearth.

References: von Frisch, *The Dance Language and Orientation of Bees*, Harvard Univ. Press, 1967; Winston, *The Biology of the Honey Bee*, Harvard Univ. Press, 1987.

32. (SA) Describe how scout bees from a clustered swarm reach a decision about a new nest site.

Model answer: Scouts search independently and each returns to advertise a site she has found by dancing on the surface of the cluster, with dance vigor and duration proportional to the quality of the cavity she assessed. Other scouts follow those dances, visit the advertised sites and assess them independently, then dance for them in turn if they judge them good. Dancing for a given site decays over successive returns unless renewed, so poorer sites lose support while better ones accumulate it. Scouts also deliver inhibitory stop signals to bees dancing for competing sites. When the number of scouts present at one site exceeds a quorum, those scouts return and begin piping, which warms the swarm for flight, and the swarm departs.

Rationale: The system reaches a fast decision that is strongly biased toward quality without requiring any bee to compare all the options, and speed matters because a clustered swarm is exposed and has finite reserves.

References: Seeley, *Honeybee Democracy*, Princeton Univ. Press, 2010; Seeley & Visscher, *Behav. Ecol. Sociobiol.* 56:594-601 (2004).

33. (MC) Guard bees distinguish nestmates from intruders principally by:

Answer: C) A learned chemical template based on cuticular hydrocarbons, which are strongly influenced by the comb the bees occupy and by the colony's forage and so drift with season

Rationale: Because the signature is learned and environmentally influenced rather than fixed, colonies sharing comb and diet accept each other more readily. This is the mechanism behind the newspaper combine, which delays contact long enough for the two odors to merge. It also explains why drifting increases when hives look and smell alike, and why returning foragers loaded with nectar are challenged less during a flow than during a dearth.

References: *Breed, Bee World 79:76-89 (1998); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

34. (SA) Explain why drifting between colonies in an apiary matters epidemiologically, and give three layout measures that reduce it.

Model answer: Drifting redistributes bees between colonies, and with them Varroa mites and the viruses those mites carry, along with Vairimorpha (Nosema) spores and foulbrood organisms, so a single heavily infested colony can seed the whole apiary. It also produces misleading colony assessments, since end-of-row hives accumulate drifted bees and appear artificially strong while their neighbors dwindle. Layout measures include avoiding long straight rows of identical hives facing the same direction; varying hive colors or adding distinctive markings; orienting entrances in different directions; using irregular spacing or arranging hives in small clusters; and using landmarks such as trees, posts or shrubs to help bees locate their own hive.

Rationale: Drift is one reason mite management must be considered at the apiary level rather than colony by colony: mite immigration from a neighboring colony can undo an effective treatment within weeks.

References: *Free, J. Agric. Sci. 51:294-306 (1958); Frey & Rosenkranz, J. Econ. Entomol. 107:508-515 (2014).*

35. (MC) Robbing escalates rapidly once it begins because:

Answer: A) Successful robbers return and recruit more robbers while the target's defensive capacity falls as it loses bees, producing positive feedback that continues until it is stripped

Rationale: Because the process is self-reinforcing, speed of response matters and prevention is far better than cure. Prevention means reducing entrances before the dearth rather than during an attack, avoiding spilled syrup and exposed comb, equalizing colony strength so no colony is defenseless, and not opening colonies unnecessarily during a dearth. Once robbing has begun, the target must be reduced, screened, or removed from the apiary.

References: *Free, Bee World 35:206-210 (1954); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

36. (SA) Distinguish hygienic behavior from Varroa sensitive hygiene, and describe how each is assessed.

Model answer: Hygienic behavior is the general ability of workers to detect, uncap and remove dead or diseased brood from sealed cells, which confers resistance to American foulbrood and chalkbrood. It is assessed with a freeze-killed brood assay, in which a measured patch of sealed brood is killed with liquid nitrogen or by freezing a cut section, returned to the colony, and scored for percentage removed after 24 hours, with about 95 percent or more indicating a hygienic colony; a pin-kill test is a lower-cost approximation. Varroa sensitive hygiene is the more specific ability to detect sealed cells containing Varroa (classically those with a reproducing foundress, though recent work suggests the mite's presence rather than its offspring may be the trigger) and remove the contents, interrupting mite reproduction. It is assessed by opening infested sealed cells and determining the proportion of foundress mites that have failed to reproduce, since the reproductively successful ones have been selectively removed.

Rationale: The two traits are related but distinct, and whether they share a genetic basis is not settled, so a colony can score well on one and poorly on the other, and a breeder or a buyer of resistant stock should know which trait is being selected.

References: *Spivak & Downey, J. Econ. Entomol. 91:64-70 (1998); Harbo & Harris, J. Econ. Entomol. 92:261-265 (1999).*

37. (TF) Propolis deposited as a lining inside the nest cavity has been shown to reduce the baseline expression of immune-related genes in workers, consistent with the idea that an antimicrobial nest envelope substitutes for costly individual immune investment.

Answer: True

Rationale: This finding shifted the practical view of propolis from nuisance to asset. Some beekeepers now use rough-textured interior surfaces or propolis traps deliberately rather than scraping every surface smooth. Propolis is part of a broader set of colony-level defenses, sometimes called social immunity, that also includes hygienic behavior, grooming, undertaking and the elevation of brood nest temperature in response to chalkbrood.

References: *Simone, Evans & Spivak, Evolution 63:3016-3022 (2009); Simone-Finstrom & Spivak, Apidologie 41:295-311 (2010).*

38. (MC) Tooting and quacking heard within a hive indicate that:

Answer: D) Virgin queens are present, typically a free virgin tooting and mature virgins still in their cells quacking, which normally means a primary swarm has already issued

Rationale: Hearing this changes the management response entirely. Swarm prevention is now too late; the appropriate action is to reduce the remaining queen cells to a single good cell, or to remove all cells and introduce a mated queen, so that the colony does not throw a succession of afterswarms and reduce itself below viable strength.

References: *Michelsen, Kirchner, Andersen & Lindauer, J. Comp. Physiol. A 158:605-611 (1986); Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

39. (MC) Water collection by a colony is regulated principally by:

Answer: B) Feedback from how readily hive bees accept water from returning collectors, so a collector unloaded quickly returns for more while one that is refused ceases collecting

Rationale: The same unloading-latency feedback governs nectar foraging. Practically, this explains why water sources near an apiary become intensely used at particular times of day and season, and why the effective way to keep bees off a neighbor's pool is to provide a better source before the bees establish fidelity to the pool, not after.

References: Lindauer, Z. *vergl. Physiol.* 36:391-432 (1954); Kuhnholz & Seeley, *Behav. Ecol. Sociobiol.* 41:407-422 (1997).

40. (SA) A colony has become noticeably more defensive over several weeks with no change in weather or handling. List the possible causes you would investigate, in the order you would check them.

Model answer: First, confirm the colony is queenright with a laying queen, since queenlessness commonly increases defensiveness. Second, determine whether a queen change has occurred, by checking whether the queen is the marked one you introduced, since supersedure or an unnoticed swarm introduces different genetics through both the new queen and the drones she mated with. Third, look for evidence of nighttime predator harassment, particularly skunk activity, indicated by scratch marks on the hive front, trampled grass and disturbed entrance debris. Fourth, consider whether a dearth has begun or robbing pressure has risen in the apiary. Fifth, in areas of the southeastern US where African-derived bees occur, consider the possibility of African introgression through the drones the new queen mated with.

Rationale: The point of the ordering is that the cheap and common explanations are checked before the alarming one, and that the remedy for most of them is requeening with known gentle stock, which changes the workforce over about six weeks.

References: Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015; Schneider, DeGrandi-Hoffman & Smith, *Annu. Rev. Entomol.* 49:351-376 (2004).

41. (MC) Trophallaxis, the mouth-to-mouth exchange of food between bees, is significant because it:

Answer: D) Distributes food, water and pheromonal information rapidly through the colony, so that material given to a few bees spreads to a large share of the colony within hours and throughout it within a day or two

Rationale: Classic radiotracer work showed that labeled sugar given to a small number of foragers labeled 62 percent of foragers within 4 hours, 43 to 60 percent of all bees within 27 hours and every large unsealed larva within 48 hours. The network carries queen pheromone and other primer signals as well as nutrients, making it the colony's chemical information system. It is also the route by which orally administered treatments, and unfortunately some contaminants, distribute through the colony.

References: Nixon & Ribbands, *Proc. R. Soc. Lond. B* 140:43-50 (1952); Crailsheim, *Apidologie* 29:97-112 (1998).

42. (TF) A large beard of bees on the front of a hive on a hot, humid evening is a reliable early sign of imminent swarming, and the colony should be examined for queen cells the next day.

Answer: False

Rationale: Evening bearding in hot weather is normal thermoregulation: surplus bees move outside to reduce the heat load within the nest. Swarming occurs on warm middays, is preceded by queen cells in the brood nest, and involves a mass departure rather than a static cluster. The response to evening bearding is to confirm shade, ventilation and a water source; the check for swarming is the brood nest, not the hive front.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

43. (MC) Undertaking behavior in a colony is best described as:

Answer: C) A task performed by a relatively small subset of middle-aged workers, triggered largely by chemical changes in the corpse rather than by immobility alone

Rationale: Corpse removal follows a delay corresponding to the change in cuticular chemistry after death, and anesthetized but living bees are generally not carried out, which rules out immobility as the cue. For the beekeeper, a modest scattering of dead bees in front of a hive after a cold spell reflects normal cleanout, whereas a large pile of freshly dead bees during good weather warrants investigation.

References: *Visscher, Anim. Behav. 31:1070-1076 (1983); Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

44. (SA) Describe the differences between orientation flights and robbing at a hive entrance, giving at least four observable distinctions.

Model answer: In orientation flights, young bees face the hive and hover in slowly widening arcs, typically in the early afternoon of a warm day; there is no fighting; the bees use the entrance normally; and all of them belong to that colony, leaving and returning to it. In robbing, bees fly in a fast, weaving, searching pattern along the hive body and probe cracks, seams and corners rather than approaching the entrance directly; fighting and wrestling pairs are visible on the landing board and on the ground; dead bees accumulate; and wax flecks and torn cappings appear on the landing board and beneath the entrance as robbers chew into stored honey.

Rationale: Confusing the two is a common error with opposite consequences: orientation requires no action, robbing requires immediate entrance reduction and removal of any exposed comb or spilled feed from the apiary.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammartaro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

45. (MC) The vibration or shaking signal, in which a worker grasps a nestmate and vibrates her body, is best characterized as:

Answer: C) A nonspecific activating signal that raises the receiver's activity level and her likelihood of engaging in whatever task is in demand, with its rate rising before swarm departure

Rationale: Its nonspecific, activating character is the key contrast with the stop signal, a brief vibratory pulse delivered by butting a dancer that specifically inhibits waggle dancing. Workers also shake the queen before swarming, which is associated with her weight loss and preparation for flight.

References: *Schneider & Lewis, Apidologie 35:117-131 (2004); Nieh, Curr. Biol. 20:310-315 (2010).*

46. (MC) A colony that has been queenless for several days but still has young larvae will typically show:

Answer: C) A rising roar, agitated bees running on the combs, absence of eggs with progressively older youngest brood, emergency cells on the comb face and often increased defensiveness

Rationale: The choice describing multiple eggs on cell walls is laying workers, and the one describing single centered eggs producing only drone brood is a drone-laying queen; both arise later or from different causes. No single sign is conclusive. The definitive test when the queen cannot be found is a test frame of eggs and young larvae from a healthy colony, on which a truly queenless colony will start cells within a few days.

References: *Sammataro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

47. (TF) Colonies with African-derived genetics differ from European-derived colonies in measurable behavioral parameters, including a lower threshold for defensive response, more bees responding, longer pursuit distances, more sustained arousal, and markedly higher rates of swarming and absconding.

Answer: True

Rationale: The differences are quantitative rather than categorical, but they are large and reproducible, and they have real implications for apiary siting, protective equipment and requeening policy in the parts of the southeastern US where such bees occur. Because behavior varies with weather, colony state and disturbance, a single observation cannot classify a colony; laboratory identification is required for confirmation, while requeening with known European stock is the practical control regardless.

References: *Collins et al., Science 218:72-74 (1982); Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004).*

48. (SA) Explain what absconding is, how it differs from swarming, and list four conditions that commonly trigger it in the southeastern US.

Model answer: Absconding is the departure of the entire adult population from the hive, typically abandoning brood and stores, in response to conditions the colony finds intolerable. It differs from swarming in that swarming is reproductive, divides the colony and leaves a viable remnant with queen cells, whereas absconding leaves nothing behind and produces no increase. Common triggers in the region include severe small hive beetle infestation and slimed comb; heavy wax moth destruction; starvation during the midsummer dearth; extreme heat in an unshaded apiary; sustained ant pressure; and repeated heavy disturbance.

Rationale: Finding an empty hive with brood abandoned in the combs should therefore send the beekeeper looking for the stressor rather than recording a swarm, and the same stressor is likely affecting other colonies in the yard.

References: *Neumann & Elzen, Apidologie 35:229-247 (2004); Cooperative Extension small hive beetle publications, southeastern US.*

Section 3: Queen Biology, Mating & Rearing (Q49–71)

Part A — Questions

49. (MC) Drone congregation areas are best described as:

- **A)** Zones established each season by the first virgin queens to fly, whose pheromone trails mark the site and disperse once the local mating period has finished for the year
- **B)** Specific aerial locations, often persisting in the same place for many years, where drones from many colonies over a radius of several miles gather on warm afternoons
- **C)** Sheltered spots on the ground where drones rest between flights, and where virgin queens alight to be mated before returning to the colony to begin laying within days
- **D)** Areas immediately downwind of each apiary, containing that apiary's own drones, which is why isolated yards reliably produce queens mated to their own colonies' stock

50. (SA) Describe a queen's mating behavior, including the approximate number of drones she mates with and roughly how much sperm she retains.

51. (MC) For grafting, the larva selected should be:

- **A)** About three to four days old, since a larva of that size is robust enough to transfer without injury and has accumulated the reserves needed for rapid queen cell development
- **B)** Between four and five days old, so that the larva has already completed its worker-type feeding phase and can be redirected by the richer diet supplied in the queen cell
- **C)** As young as can be handled, ideally under 24 hours from hatching, because the duration of queen-type feeding before the pathways diverge sets ovariole number and adult weight
- **D)** Any age up to capping, since a larva placed in a queen cup receives royal jelly continuously from that moment and develops into a queen regardless of its previous diet

52. (SA) Explain why queen cells are commonly started in a queenless colony but finished in a queenright one, and name a device that accomplishes both in a single hive.

53. (MC) Counting from a graft of a larva about one day old, queen cells are capped and emerge at approximately:

- **A)** Capped and emerging on the same day, roughly 16 days after grafting, since the graft is made from an egg rather than from a larva that has already begun feeding
- **B)** Capped about 2 days after grafting and emerging about 6 days after grafting, so cells must be distributed almost immediately if they are not to emerge in the builder
- **C)** Capped about 4 to 5 days after grafting and emerging about 11 to 12 days after grafting, so cells are normally moved to nuclei or an incubator around day 10
- **D)** Capped about 8 days after grafting and emerging about 20 days after grafting, so there is a wide margin in which cells can be handled without risk to the developing queen

54. (SA) List the measurements used to assess queen quality in a laboratory setting, and state one field observation that serves as a proxy.

55. (TF) Temperature extremes during queen shipping damage stored sperm, but the damage is always accompanied by visible signs in the queen such as darkened wings or reduced size, so affected queens can be culled on arrival.

True / False

56. (MC) When introducing a caged mated queen, the candy plug delay works because:

- **A)** The candy provides the colony's only food during the introduction period, so the bees must chew through to reach it, which is why a colony with stores often fails to release her
- **B)** The delay allows the colony to acquire the queen's pheromonal signature through contact and food exchange through the screen, so that at release the bees treat her as their own
- **C)** The delay allows the colony to consume the last of its brood pheromone, without which the workers cannot recognize a laying queen as belonging to their own colony
- **D)** The delay gives the queen time to complete her final maturation, since queens are shipped before they are fully developed and cannot begin laying for several days after arrival

57. (SA) A colony shows single eggs centered in worker cells and normal laying behavior, but roughly half the sealed brood is drone brood with domed cappings in worker-sized cells. Diagnose the condition and explain the mechanism.

58. (MC) Emergency queens reared by a colony from its own larvae are:

- **A)** Often of acceptable quality, because colonies given a choice tend to select young larvae, but at genuine risk when only older larvae are available, in which case quality suffers
- **B)** Always inferior to grafted queens, because a colony under the stress of queenlessness cannot provision its cells adequately and produces undersized queens with few ovarioles
- **C)** Superior to grafted queens, because the colony selects the best-nourished larva available and provisions the resulting cell more generously than any cell builder does
- **D)** Genetically distinct from grafted queens raised from the same mother, since emergency cells are drawn from larvae the colony has already begun feeding as workers

59. (SA) Describe the notching or on-the-spot method of directing queen rearing without grafting, and state its advantage.

60. (MC) A mating nucleus should be:

- **A)** As large as can be assembled, ideally a full two-story colony, so that the virgin queen is well provisioned and the unit can be returned to production immediately after mating
- **B)** Queenright at the time the cell is introduced, so that the resident laying queen maintains colony cohesion until the new virgin has emerged, mated and begun laying herself
- **C)** Small enough to be economical of resources but populous enough to hold brood nest temperature, feed the queen and defend itself, with emerging brood, stores and robbing protection
- **D)** Stocked with older foraging bees rather than young bees, since foragers orient reliably and will not drift away from a small unit during the virgin queen's mating period

61. (TF) Drone mother colonies must be established well in advance of a mating program, because a drone requires about 16 days from egg to emergence and a further two to three days to reach sexual maturity.

True / False

62. (MC) The international queen marking color code assigns:

- **A)** White to years ending 1 or 6, yellow to 2 or 7, red to 3 or 8, green to 4 or 9, and blue to 5 or 0
- **B)** Red to years ending 1 or 6, green to 2 or 7, blue to 3 or 8, white to 4 or 9, and yellow to 5 or 0
- **C)** Blue to years ending 1 or 6, white to 2 or 7, yellow to 3 or 8, red to 4 or 9, and green to 5 or 0
- **D)** Green to years ending 1 or 6, blue to 2 or 7, white to 3 or 8, yellow to 4 or 9, and red to 5 or 0

63. (SA) Explain why many beekeepers in the southeastern US requeen in late summer or early autumn rather than in spring, and state one drawback of doing so.

64. (MC) A colony made queenless today will typically begin building emergency queen cells:

- **A)** Only after the beekeeper supplies a queen cup, since workers will not modify an existing worker cell into a queen cell without a prepared foundation
- **B)** After about ten days, once the colony has exhausted the queen pheromone already distributed through the population and confirmed that no queen remains
- **C)** Only once all open brood has been capped, so that the nurse bees are released from feeding duties and can devote their glandular output to queen rearing
- **D)** Within hours, since the loss of queen pheromone is detected quickly, with cells usually visible within a day or two of the colony becoming queenless

65. (SA) A split made in early spring is left to rear its own queen. Give the expected timeline to a laying queen and list three things that can go wrong.

66. (MC) Introducing a mated queen into a colony with established laying workers usually fails because:

- **A)** The introduced queen cannot lay in cells that already contain worker-laid eggs, so she abandons laying and is superseded within the first brood cycle
- **B)** The colony has no bees young enough to feed a laying queen, so she starves within the cage even when the attendants and the candy plug are intact
- **C)** The laying workers physically block the entrance to the cage, preventing the candy plug from being chewed through and the queen from ever being released
- **D)** Workers with activated ovaries behave in some respects as though the colony were queenright, and the colony typically balls and kills the introduced queen

67. (TF) Supersedure is triggered by an integrated assessment of queen quality, including declining mandibular pheromone output, reduced egg-laying rate and reduced deposition of tarsal or footprint pheromone on the comb, rather than by any single cue.

True / False

68. (MC) Non-grafting queen rearing methods such as the Miller and Hopkins techniques work by:

- **A)** Presenting comb with very young larvae to a queenless cell builder in a way that exposes selected larvae, so bees build cells from them without any transfer by the beekeeper
- **B)** Injecting a small quantity of royal jelly into selected worker cells with a fine syringe, which induces the colony to extend those cells downward into queen cells

- **C)** Feeding the cell-building colony a preparation that raises juvenile hormone titers, which causes it to rear queens from larvae of any age currently present in the nest
- **D)** Chilling a comb of young brood briefly so that only the most vigorous larvae survive, after which the colony rears queens from the survivors it judges strongest

69. (SA) Explain what a queen bank is, why it requires an unusual colony structure, and state two limitations.

70. (MC) Vairimorpha (Nosema) infection of a queen is of practical concern because:

- **A)** It produces visible discoloration and swelling of the queen's abdomen, allowing infected queens to be identified and culled on inspection before they are introduced to a colony
- **B)** It renders the queen permanently sterile within days of infection, so that a colony headed by an infected queen shows an abrupt and complete cessation of egg laying
- **C)** It can infect the queen's midgut and is associated with altered physiology (including shifts in vitellogenin and mandibular pheromone levels) and with supersedure, and can be acquired from infected attendants used in cages and banks
- **D)** It infects only workers and never queens, so a queen from an infected colony can be moved to a clean colony without any risk of carrying the parasite with her

71. (SA) You are asked to evaluate two queen sources by their performance in your own apiary. Describe how you would set up a fair comparison.

Part B — Answer Key: Section 3

49. (MC) Drone congregation areas are best described as:

Answer: B) Specific aerial locations, often persisting in the same place for many years, where drones from many colonies over a radius of several miles gather on warm afternoons

Rationale: The properties of these areas are why open mating cannot be treated as controlled mating: a queen's daughters are fathered by drones from every colony within a broad radius, including feral ones. This is the mechanism behind the repeated observation that purchased selected genetics do not persist in open-mated daughters, and the reason drone saturation shifts but never determines paternity.

References: Koeniger, Koeniger, Ellis & Connor, *Mating Biology of Honey Bees*, Wicwas, 2014; Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997.

50. (SA) Describe a queen's mating behavior, including the approximate number of drones she mates with and roughly how much sperm she retains.

Model answer: A virgin queen matures for about five to six days after emergence, then flies on warm calm afternoons to drone congregation areas, mating in flight with about a dozen drones on average (the range is wide, and twenty or more is reported), usually across one to three flights over one to several days. Drones die in the act. She receives on the order of tens of millions of spermatozoa into her oviducts, of which only a small fraction, commonly cited as around five to seven million, migrates into and is retained in the spermatheca; the remainder is expelled within a day or two. That stored sperm must last her entire productive life.

Rationale: Two practical consequences follow: extended cool or wet weather during the mating window produces poorly mated queens that fail early, and stored sperm cannot be replenished, so a queen who mated poorly will become a drone layer as the supply is exhausted.

References: *Koeniger, Koeniger, Ellis & Connor, Mating Biology of Honey Bees, Wicwas, 2014; Woyke, J. Apic. Res. 1:37-42 (1962).*

51. (MC) For grafting, the larva selected should be:

Answer: C) As young as can be handled, ideally under 24 hours from hatching, because the duration of queen-type feeding before the pathways diverge sets ovariole number and adult weight

Rationale: Queens reared from older larvae are measurably inferior and are superseded more often. Practical aids include confining the breeder queen on a comb for a day to synchronize larval age, grafting in good light with magnification, and protecting larvae from chilling and drying during transfer. Priming cell cups with a little diluted royal jelly, or double grafting, improves acceptance and early nutrition.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Woyke, J. Apic. Res. 10:45-55 (1971).*

52. (SA) Explain why queen cells are commonly started in a queenless colony but finished in a queenright one, and name a device that accomplishes both in a single hive.

Model answer: A queenless, broodless colony packed with young bees accepts grafts at a much higher rate, because the absence of queen pheromone and of young larvae releases the impulse to rear queens. However, such a colony, particularly a confined swarm box, cannot sustain optimal feeding, thermal stability and provisioning for the full larval period. A strong queenright colony above a queen excluder provides better nutrition, temperature and stores for finishing. A Cloake board, a split board with a removable slide and a queen excluder plus an upper entrance, accomplishes both: inserting the slide makes the upper box functionally queenless for starting, and removing it about a day after grafting restores queenright conditions for finishing.

Rationale: The sequence is typically to insert the slide a day before grafting, graft, then remove the slide roughly 24 hours later.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

53. (MC) Counting from a graft of a larva about one day old, queen cells are capped and emerge at approximately:

Answer: C) Capped about 4 to 5 days after grafting and emerging about 11 to 12 days after grafting, so cells are normally moved to nuclei or an incubator around day 10

Rationale: Timing the move is critical for two reasons: queen pupae are vulnerable to chilling and mechanical shock earlier in development, and the first queen to emerge will destroy the remaining cells if they are left together. Cells should be kept upright and warm during transfer, which in a southeastern summer means never leaving them in a hot vehicle.

References: Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

54. (SA) List the measurements used to assess queen quality in a laboratory setting, and state one field observation that serves as a proxy.

Model answer: Live weight at emergence or at the onset of laying; the number of ovarioles; the diameter of the spermatheca; and the number and viability of stored spermatozoa. Commonly cited benchmarks include roughly 190 milligrams or more at emergence, on the order of 300 or more ovarioles in total, a spermatheca above about one millimeter in diameter, and stored sperm counts above roughly three to four million with high viability. The practical field proxy is the quality and extent of the brood pattern she produces over several weeks, combined with the colony's build-up and the absence of repeated supersedure attempts.

Rationale: The field proxy must be used with care, because a spotty brood pattern can be caused by mites and viruses, chilled brood, disease, inbreeding or a pollen-bound nest with a perfectly sound queen. Those should be excluded before a queen is condemned.

References: Delaney, Keller, Caren & Tarpy, *Apidologie* 42:1-13 (2011); Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

55. (TF) Temperature extremes during queen shipping damage stored sperm, but the damage is always accompanied by visible signs in the queen such as darkened wings or reduced size, so affected queens can be culled on arrival.

Answer: False

Rationale: There is no outward sign, and that is precisely what makes thermal damage insidious. A queen exposed to heat or cold in transit can look and behave normally, be accepted, lay well briefly and then produce patchy or drone-heavy brood or be superseded. Because the beekeeper cannot screen for it, the controls are preventive: collect queens promptly, hold them at moderate temperature out of sun, and introduce them without long delay.

References: Pettis, Rice, Joselow, vanEngelsdorp & Chaimanee, *PLoS ONE* 11:e0147220 (2016); McAfee et al., *Nat. Sustain.* 3:367-376 (2020).

56. (MC) When introducing a caged mated queen, the candy plug delay works because:

Answer: B) The delay allows the colony to acquire the queen's pheromonal signature through contact and food exchange through the screen, so that at release the bees treat her as their own

Rationale: Because acceptance depends on this gradual chemical familiarization, the errors that defeat it are predictable: introducing into a colony that is not truly queenless, leaving a queen cell or an unnoticed virgin present, and opening the colony repeatedly during the introduction period. Acceptance is also poorer during dearth and robbing pressure, which in the southeastern US argues for feeding and reduced entrances when requeening in late summer.

References: Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

57. (SA) A colony shows single eggs centered in worker cells and normal laying behavior, but roughly half the sealed brood is drone brood with domed cappings in worker-sized cells. Diagnose the condition and explain the mechanism.

Model answer: This is a failing or partially failing queen, sometimes called a drone layer. Her laying behavior is normal, which is why the eggs are single and centered, but a proportion of the eggs are not being fertilized because her stored sperm supply is depleted or its viability has been reduced. Unfertilized eggs develop as drones, and drone larvae in worker-sized cells produce the characteristic raised, domed cappings. Common causes include advanced queen age, poor mating during unfavorable weather, and thermal damage to stored sperm during shipping.

Rationale: The essential discrimination is from laying workers, which place multiple eggs erratically on cell walls rather than singly and centered. The remedy differs: a drone-laying queen must be found and removed before a new queen is introduced, whereas a laying-worker colony resists queen introduction and is usually best combined with a queenright colony.

References: Shimanuki & Knox, *Diagnosis of Honey Bee Diseases*, USDA Agriculture Handbook 690, 2000; Pettis, Rice, Joselow, vanEngelsdorp & Chaimanee, *PLoS ONE* 11:e0147220 (2016).

58. (MC) Emergency queens reared by a colony from its own larvae are:

Answer: A) Often of acceptable quality, because colonies given a choice tend to select young larvae, but at genuine risk when only older larvae are available, in which case quality suffers

Rationale: The mature position is conditional rather than dogmatic. The practical safeguards are to verify that larvae under about 24 hours old were present when the colony was made queenless, to use the notching technique to direct the bees to larvae of known age, or to supply a ripe cell or a mated queen instead. A colony made queenless with only older larvae present is the situation to avoid.

References: Hatch, Tarpy & Fletcher, *Insectes Soc.* 46:372-377 (1999); Laidlaw & Page, *Queen Rearing and Bee Breeding*, Wicwas, 1997.

59. (SA) Describe the notching or on-the-spot method of directing queen rearing without grafting, and state its advantage.

Model answer: The beekeeper identifies a comb containing larvae of a verified young age, then uses a hive tool to notch or cut away the lower edge of the cell wall beneath a row of selected cells, exposing those larvae along a scraped edge. In a colony made queenless, the bees preferentially build queen cells from the exposed larvae at the notch. The advantage is control over the age of the larvae used, and therefore over queen quality, without the skill and equipment required for grafting; it also concentrates the resulting cells in a known, accessible location so they can be counted, cut out and distributed.

Rationale: The honest caveat is that colonies given a choice already tend to select young larvae, so notching helps most when the beekeeper cannot otherwise verify larval age, and when they want the cells in a predictable place.

References: *Hatch, Tarpy & Fletcher, Insectes Soc. 46:372-377 (1999); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

60. (MC) A mating nucleus should be:

Answer: C) Small enough to be economical of resources but populous enough to hold brood nest temperature, feed the queen and defend itself, with emerging brood, stores and robbing protection

Rationale: In the southeastern US the hazards for small units are specific and severe: robbing during the dearth, small hive beetle, which overwhelms nucs quickly, and summer heat. Mating nuclei therefore need shade, reduced entrances, beetle traps, tight sizing so the bees cover all the comb, and frequent attention, since a nuc can be lost between weekly visits.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Cooperative Extension small hive beetle publications, southeastern US.*

61. (TF) Drone mother colonies must be established well in advance of a mating program, because a drone requires about 16 days from egg to emergence and a further two to three days to reach sexual maturity.

Answer: False

Rationale: The stem transposes the queen's timetable (about 16 days to emergence and only a few days of maturation) onto the drone. A drone requires about 24 days from egg to emergence and a further twelve to sixteen days to reach sexual maturity, so drone production must begin roughly six weeks before the mating window. The conclusion that drone colonies need long lead time is right; the arithmetic given for it is wrong, and using it would leave a breeder without mature drones when the queens fly.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Koeniger, Koeniger, Ellis & Connor, Mating Biology of Honey Bees, Wicwas, 2014.*

62. (MC) The international queen marking color code assigns:

Answer: A) White to years ending 1 or 6, yellow to 2 or 7, red to 3 or 8, green to 4 or 9, and blue to 5 or 0

Rationale: The mnemonic is 'Will You Raise Good Bees'. Marking serves three purposes beyond making the queen easier to find: it records the year of introduction, it makes supersedure immediately obvious when an unmarked queen appears, and it protects a valued queen from accidental removal during splitting or requeening.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Root, ABC and XYZ of Bee Culture, 41st ed., A.I. Root Co., 2007.*

63. (SA) Explain why many beekeepers in the southeastern US requeen in late summer or early autumn rather than in spring, and state one drawback of doing so.

Model answer: A young queen going into autumn maintains a higher laying rate and stronger pheromone output, which supports the production of a good population of long-lived winter bees, and she carries the colony into the following spring with less swarming pressure and less risk of mid-season superseding. The requeening interval also produces a brood break that can be combined usefully with mite treatment, since a broodless window greatly increases the efficacy of treatments that do not penetrate cappings. The drawback is that acceptance is poorer during the late-summer dearth, when robbing pressure is high and colonies are less tolerant, so feeding and reduced entrances are needed, and good queens can be harder to obtain late in the season.

Rationale: A candidate should also note that requeening always carries an acceptance risk and a cost, and that a demonstrably excellent queen may be worth retaining.

References: *Cooperative Extension apiculture publications, southeastern US; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

64. (MC) A colony made queenless today will typically begin building emergency queen cells:

Answer: D) Within hours, since the loss of queen pheromone is detected quickly, with cells usually visible within a day or two of the colony becoming queenless

Rationale: The speed of the response is why a beekeeper requeening a colony must destroy cells not only at the time of introduction but again about a week later, since cells started before the new queen was accepted will otherwise mature. It also explains why a test frame of eggs and young larvae gives a reliable answer about queenlessness within three to four days.

References: *Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

65. (SA) A split made in early spring is left to rear its own queen. Give the expected timeline to a laying queen and list three things that can go wrong.

Model answer: Emergency cells are started within a day; a queen emerges roughly twelve to sixteen days after the split, depending on the age of the larvae selected; she matures for about five to six days, mates over the following days if weather permits, and begins laying, so eggs are normally expected about three to four weeks after the split. Things that can go wrong: the colony selects an older larva and produces an undersized queen; the virgin fails to return from a mating flight because of birds, weather or disturbance; poor mating weather produces a drone layer; the split is too weak to keep the cells warm or to defend itself against robbing and beetles; and the beekeeper opens the colony repeatedly during the mating period and disrupts it.

Rationale: The alternative of introducing a purchased mated queen or a ripe cell shortens the broodless interval by two to three weeks and gives known genetics, at the cost of the purchase price and the acceptance risk.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

66. (MC) Introducing a mated queen into a colony with established laying workers usually fails because:

Answer: D) Workers with activated ovaries behave in some respects as though the colony were queenright, and the colony typically balls and kills the introduced queen

Rationale: The standard remedy is to combine the laying-worker colony with a strong queenright colony, which recovers the bees and equipment. Shaking its bees out in front of the queenright colony, so that they drift in and are accepted a few at a time, is more reliable than a straight newspaper combine, in which the laying-worker bees may attack the receiving colony's queen; a newspaper combine needs an extended mixing period. Giving repeated frames of open brood at weekly intervals, which suppresses laying-worker ovary development, is a slower alternative. Often the most sensible judgment is that the colony is not worth rescuing individually.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammataro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

67. (TF) Supersedure is triggered by an integrated assessment of queen quality, including declining mandibular pheromone output, reduced egg-laying rate and reduced deposition of tarsal or footprint pheromone on the comb, rather than by any single cue.

Answer: True

Rationale: Because the assessment is integrated, anything that damages a queen can precipitate supersedure: injury during marking or handling, disease, poor mating, thermal damage to stored sperm, and simple age. This is why supersedure often follows rough handling, and why a beekeeper who has just marked or clipped a queen should be alert to a supersedure attempt in the following weeks.

References: *Free, Pheromones of Social Bees, Chapman & Hall, 1987; Pettis, Winston & Collins, Insectes Soc. 42:113-121 (1995).*

68. (MC) Non-grafting queen rearing methods such as the Miller and Hopkins techniques work by:

Answer: A) Presenting comb with very young larvae to a queenless cell builder in a way that exposes selected larvae, so bees build cells from them without any transfer by the beekeeper

Rationale: The Miller method uses a comb with jagged foundation edges so young larvae occupy the exposed margins; the Hopkins method lays a comb horizontally over a queenless colony with most larvae destroyed so that isolated larvae remain. Both avoid grafting, which suits beekeepers who cannot handle very young larvae, at the cost of more awkward cell handling. Modern cell-cup systems achieve a similar result with removable cups.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Root, ABC and XYZ of Bee Culture, 41st ed., A.I. Root Co., 2007.*

69. (SA) Explain what a queen bank is, why it requires an unusual colony structure, and state two limitations.

Model answer: A queen bank is a colony used to hold a number of caged mated queens for a period until they are needed. It requires an unusual structure because caged queens are not laying and cannot be fed by the colony in the ordinary way; instead each must be fed by attendant workers through the

cage screen, which demands a very heavy population of young nurse-age bees, usually maintained above a queen excluder over a strong colony, together with continuous access to a protein source and syrup, good ventilation and stable temperature. Limitations: banks fail through nurse-bee depletion, so fresh young bees must be rotated in; and prolonged banking carries real costs, with poorer queen survival and a slower start after introduction (surviving queens show little loss of sperm count or viability), so a bank is a short-term holding measure rather than a storage strategy.

Rationale: In the southeastern US the additional limitation is heat, which makes ventilation and shade essential, and small hive beetle, which will exploit a bank that is not tightly managed.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

70. (MC) Vairimorpha (Nosema) infection of a queen is of practical concern because:

Answer: C) It can infect the queen's midgut and is associated with altered physiology (including shifts in vitellogenin and mandibular pheromone levels) and with supersedure, and can be acquired from infected attendants used in cages and banks

Rationale: The transmission route through attendants is the operationally useful point: escort bees used in queen cages should come from colonies with low spore counts. There is no reliable external sign, so diagnosis requires microscopy. For a queen producer, this is one of several reasons to monitor Nosema in the colonies supplying bees to cell builders, banks and mating nuclei.

References: *Fries, J. Invertebr. Pathol. 103:573-579 (2010); Higes, Martin-Hernandez & Meana, Apidologie 41:375-392 (2010).*

71. (SA) You are asked to evaluate two queen sources by their performance in your own apiary. Describe how you would set up a fair comparison.

Model answer: Obtain a comparable number of queens from each source, ideally at least ten or more per source rather than one or two, since single-colony comparisons are dominated by chance. Introduce them into colonies equalized as far as possible for population, brood, stores and equipment, and distribute both sources across every apiary and every position rather than putting one source in one yard, so that site and position effects do not confound the comparison. Manage all colonies identically. Record defined measures over a full season: acceptance rate, time to laying, brood pattern quality, colony build-up, temperament, mite population growth, honey production and overwintering survival, using the same scoring method and, where possible, scoring without knowing which source a colony came from.

Rationale: The central point is that a queen's genetic merit is expressed by her workers and confounded by site, forage and management, so replication across locations and seasons is what turns an impression into evidence.

References: *Ruttner, Breeding Techniques and Selection for Breeding of the Honeybee, BIBBA, 1988; Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997.*

Section 4: Swarming, Supersedure & Absconding (Q72–85)

Part A — Questions

72. (MC) Which combination of factors best explains the initiation of reproductive swarming?

- **A)** Nectar dearth, which drives the colony to divide so that each portion can seek forage independently, which is why swarming peaks during the midsummer dearth period
- **B)** Queen age acting alone, so that a colony headed by a queen in her second season will prepare to swarm regardless of its population, its available space or the forage on offer
- **C)** Day length reaching a fixed threshold, which triggers queen cell construction on approximately the same calendar date each year irrespective of colony condition
- **D)** Congestion reducing the per-bee share of queen mandibular and footprint pheromone, together with surplus young nurse bees, ample incoming forage and a mature drone population

73. (SA) Distinguish swarm cells, supersedure cells and emergency cells by number, position and colony context, and explain why position alone is unreliable.

74. (MC) A primary swarm normally issues at approximately:

- **A)** The time the first virgin queen emerges from her cell, departing with her while the old queen remains behind with the brood and the remaining sealed queen cells
- **B)** Only after the colony's stores have been consumed, which is why swarming is most frequent at the end of a flow rather than during the period of most rapid build-up
- **C)** The time the first queen cells are capped, roughly day 8 from the egg, departing with the old mated queen and a large proportion of the workers, chiefly younger bees
- **D)** About three weeks after cells are first started, once the new queen has emerged, mated successfully and begun laying, so that neither colony is left without a queen

75. (SA) Describe the Demaree method and explain why it is preferred over a split when the objective is a honey crop.

76. (MC) An artificial swarm performed by the Pagden method works by:

- **A)** Moving the parent colony aside and placing the queen with a single frame of brood in a hive of drawn comb or foundation on the original site, so returning flying bees join her and form a unit with no queen cells
- **B)** Adding supers and drawn comb without any manipulation of the brood nest, on the principle that additional storage space alone removes the congestion that drives swarming
- **C)** Confining the queen in a cage within the colony for three weeks, so that the brood nest empties and the swarming impulse subsides before she is released to resume laying
- **D)** Removing every frame of brood from the apiary and redistributing it among unrelated colonies, so that the swarming colony is left with only the queen and its foragers

77. (TF) Destroying all queen cells found during an inspection, with no other change to the colony, is poor swarm control because the underlying congestion remains, cells are rebuilt within days, a hidden cell is easily missed, and if the colony has already swarmed the beekeeper may leave it hopelessly queenless.

True / False

78. (MC) Afterswarms differ from primary swarms in that they:

- **A)** Contain no queen of any kind, which is why they usually return to the parent colony within a day or two unless the beekeeper captures and requeens them promptly
- **B)** Contain the old mated queen and are larger than the primary swarm, since they include the foragers that had been away from the hive when the first swarm departed
- **C)** Issue only in late summer or autumn, after the main flow has ended, and are therefore distinguished from primary swarms chiefly by the season in which they occur
- **D)** Contain one or more virgin queens, are usually smaller, and may issue in succession over several days, potentially reducing the parent colony below viable strength

79. (SA) Explain why a swarm begins with a reduced mite load, and why swarming is nonetheless unacceptable as a Varroa management strategy.

80. (MC) Scouts assessing a potential nest cavity show measurable preferences. The most attractive combination is approximately:

- **A)** Any available cavity regardless of its dimensions, since scouts assess only whether a space is dry and dark and do not discriminate on volume, entrance size or height
- **B)** A volume of roughly 5 liters with a large entrance at the top of the cavity, close to the ground, since scouts prefer cavities they can defend easily against predators
- **C)** A volume of roughly 40 liters, an entrance of about 10 to 30 square centimeters located low in the cavity, several meters above the ground, with old comb odor present
- **D)** A volume of 150 liters or more with several entrances, since a large cavity with multiple exits allows the colony to expand and to ventilate during hot weather

81. (SA) You capture a swarm of unknown origin. Describe how you would handle it before adding it to your apiary, and give the reasons.

82. (TF) Adding a frame of open brood to a newly hived swarm strongly discourages absconding and carries no disease risk, since the bees of a swarm remove any infected material before it can affect them.

True / False

83. (MC) Absconding differs from swarming principally in that:

- **A)** In absconding the colony divides into two viable units, each with a queen, so that the beekeeper who captures the departing portion has effectively made an increase
- **B)** Absconding always involves a virgin queen, which is why it follows a supersedure attempt and why the abandoned colony is usually found to contain opened queen cells
- **C)** Absconding occurs only in spring during the swarming season, and is distinguished from swarming solely by the fact that the departing bees do not cluster before leaving
- **D)** In absconding the entire adult population departs, typically abandoning brood and stores, as an escape response to intolerable conditions rather than as a reproductive event

84. (SA) Explain why supering ahead of the bees is standard swarm-prevention practice during a flow, and state the counterbalancing consideration in the southeastern US.

85. (MC) A colony that swarmed three weeks ago is inspected and found to have a laying queen but roughly half the population of comparable colonies. The most appropriate action for a beekeeper hoping for a crop is to:

- **A)** Support its recovery with adequate space and stores and possibly a frame of emerging brood from a healthy colony, accepting that it may make little or no surplus this season
- **B)** Combine it with the strongest colony in the yard, since two colonies of unequal strength will produce less total surplus than one very strong colony working the same flow
- **C)** Treat it for American foulbrood as a precaution, since a colony that has swarmed and lost population is at heightened risk of brood disease during its recovery period
- **D)** Requeen it immediately with a purchased mated queen, since a queen that has just begun laying after a swarm is unlikely to build the colony quickly enough to make a crop

Part B — Answer Key: Section 4

72. (MC) Which combination of factors best explains the initiation of reproductive swarming?

Answer: D) Congestion reducing the per-bee share of queen mandibular and footprint pheromone, together with surplus young nurse bees, ample incoming forage and a mature drone population

Rationale: Swarming is a reproductive response to prosperity plus crowding, which is why the effective interventions relieve the condition rather than removing its symptoms. Congestion both dilutes queen pheromone across more bees and physically restricts the queen's movement over the comb, reducing her deposition of tarsal pheromone and releasing the inhibition on queen cup development. Dearth usually suppresses reproductive swarming, though it can precipitate absconding.

References: *Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987; Simpson, Bee World 39:193-202 (1958).*

73. (SA) Distinguish swarm cells, supersedure cells and emergency cells by number, position and colony context, and explain why position alone is unreliable.

Model answer: Swarm cells are typically numerous, often ten or more, built along the bottom bars and lower comb margins of a congested, populous, queenright colony during a build-up or flow. Supersedure cells are usually few, often one to three, built on the comb face in a colony of ordinary population whose queen is aging, injured or failing but still present. Emergency cells are converted from existing worker cells containing young larvae, so they appear on the comb face, often in a group, in a colony that has abruptly lost its queen. Position alone is unreliable because supersedure and emergency cells share the comb face, congested colonies sometimes build swarm cells on the face, and a colony may pursue more than one course at once.

Rationale: The reliable reading comes from context: presence or absence of the queen, colony population and congestion, brood pattern, drone population, season and forage. Finding eggs alongside sealed cells, or an unmarked queen where a marked one was expected, changes the interpretation entirely.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

74. (MC) A primary swarm normally issues at approximately:

Answer: C) The time the first queen cells are capped, roughly day 8 from the egg, departing with the old mated queen and a large proportion of the workers, chiefly younger bees

Rationale: The eight-day capping interval is the arithmetic behind the standard 7-day swarm-season inspection cadence: an interval longer than that can allow a colony to build, cap and depart between visits. The old queen is fed less and shaken by workers in the days before departure so that she loses roughly a quarter of her mass and can fly, which is why a hived swarm's queen resumes laying quickly.

References: *Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

75. (SA) Describe the Demaree method and explain why it is preferred over a split when the objective is a honey crop.

Model answer: The queen is left in the bottom box on one or two frames of open brood together with drawn comb or foundation; a queen excluder is placed above her, usually with a honey super between; and the great majority of the sealed brood and its combs are moved to a box above the excluder. All queen cells started in the upper box must be destroyed about a week later. It is preferred over a split when a crop is the objective because the colony remains a single large foraging unit, so its full foraging force is available for the flow, whereas a split divides the workforce between two units and generally sacrifices surplus.

Rationale: The manipulation relieves congestion around the queen and restores laying space, addressing the underlying condition rather than the symptom. Its principal failure mode is neglecting the follow-up inspection of the upper box, where queenless brood will start cells that can produce a virgin above the excluder.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Root, ABC and XYZ of Bee Culture, 41st ed., A.I. Root Co., 2007.*

76. (MC) An artificial swarm performed by the Pagden method works by:

Answer: A) Moving the parent colony aside and placing the queen with a single frame of brood in a hive of drawn comb or foundation on the original site, so returning flying bees join her and form a unit with no queen cells

Rationale: The method exploits forager fidelity to the original site to reproduce artificially the population split a natural swarm accomplishes, satisfying the impulse while retaining both halves. Its requirements are that the queen be located and moved, that the parent colony's cells be reduced to one good cell, and that the beekeeper account for the parent colony's loss of foragers. Variants such as the Snelgrove board manage the returning foragers more elaborately to concentrate strength for a flow.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Snelgrove, Swarming: Its Control and Prevention, 1934.*

77. (TF) Destroying all queen cells found during an inspection, with no other change to the colony, is poor swarm control because the underlying congestion remains, cells are rebuilt within days, a hidden cell is easily missed, and if the colony has already swarmed the beekeeper may leave it hopelessly queenless.

Answer: True

Rationale: Cell destruction has a legitimate place within a manipulation that also addresses the cause, such as a Demaree or an artificial swarm, but on its own it usually delays rather than prevents swarming. The queenless risk is the specific hazard: a beekeeper who has not confirmed whether the old queen is still present can remove the colony's only means of requeening itself.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammataro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

78. (MC) Afterswarms differ from primary swarms in that they:

Answer: D) Contain one or more virgin queens, are usually smaller, and may issue in succession over several days, potentially reducing the parent colony below viable strength

Rationale: Once a primary swarm has gone, the management objective changes from prevention to limiting the casts. The standard action is to reduce the remaining cells to a single good cell, or to remove all cells and introduce a mated queen. Leaving a full complement invites repeated afterswarms, and a colony that has cast three times in spring will neither make a crop nor reliably survive the summer.

References: *Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

79. (SA) Explain why a swarm begins with a reduced mite load, and why swarming is nonetheless unacceptable as a Varroa management strategy.

Model answer: A swarm departs carrying only the mites present on the adult bees it takes with it, leaving behind those developing in sealed brood, and the brood break that follows while the swarm draws comb further interrupts mite reproduction, so mites per bee are reduced. It is unacceptable as a management strategy because the parent colony retains a heavy mite population; the swarm still carries mites and their viruses; the beekeeper loses the honey crop and much of the colony's population; escaped swarms establish feral colonies that spread mites and disease across the landscape; and swarming creates nuisance and liability problems in settled areas.

Rationale: The legitimate application of the same biology is a deliberate brood break through a split, a queen cage or requeening, combined with a treatment such as oxalic acid that is highly effective when no sealed brood is present.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Seeley, Apidologie 38:19-29 (2007).*

80. (MC) Scouts assessing a potential nest cavity show measurable preferences. The most attractive combination is approximately:

Answer: C) A volume of roughly 40 liters, an entrance of about 10 to 30 square centimeters located low in the cavity, several meters above the ground, with old comb odor present

Rationale: These preferences are why a single deep Langstroth box makes an effective bait hive, and why adding a frame of old dark comb or a lemongrass oil lure improves occupancy. In the southeastern US the practical corollary is that traps must be deployed well before the early swarm season and checked regularly, so captured swarms are hived before they fill the box with comb.

References: *Seeley & Morse, Insectes Soc. 25:323-337 (1978); Seeley, Honeybee Democracy, Princeton Univ. Press, 2010.*

81. (SA) You capture a swarm of unknown origin. Describe how you would handle it before adding it to your apiary, and give the reasons.

Model answer: Hive it on foundation or clean comb rather than on comb of unknown history, so that it brings as little with it as possible. Keep it separated from the rest of the apiary for a period while you observe it. Watch for temperament over several inspections, for queen performance once she begins laying, and for signs of disease in the first brood cycle. Perform a mite assessment, since a swarm carries phoretic mites even though its load is reduced. Only then integrate it, and consider requeening with known stock, particularly in parts of the southeastern US where African-derived bees occur, since this replaces both the maternal line and, over about six weeks, the workforce.

Rationale: The reasons are disease, mites, temperament and genetics: a swarm of unknown origin may carry foulbrood spores or viruses, may be unusually defensive, and its genetics are unknown and uncontrolled.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004).*

82. (TF) Adding a frame of open brood to a newly hived swarm strongly discourages absconding and carries no disease risk, since the bees of a swarm remove any infected material before it can affect them.

Answer: False

Rationale: The anchoring effect is real, but the claim of no risk is wrong. Brood comb carries whatever the donor colony holds, including American and European foulbrood, Vairimorpha (Nosema), viruses and Varroa, into a swarm that would otherwise have started comparatively clean. The disciplined practice is to take the frame only from a colony of verified health, or to confine the swarm briefly with an excluder over the entrance and feed instead.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

83. (MC) Absconding differs from swarming principally in that:

Answer: D) In absconding the entire adult population departs, typically abandoning brood and stores, as an escape response to intolerable conditions rather than as a reproductive event

Rationale: In the southeastern US the leading triggers are severe small hive beetle infestation and slimed comb, wax moth destruction, starvation during the dearth, extreme heat in an unshaded apiary, ant pressure and repeated heavy disturbance. Finding an empty hive with brood abandoned in the combs should prompt a search for the precipitating stress rather than being recorded as a swarm, since the same stress is probably acting on other colonies in the yard.

References: *Neumann & Elzen, Apidologie 35:229-247 (2004); Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

84. (SA) Explain why supering ahead of the bees is standard swarm-prevention practice during a flow, and state the counterbalancing consideration in the southeastern US.

Model answer: Adding storage space before the colony needs it relieves congestion in the brood nest, which raises the per-bee share of queen pheromone and restores laying space, addressing two of the principal drivers of the swarming impulse. During a strong flow, bees will fill the space quickly, so there is little cost to being early. The counterbalancing consideration in the region is small hive beetle: undefended super space on a colony that lacks the population to patrol it becomes beetle habitat, so the practice should be applied generously to strong colonies during a flow and conservatively to weak ones, with supers removed promptly when the flow ends.

Rationale: The same reasoning applies to giving foundation, which a colony draws well during a flow and poorly during a dearth.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension small hive beetle publications, southeastern US.*

85. (MC) A colony that swarmed three weeks ago is inspected and found to have a laying queen but roughly half the population of comparable colonies. The most appropriate action for a beekeeper hoping for a crop is to:

Answer: A) Support its recovery with adequate space and stores and possibly a frame of emerging brood from a healthy colony, accepting that it may make little or no surplus this season

Rationale: A colony that swarmed and successfully requeened itself is functional but demographically behind, and it needs time rather than intervention. Requeening a newly mated queen accomplishes nothing and risks losing an accepted queen. Boosting with emerging brood is the standard remedy, subject to the donor being healthy and not being weakened below its own requirements.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammartaro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

Section 5: Genetics, Stock Selection & African-Derived Bees (Q86–102)

Part A — Questions

86. (MC) Full sisters in a honey bee colony are related by three quarters rather than one half because:

- **A)** Drones are haploid, so all daughters of one drone receive his entire genome rather than a random half, raising average relatedness among sisters sharing that father
- **B)** Queens reproduce parthenogenetically for female offspring, so worker sisters are effectively clones of their mother and differ only in the drones that fathered them
- **C)** Workers exchange genetic material during trophallaxis, so that bees within a colony become progressively more similar to one another over the course of the season
- **D)** The queen contributes twice as many chromosomes to each daughter as the drone does, so the maternal contribution dominates and raises relatedness among all her offspring

87. (SA) Explain why colony-level genetic diversity, arising from a queen mating with many drones, improves colony performance. Give two specific documented benefits.

88. (MC) A beekeeper purchases queens of a selected mite-resistant stock, is pleased with their performance, and rears open-mated daughters from them the following year. The resistance is likely to diminish because:

- **A)** Resistance traits are not heritable at all and reflect only the conditions under which the purchased colonies were managed by the breeder before they were shipped
- **B)** The trait is carried in the queen's own body rather than in her genes, so it is lost as soon as the original purchased queen is replaced by any daughter, however she mates
- **C)** Mite resistance is polygenic and expressed by the workers, whose fathers are local drones, so each generation of open mating dilutes the alleles toward the population average
- **D)** The trait is lost during transport, since the thermal stress of shipping damages the specific gene regions responsible for hygienic behavior in the queen's stored sperm

89. (MC) Which pairing of stock and general characteristics is most accurate?

- **A)** Italian-derived stock: dark, slow to build in spring and very frugal in dearth; Carniolan-derived: yellow, slow building, heavy consumers of stores and notably poor winterers
- **B)** Russian-derived stock: selected in isolation from Varroa and therefore naive to it; Italian-derived: dark, frugal and noted for an unusually restrained spring build-up
- **C)** Carniolan-derived stock: yellow, slow to build and prone to robbing; Russian-derived: selected purely for honey yield with no history of exposure to parasitic mites
- **D)** Italian-derived stock: light, prolific, good comb builders and generally gentle, but rearing brood late; Carniolan-derived: dark, very rapid build-up, frugal, more swarm-prone

90. (SA) Summarize how African-derived honey bees came to be present in the Americas, and state how they spread.

91. (MC) Identification of African-derived honey bees:

- **A)** Can be done from a single wing, by measuring the cubital index of one forager, which separates the two populations without overlap and requires no other measurement
- **B)** Can be done reliably in the field by color, since African-derived bees are consistently darker and smaller than European-derived bees of any commercially available stock
- **C)** Cannot be done reliably by appearance or by a single behavioral observation; confirmation requires laboratory analysis such as morphometric measurement or a molecular assay
- **D)** Is unnecessary in practice, since a colony's defensive behavior on any single inspection is sufficient to classify it and to determine whether requeening is required

92. (SA) Explain why requeening is the primary management response to a colony with undesirable African-derived genetics, and describe how long the change takes.

93. (TF) All drones produced by one queen are genetically identical, since they develop from unfertilized eggs carrying only her genes.

True / False

94. (MC) Varroa sensitive hygiene is best defined as:

- **A)** A tendency to abscond once mite levels exceed a threshold, so that the colony abandons its infested comb and re-establishes elsewhere with a much reduced mite burden
- **B)** The detection of sealed brood cells containing reproducing Varroa foundresses and the removal or disturbance of the contents, which causes those mites' reproduction to fail
- **C)** A physiological resistance in the queen, whose brood produces a compound that prevents Varroa foundresses from reproducing successfully in cells containing her offspring
- **D)** The removal of phoretic mites from the bodies of adult bees by self-grooming and by allogrooming, measured as the proportion of fallen mites showing physical damage

95. (SA) Describe how a beekeeper with fifty colonies could begin selecting their own stock, and state the records required.

96. (MC) Selecting intensively for a single trait such as maximum honey yield, without attention to other characteristics, is hazardous because:

- **A)** Honey yield cannot be measured accurately enough to support selection, since colony weight varies with stores and brood as well as with the surplus actually produced
- **B)** Honey yield has no heritable component at all, being determined entirely by forage and weather, so selection on it produces no genetic change of any kind in the stock
- **C)** Traits are genetically correlated, so intense selection on one can move others such as defensiveness, swarming tendency or wintering ability, and can narrow diversity
- **D)** Selection for production traits is prohibited under the breeding standards adopted by most national and regional beekeeping organizations in the United States

97. (TF) Because a colony's observable traits are produced by its workers, and workers derive half their genes from the drones the queen mated with, evaluating a queen's genetic merit requires assessing the colony she heads rather than the queen herself.

True / False

98. (MC) Rothenbuhler's classic work on hygienic behavior is significant because it:

- **A)** Showed that hygienic behavior has no measurable effect on the incidence of brood disease, and that its apparent benefit reflected differences in colony strength
- **B)** Proved that only the queen performs the behavior, uncapping affected cells during her laying circuit so that workers can remove the diseased brood she has exposed
- **C)** Established that hygienic behavior is learned by young bees from older workers, and can therefore be spread through an apiary simply by exchanging frames between colonies
- **D)** Demonstrated through controlled crosses that hygienic behavior has a genetic basis and separated uncapping from removal as components, establishing that it could be selected

99. (SA) Explain what feral colonies contribute to the genetics of a managed apiary, and what a beekeeper can and cannot control.

100. (MC) A colony in a closed breeding line shows a scattered brood pattern with roughly a quarter of the cells empty, but with no ropiness, no odor, no scale, negligible mite counts and a queen laying normally. The most likely explanation is:

- **A)** A pollen-bound brood nest, in which stored beebread occupies a proportion of the cells and prevents the queen from laying in an otherwise continuous brood area
- **B)** Chilled brood from an inspection conducted in cool weather, which killed a proportion of the larvae scattered across the comb and left the remainder unaffected
- **C)** European foulbrood at an early stage, in which affected larvae are removed by the colony before the characteristic discoloration and odor have had time to develop
- **D)** Inbreeding, producing fertilized eggs homozygous at the sex-determining locus that develop as diploid drones and are removed by nurse bees shortly after they hatch

101. (MC) An F1 hybrid queen purchased from a breeder performs excellently, but her open-mated daughters are variable and some are noticeably more defensive. The best explanation is that:

- **A)** Hybrid queens are effectively sterile in the second generation, so their daughters produce workers of mixed and unpredictable parentage from stored sperm of poor quality
- **B)** Hybrid vigor and a controlled cross produced the mother's performance, but her daughters segregate genetically and mate with local drones, so their colonies vary widely
- **C)** Defensiveness is entirely environmental, so the variation among daughter colonies reflects differences in their sites and forage rather than any genetic difference
- **D)** The purchased queen was mislabeled by the breeder, and her daughters therefore reveal the true genetics of the stock rather than those advertised at the time of sale

102. (SA) A beekeeper wants to reduce reliance on miticides by requeening with resistant stock. State the three operational conditions that must accompany the stock change for the strategy to have a fair chance.

Part B — Answer Key: Section 5

86. (MC) Full sisters in a honey bee colony are related by three quarters rather than one half because:

Answer: A) Drones are haploid, so all daughters of one drone receive his entire genome rather than a random half, raising average relatedness among sisters sharing that father

Rationale: The consequence for a colony is that multiple mating produces a mixture of full sisters at three quarters and half sisters at one quarter, lowering average relatedness across the colony. This relatedness asymmetry underlies worker policing, in which workers remove other workers' male eggs, and it is why laying workers become conspicuous only after prolonged queenlessness when both pheromonal inhibition and policing have decayed.

References: Ratnieks & Visscher, *Nature* 342:796-797 (1989); Winston, *The Biology of the Honey Bee*, Harvard Univ. Press, 1987.

87. (SA) Explain why colony-level genetic diversity, arising from a queen mating with many drones, improves colony performance. Give two specific documented benefits.

Model answer: Patriline within a colony differ in the stimulus intensity at which individual bees begin a given task, so a genetically diverse colony responds to changing conditions in a graded rather than an all-or-nothing manner. Documented benefits include more precise thermoregulation, with diverse colonies holding brood nest temperature within a narrower band than genetically uniform ones; and improved overall colony productivity and winter survival, with diverse colonies building more comb, storing more food and surviving winter at higher rates. Lower pathogen loads and faster foraging (reported at 27 to 78 percent faster on most mornings sampled) are further documented benefits.

Rationale: The practical implication is that breeding programs must avoid narrowing within-colony diversity, and that instrumental insemination with a single drone, useful for genetic studies, produces colonies that underperform.

References: Mattila & Seeley, *Science* 317:362-364 (2007); Jones, Myerscough, Graham & Oldroyd, *Science* 305:402-404 (2004).

88. (MC) A beekeeper purchases queens of a selected mite-resistant stock, is pleased with their performance, and rears open-mated daughters from them the following year. The resistance is likely to diminish because:

Answer: C) Mite resistance is polygenic and expressed by the workers, whose fathers are local drones, so each generation of open mating dilutes the alleles toward the population average

Rationale: The options for maintaining a trait are therefore to buy replacement queens from the selected source on a schedule, to use instrumental insemination or a genuinely isolated mating area, or to participate in a program with controlled matings. Saturating the local area with drones from selected colonies shifts the odds but never determines paternity, because feral and neighboring drones remain present at congregation areas.

References: Harbo & Harris, *J. Apic. Res.* 44:21-23 (2005); Ruttner, *Breeding Techniques and Selection for Breeding of the Honeybee*, BIBBA, 1988.

89. (MC) Which pairing of stock and general characteristics is most accurate?

Answer: D) Italian-derived stock: light, prolific, good comb builders and generally gentle, but rearing brood late; Carniolan-derived: dark, very rapid build-up, frugal, more swarm-prone

Rationale: Stock choice is a set of trade-offs matched to a region and a management style. In the southeastern US the long season and early spring suit prolific stock, but rapid-building Carniolan-derived lines demand close swarm management during the early build-up. Russian-derived stock was imported for its long history of coexistence with Varroa, and various lines are selected specifically for Varroa sensitive hygiene.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Rinderer et al., Apidologie 32:381-394 (2001).*

90. (SA) Summarize how African-derived honey bees came to be present in the Americas, and state how they spread.

Model answer: Colonies of the African subspecies *Apis mellifera scutellata* were imported to South America in the mid-1950s for a breeding program intended to improve performance under tropical conditions, and swarms escaped in 1957. The resulting population hybridized with resident European-derived stock and spread through South and Central America, reaching the southwestern United States in 1990 and subsequently expanding into parts of the southern and southeastern US. Spread occurs by swarming and absconding, which move colonies across the landscape, and by drones from African-derived colonies mating with European-derived queens, which introduces the genetics into managed and feral populations without any colony movement.

Rationale: Understanding both mechanisms matters practically: even a beekeeper who never acquires an African-derived colony can find their open-mated queens producing more defensive workers if such drones are present locally.

References: *Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004); Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

91. (MC) Identification of African-derived honey bees:

Answer: C) Cannot be done reliably by appearance or by a single behavioral observation; confirmation requires laboratory analysis such as morphometric measurement or a molecular assay

Rationale: African-derived bees average slightly smaller, but the ranges overlap and field identification by eye is unreliable. Behavior varies with weather, colony state and disturbance, so one defensive episode proves nothing. For a beekeeper the practical response to a persistently and extremely defensive colony in an affected part of the southeastern US is to requeen with known European stock, and to submit a sample to the state regulatory agency or an approved laboratory if formal identification matters.

References: *Rinderer, Buco, Rubink, Daly & Stelzer, Apidologie 24:569-585 (1993); Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004).*

92. (SA) Explain why requeening is the primary management response to a colony with undesirable African-derived genetics, and describe how long the change takes.

Model answer: The workers present in the colony carry the genetics of the existing queen and the drones she mated with, and their behavior cannot be altered. Introducing a mated queen of known

gentle European stock changes the genetics of all subsequent workers, so the colony's temperament shifts as the existing population is replaced by her daughters. Because worker lifespan during the active season is roughly four to six weeks, her first daughters emerge about 21 days after she begins laying, so temperament begins shifting noticeably at three to four weeks, is clearly changed by about six weeks, and is essentially complete after two brood cycles, six to eight weeks from a successful introduction.

Rationale: In the interim the colony must be handled with full precautions, and finding and removing the old queen in a highly defensive colony may require assistance, full protective equipment, cool early-morning timing, or moving the colony to a remote location first. Requeening also does not address drones already produced, which is why area-wide management and maintaining requeened managed colonies matter.

References: *Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004); Cooperative Extension African honey bee publications, southeastern US.*

93. (TF) All drones produced by one queen are genetically identical, since they develop from unfertilized eggs carrying only her genes.

Answer: False

Rationale: Drones are haploid and carry only maternal genes, but each unfertilized egg is produced through meiosis with recombination, so each drone carries a different random half of the queen's diploid genome. Drones from one queen are therefore related to one another by one half, not by one. The practical relevance is that using a single drone mother colony does not produce genetically uniform drones; controlling paternal variance requires instrumental insemination with semen from a single drone.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

94. (MC) Varroa sensitive hygiene is best defined as:

Answer: B) The detection of sealed brood cells containing reproducing Varroa foundresses and the removal or disturbance of the contents, which causes those mites' reproduction to fail

Rationale: VSH is distinct from grooming behavior, which acts on adult bees, and from general hygienic behavior toward dead brood. All three contribute to resistance and are inherited separately. The trait is measured as the proportion of foundress mites in sealed brood that have failed to reproduce, because removal of infested pupae is the primary mechanism and that proportion is its footprint, although how much of the non-reproduction is a by-product of removal is still debated, and a buyer of resistant stock should know which trait a supplier selects for.

References: *Harbo & Harris, J. Econ. Entomol. 92:261-265 (1999); Harbo & Harris, J. Apic. Res. 44:21-23 (2005).*

95. (SA) Describe how a beekeeper with fifty colonies could begin selecting their own stock, and state the records required.

Model answer: Evaluate every colony across a full season against a defined set of criteria: gentleness and calmness on the comb, honey production, brood pattern quality, mite population growth measured by consistent alcohol wash counts, disease incidence, spring build-up and overwintering survival. Record these systematically by hive identification, so that impressions become comparable data. Identify the best-performing colonies over at least one full season, preferably two, and rear queens from them, either by grafting or by notching, distributing the daughters across the operation. Cull or requeen the poorest colonies. Where possible, place drone comb in the best colonies so they contribute drones to local matings, while recognizing that this shifts rather than controls paternity.

Rationale: The essential records are dated, colony-by-colony entries covering queen status and age, brood assessment, mite counts before and after any treatment, treatments applied, honey harvested, temperament scores and overwintering outcome. Without them, selection is memory rather than evidence, and memory favors whichever colony was inspected on a good day.

References: *Ruttner, Breeding Techniques and Selection for Breeding of the Honeybee, BIBBA, 1988; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

96. (MC) Selecting intensively for a single trait such as maximum honey yield, without attention to other characteristics, is hazardous because:

Answer: C) Traits are genetically correlated, so intense selection on one can move others such as defensiveness, swarming tendency or wintering ability, and can narrow diversity

Rationale: Correlated response is the standard caution in quantitative genetics, and honey bee breeding programs therefore use selection indices weighting several traits together. Narrowing diversity is a compounding hazard, given both the demonstrated colony-level benefits of within-colony genetic diversity and the risk of losing sex-determination alleles in a small closed population.

References: *Ruttner, Breeding Techniques and Selection for Breeding of the Honeybee, BIBBA, 1988; Bienefeld, Ehrhardt & Reinhardt, Apidologie 38:77-85 (2007).*

97. (TF) Because a colony's observable traits are produced by its workers, and workers derive half their genes from the drones the queen mated with, evaluating a queen's genetic merit requires assessing the colony she heads rather than the queen herself.

Answer: True

Rationale: This is the fundamental oddity of honey bee breeding: the individual selected is not the individual whose performance is measured, and the measured performance is confounded by paternal contributions the breeder usually cannot control. It is why serious programs test many daughter queens across multiple locations rather than judging a line from one hive, and why colony records over a full season are the minimum useful evidence.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Ruttner, Breeding Techniques and Selection for Breeding of the Honeybee, BIBBA, 1988.*

98. (MC) Rothenbuhler's classic work on hygienic behavior is significant because it:

Answer: D) Demonstrated through controlled crosses that hygienic behavior has a genetic basis and separated uncapping from removal as components, establishing that it could be selected

Rationale: Modern work has shown the genetic architecture to be more complex and polygenic than the original simple model, but the experimental demonstration that a behavioral disease-resistance trait is heritable and selectable was foundational. It underlies the practical availability of hygienic stock and the freeze-killed brood assay that a working beekeeper can perform.

References: *Rothenbuhler, Am. Zool. 4:111-123 (1964); Spivak & Downey, J. Econ. Entomol. 91:64-70 (1998).*

99. (SA) Explain what feral colonies contribute to the genetics of a managed apiary, and what a beekeeper can and cannot control.

Model answer: Feral colonies contribute drones to local congregation areas, so they father a share of the workers in every open-mated colony in the vicinity. They also serve as reservoirs of Varroa and disease, and in parts of the southeastern US they may carry African-derived genetics that are introduced into managed stock through those matings. A beekeeper can control the maternal line completely, by choosing which queens head their colonies and requeening from a known source on a schedule. They cannot control paternity under open mating, since drone congregation areas draw from a radius of several miles including feral colonies and neighboring apiaries.

Rationale: The practical consequences are that requeening is the effective lever, that a captured feral swarm should be observed and usually requeened, and that expectations about the performance of open-mated daughters should be modest.

References: *Koeniger, Koeniger, Ellis & Connor, Mating Biology of Honey Bees, Wicwas, 2014; Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004).*

100. (MC) A colony in a closed breeding line shows a scattered brood pattern with roughly a quarter of the cells empty, but with no ropiness, no odor, no scale, negligible mite counts and a queen laying normally. The most likely explanation is:

Answer: D) Inbreeding, producing fertilized eggs homozygous at the sex-determining locus that develop as diploid drones and are removed by nurse bees shortly after they hatch

Rationale: The diagnostic key is the absence of any disease sign combined with an otherwise normal-laying queen. The removal happens within hours of hatching, so the beekeeper sees empty cells rather than dead larvae. The remedy is the introduction of unrelated genetics, which is why closed breeding programs maintain many independent lines and use rotational mating schemes to keep the rate of inbreeding low.

References: *Woyke, J. Apic. Res. 2:19-24 (1963); Page & Laidlaw, J. Apic. Res. 21:30-37 (1982).*

101. (MC) An F1 hybrid queen purchased from a breeder performs excellently, but her open-mated daughters are variable and some are noticeably more defensive. The best explanation is that:

Answer: B) Hybrid vigor and a controlled cross produced the mother's performance, but her daughters segregate genetically and mate with local drones, so their colonies vary widely

Rationale: This is the practical genetics behind a common complaint. It argues for buying replacement queens from the producer rather than propagating from a hybrid, or for committing to deliberate selection over several generations if the beekeeper wants their own line. It is also a reason to evaluate daughters before distributing them widely.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997.*

102. (SA) A beekeeper wants to reduce reliance on miticides by requeening with resistant stock. State the three operational conditions that must accompany the stock change for the strategy to have a fair chance.

Model answer: First, continued quantitative mite monitoring with defined action thresholds, so that the stock's performance is verified rather than assumed and treatment is applied when it underperforms. Second, control of mite immigration, which requires apiary-level and ideally area-wide thinking: prompt attention to collapsing colonies, sensible hive density, layout that limits drift, and communication with neighboring beekeepers. Third, maintenance of the genetics, since open-mated daughters regress toward the local population, so the beekeeper must requeen from the resistant source on a defined schedule or participate in a program controlling matings. Sound nutrition and general management form the necessary background.

Rationale: The common failure mode is adopting resistant stock and abandoning monitoring, which converts a promising strategy into an untested assumption and is usually discovered the following winter.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Rinderer et al., Apidologie 41:409-424 (2010).*

Section 6: Equipment, Apiary Design & Regional Siting (Q103–114)

Part A — Questions

103. (MC) Bee space is best stated as:

- **A)** A gap of about 1 millimeter, which bees seal with propolis, and which defines the tolerance to which frame rests and box rims must be manufactured for equipment to fit
- **B)** A gap of roughly 6 to 9 millimeters, about one quarter to three eighths of an inch, left open as a passageway; smaller gaps are propolized and larger ones filled with comb
- **C)** A gap of about 50 millimeters, the distance bees maintain between the top bars and the inner cover, and the reason burr comb forms when that clearance is reduced
- **D)** A gap of about 25 millimeters, matching the thickness of a drawn comb, which is the spacing maintained between the faces of adjacent combs in a natural nest cavity

104. (SA) Compare all-deep, all-medium and eight-frame equipment for a sideline operation in the southeastern US, addressing weight, interchangeability and heat.

105. (MC) The functional gap in a standard queen excluder is approximately:

- **A)** 4.1 to 4.4 millimeters, which passes workers but not the wider thorax of a laying queen or of most drones
- **B)** 2.5 millimeters, which passes only the youngest workers and therefore also excludes older foragers from the supers
- **C)** 6.5 millimeters, matching bee space, so that workers pass freely while the queen is deterred by the length of the slot
- **D)** 8.0 millimeters, which admits workers and drones freely and excludes only the queen's fully extended abdomen

106. (SA) Describe the considerations that should govern apiary siting in the southeastern US, giving at least six.

107. (MC) A screened bottom board should be understood as:

- **A)** A requirement of most state apiary regulations, adopted so that inspectors can assess mite levels without opening colonies during routine apiary inspection visits
- **B)** A physical barrier that excludes small hive beetles from the colony, since adult beetles cannot pass the mesh while workers and drones move through it without difficulty
- **C)** An effective stand-alone control that removes enough mites through natural fall to hold populations below threshold, eliminating the need for any other intervention
- **D)** A monitoring aid allowing natural mite fall to be counted, plus some ventilation benefit, producing at most a small reduction in mite population and not a control measure

108. (TF) Nine or eight frames evenly spaced in a ten-frame super produce thicker combs that are easier to uncap, and applying the same spacing to frames of foundation produces equally regular results.

True / False

109. (SA) Explain how a beekeeper should protect hives from imported fire ants, and state why hive stands are central to the approach.

110. (MC) With respect to winter moisture in a hive, the physically correct account is that:

- **A)** Metabolic water vapor condenses on the coldest surface, usually the inner cover, and dripping condensate is more damaging than cold air, so vapor must escape or the top be warmed
- **B)** Cold air itself is the principal killer of wintering colonies, so hives should be sealed as tightly as possible and all upper ventilation closed before the onset of winter
- **C)** Bees produce almost no water vapor while clustered, so condensation in a winter hive originates from ground moisture rising through the bottom board and the entrance
- **D)** Insulating above the cluster increases condensation onto the bees by trapping vapor, which is why insulated inner covers are avoided in favor of open ventilated covers

111. (MC) Radial and tangential extractors differ in that:

- **A)** Radial extractors can be used only on comb honey and cut comb, while tangential extractors are the only type suitable for extracting fully capped frames of honey
- **B)** Radial extractors hold frames like spokes and empty both faces at once with no reversing, while tangential extractors present one face outward and must be turned
- **C)** Tangential extractors are always motor driven and radial extractors always hand cranked, which is the practical distinction for a beekeeper choosing between them
- **D)** Radial extractors require each frame to be reversed halfway through the cycle, while tangential extractors empty both faces at once because the frames lie flat

112. (SA) Explain what a slatted rack does and evaluate the strength of the evidence for each of its claimed benefits.

113. (TF) Preparing an apiary for a severe tropical storm should include strapping each hive to its stand and the stand to the ground, reducing stack height where practical, and moving colonies off flood-prone low ground.

True / False

114. (MC) The principal analytical value of a hive scale that records weight continuously is that:

- **A)** The shape and slope of the weight curve reveal the onset and end of flows, dearth, robbing, swarm departures and winter consumption, none visible from a single inspection
- **B)** It detects Varroa infestation, since the weight of a heavily infested colony declines measurably as the mite population reduces the emergence weight of each new bee
- **C)** It replaces the need for physical inspection entirely, since every management-relevant condition inside the colony produces a distinctive signature in the weight record
- **D)** It measures the colony's adult population directly and continuously, allowing the beekeeper to track build-up and decline without ever opening the hive to assess frames

Part B — Answer Key: Section 6

103. (MC) Bee space is best stated as:

Answer: B) A gap of roughly 6 to 9 millimeters, about one quarter to three eighths of an inch, left open as a passageway; smaller gaps are propolized and larger ones filled with comb

Rationale: The tolerance is narrow, which is why the principle works as a design constraint. Practical consequences appear constantly: burr comb between boxes indicates an oversized gap, heavy propolizing indicates an undersized one, and mixing top-bee-space and bottom-bee-space equipment in a single stack creates both faults at once. Warped, mismatched or damaged equipment is a persistent source of comb problems.

References: *Langstroth, Langstroth on the Hive and the Honey-Bee, 1853; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

104. (SA) Compare all-deep, all-medium and eight-frame equipment for a sideline operation in the southeastern US, addressing weight, interchangeability and heat.

Model answer: A ten-frame deep of capped honey weighs roughly 80 to 90 pounds and a ten-frame medium roughly 50 to 60; eight-frame equivalents are proportionally lighter. All-medium equipment makes every box and frame interchangeable, simplifies inventory and manipulation, and keeps individual lifts manageable, at the cost of more boxes to handle and slightly more disruption at box junctions within the brood nest. All-deep brood chambers concentrate the brood nest with fewer interruptions but produce lifts that are a genuine injury risk. Eight-frame equipment reduces weight further and suits colonies that overwinter as a taller, narrower cluster. In the southeastern US the heat consideration is decisive for many beekeepers: repeated heavy lifting in a full suit in midsummer is both an injury and a heat illness hazard, which is a strong argument for mediums or eight-frame boxes.

Rationale: Whatever is chosen, standardizing across the operation is worth more than the theoretical merits of any single configuration.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammartaro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

105. (MC) The functional gap in a standard queen excluder is approximately:

Answer: A) 4.1 to 4.4 millimeters, which passes workers but not the wider thorax of a laying queen or of most drones

Rationale: The tolerance is narrow, which explains why a distorted, damaged or poorly manufactured excluder can pass a queen, and why small or virgin queens sometimes pass a sound one. Two practical corollaries follow: inspect excluders for distortion before use, and remember that drones trapped above an excluder will die at it, which argues for an upper entrance during a flow or for periodic release.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Root, ABC and XYZ of Bee Culture, 41st ed., A.I. Root Co., 2007.*

106. (SA) Describe the considerations that should govern apiary siting in the southeastern US, giving at least six.

Model answer: Morning sun with some afternoon shade in summer, so bees fly early while heat stress and bearding are reduced; well-drained ground above flood level, since the coastal plain and river bottoms of the region flood and standing water kills colonies that survive the wind; good air drainage rather than a low frost pocket; vehicle access adequate in wet conditions, since supers must be carried; a dependable water source nearby, both for the colonies and to keep them away from neighbors' pools and stock tanks; protection from prevailing winter wind; separation from neighbors, livestock, public paths and tethered animals, with flyway barriers where appropriate; hive stands to raise equipment above damp ground and to allow ant barriers; and consideration of surrounding forage and pesticide use across a two- to three-mile radius rather than only the immediate property.

Rationale: An additional regional point is that heavily shaded, moist sites are associated with greater small hive beetle pressure, so full-day deep shade is a poor choice even though some afternoon shade is valuable.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

107. (MC) A screened bottom board should be understood as:

Answer: D) A monitoring aid allowing natural mite fall to be counted, plus some ventilation benefit, producing at most a small reduction in mite population and not a control measure

Rationale: Controlled trials have found only modest reductions attributable to screened bottoms. Their real value is monitoring and, in the southeastern summer, ventilation, and some beetle trap designs use the space beneath them. The consequential error is believing that a screened bottom is treating the mites, which is a recurring reason colonies are lost in autumn.

References: *Ellis, Delaplane & Hood, Am. Bee J. 141:813-816 (2001); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

108. (TF) Nine or eight frames evenly spaced in a ten-frame super produce thicker combs that are easier to uncap, and applying the same spacing to frames of foundation produces equally regular results.

Answer: False

Rationale: The first half is correct and the second is not. Bees build deeper cells at wider spacing, but they need an accurate reference to build straight, which drawn comb supplies and foundation does not. Foundation spaced wide produces wavy, cross-built comb. The rule is to draw comb at full frame complement and reduce spacing only afterward, using spacers or a follower so the frames stay evenly positioned.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Root, ABC and XYZ of Bee Culture, 41st ed., A.I. Root Co., 2007.*

109. (SA) Explain how a beekeeper should protect hives from imported fire ants, and state why hive stands are central to the approach.

Model answer: Keep hives on stands so that ants must follow a defined path, then treat that path: stand legs set in containers of oil, or coated with a grease or sticky barrier, deny access. Keep vegetation cleared from around and beneath the stand so ants cannot bridge to the hive from grass or brush. Maintain strong colonies, since ants principally exploit weak colonies, nucs and newly hived swarms. Where baiting is used, apply an approved fire ant bait to mounds at a distance from the hives, following the label, so that hive products are not contaminated. Stands are central because without them the hive sits in the ants' foraging substrate and no barrier is possible.

Rationale: Stands serve several other purposes in the region: they raise equipment above damp ground and minor flooding, improve air circulation, reduce back strain, and make hives less accessible to skunks.

References: *Morse & Flottum (eds.), Honey Bee Pests, Predators, and Diseases, 3rd ed., A.I. Root, 1997; Cooperative Extension apiculture publications, southeastern US.*

110. (MC) With respect to winter moisture in a hive, the physically correct account is that:

Answer: A) Metabolic water vapor condenses on the coldest surface, usually the inner cover, and dripping condensate is more damaging than cold air, so vapor must escape or the top be warmed

Rationale: The choice claiming that insulating above the cluster increases condensation onto the bees inverts the physics, and is the misconception this item targets. In the humid southeastern US the issue is if anything more relevant, not less: mild wet winters produce plenty of vapor, and a tightly sealed hive with a cold inner cover will drip. A small upper vent, a slight forward tilt for drainage, or an insulated inner cover all address it.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Mitchell, Int. J. Biometeorol. 60:629-638 (2016).*

111. (MC) Radial and tangential extractors differ in that:

Answer: B) Radial extractors hold frames like spokes and empty both faces at once with no reversing, while tangential extractors present one face outward and must be turned

Rationale: Radial extraction is faster and requires less handling; tangential extraction, run slowly, can be gentler on fragile new comb. In either case the honey should be warm to reduce viscosity, speed should be increased gradually, and very heavy or newly drawn combs handled carefully to avoid blowing out the midrib. Old dark comb is structurally stronger and tolerates radial extraction better than pale new comb.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammataro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

112. (SA) Explain what a slatted rack does and evaluate the strength of the evidence for each of its claimed benefits.

Model answer: A slatted rack is a frame of wooden slats placed between the bottom board and the lowest brood box, adding space beneath the brood nest. Its clustering-space function follows directly from geometry: it gives bees a place to cluster off the brood combs in hot weather, reducing bearding

on the hive front. Its draft-buffering effect is widely reported by beekeepers, who say air entering the entrance no longer blows across the lowest combs so the queen lays to the bottom bar of the lower frames, but this has not been tested in controlled trials. Its claimed effect in reducing swarming, by relieving congestion beneath the brood nest, is the least supported: it rests on beekeeper observation, is plausible but not demonstrated, and should be presented as such. None of the three claims has been tested in controlled trials.

Rationale: In the southeastern US the ventilation and clustering functions are the practical reasons for use. Being able to distinguish a well-supported claim from a widely repeated one is itself part of the competence being tested.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Root, ABC and XYZ of Bee Culture, 41st ed., A.I. Root Co., 2007.*

113. (TF) Preparing an apiary for a severe tropical storm should include strapping each hive to its stand and the stand to the ground, reducing stack height where practical, and moving colonies off flood-prone low ground.

Answer: True

Rationale: Wind, falling limbs and flooding are the three hazards, and colonies that survive the wind are frequently lost afterward to standing water. Ratchet straps prevent boxes from separating and combs from being destroyed; lowering stacks reduces the lever arm. Post-storm, colonies frequently need feeding because forage has been stripped, and access roads may be impassable for some time, which should be part of the plan.

References: *Cooperative Extension apiculture disaster preparedness publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

114. (MC) The principal analytical value of a hive scale that records weight continuously is that:

Answer: A) The shape and slope of the weight curve reveal the onset and end of flows, dearth, robbing, swarm departures and winter consumption, none visible from a single inspection

Rationale: A scale record is a time series of net colony mass, and its power lies in interpretation: a sharp mid-morning drop suggests a swarm, a rapid asymmetric gain suggests the colony is robbing a neighbor, steady overnight loss quantifies consumption, and inflection points define the flow. For a beekeeper building a local bloom calendar in the southeastern US, a scale is the most efficient way to learn when the flows and dearths actually occur at a given site.

References: *Meikle & Holst, Apidologie 46:10-22 (2015); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

Section 7: The Southeastern Beekeeping Year – Seasonal Management (Q115–139)

Part A — Questions

115. (SA) Describe the shape of the beekeeping year in the southeastern US, naming the major periods of surplus, the major dearth, and the character of the winter.

116. (MC) In much of the southeastern US, swarm-season inspections at roughly 7-day intervals should begin:

- **A)** In late winter or very early spring, since colonies reach swarming condition far earlier than in northern states and cells are capped about eight days from the egg
- **B)** In late spring after the main flow has begun, once colonies have reached full population and the surplus is being stored, which is when queen cells are first constructed
- **C)** In midsummer during the dearth, since a colony deprived of forage divides in order to improve its chances, making the dearth the peak period for reproductive swarming
- **D)** Only after a swarm has been observed leaving the apiary, since inspections before that point disturb colonies without yielding information about their swarming intentions

117. (SA) Explain why the midsummer dearth in the southeastern US is the most demanding period of the management year, listing at least five distinct risks it creates.

118. (MC) The single most consequential monitoring point in the management year is:

- **A)** Midwinter, because mites reproduce most rapidly in a clustered colony where the bees are packed closely together and the mites can transfer readily between adult hosts
- **B)** Late summer, because the bees reared then become the overwintering population, and mites feeding on them during pupation and the viruses transmitted produce compromised bees
- **C)** Early spring, since the mite population reaches its annual peak as the first brood is capped and declines steadily through the remainder of the active season thereafter
- **D)** During the main honey flow, when the colony is at maximum population and the mites therefore have the largest number of brood cells available in which to reproduce

119. (SA) A colony has filled its brood nest with nectar during a heavy spring flow and the queen has little room to lay. Explain what is happening and how you would respond.

120. (MC) Reversing brood boxes in late winter is appropriate when:

- **A)** Always on a fixed date each year, since the manipulation is beneficial regardless of where the cluster and the brood happen to be located within the hive at that time
- **B)** The colony is already preparing to swarm and has capped queen cells, since reversing at that point disrupts the cells and interrupts the sequence before the swarm issues
- **C)** The cluster has moved up into the top box leaving the lower one empty, so placing the empty box above restores expansion room; not if brood spans both boxes in cold weather
- **D)** Never under any circumstances, since moving boxes in late winter inevitably chills brood and the practice has been abandoned by experienced beekeepers in every region

121. (SA) Explain the difference between 1:1 and 2:1 sugar syrup in composition and purpose, and give two cautions about feeding.

122. (MC) Feeding a protein patty to a colony in the southeastern US carries a specific regional risk:

- **A)** Patties attract Varroa mites from neighboring colonies, since the mites are drawn to the protein source, which is why patty feeding raises mite counts within a week or two
- **B)** Protein patties are an excellent substrate for small hive beetle larvae, so patties should be sized for a few days' consumption and withheld from colonies too weak to patrol
- **C)** Protein feeding suppresses the queen's laying by supplying nurse bees with more protein than the brood requires, so the colony reduces brood rearing until the patty is gone
- **D)** Patties absorb moisture from humid regional air and ferment into an alcoholic mass that the bees will not consume, so they must be replaced every few days to remain useful

123. (SA) Describe the actions a beekeeper should take in the weeks immediately after the main spring flow ends, and give the reason for each.

124. (TF) Because colonies in much of the southeastern US experience a long and reliable broodless period in midwinter, treatments that reach only the mites on adult bees are more dependable there than in northern states.

True / False

125. (MC) Splitting colonies in the southeastern US is most commonly done in spring because it simultaneously:

- **A)** Guarantees that both halves will produce surplus honey, since each retains the foraging force it had before the division and continues working the same flow independently
- **B)** Controls swarming, makes increase, replaces expected losses and creates a brood break useful in mite management, while the season is long enough for both halves to build
- **C)** Increases the honey crop in the season it is performed, since two smaller colonies together forage more efficiently than one large colony working the same available forage
- **D)** Eliminates small hive beetle from the parent colony by dividing the adult population, so that each half contains too few beetles to establish a reproducing population

126. (SA) Describe how a beekeeper produces a distinct varietal honey such as a sourwood or tupelo crop, and identify the single most important step.

127. (MC) Autumn goldenrod and aster bloom in the southeastern US is chiefly valuable because it:

- **A)** Suppresses small hive beetle populations through compounds present in the nectar, which is why beetle pressure falls sharply once the autumn bloom is fully underway
- **B)** Is harvested as a premium light varietal commanding a substantial price, which is why it is worth pulling supers immediately before the goldenrod bloom begins in earnest
- **C)** Produces the region's principal surplus crop, which is why colonies are supered specifically for it and why the honey is harvested rather than left on for winter stores
- **D)** Supplies the late nectar and, more importantly, the pollen that allows colonies to rear the healthy, well-provisioned bees that will overwinter successfully

128. (SA) List the actions that should be completed in early to mid autumn to prepare colonies for winter in the southeastern US, and note how the emphasis differs from northern practice.

129. (MC) A colony is found in midwinter with a small cluster on empty comb and capped honey two frames away. The most appropriate immediate action is to:

- **A)** Place fondant or dry sugar directly above the cluster, and if weather permits a brief manipulation, move capped honey adjacent, since the risk is isolation starvation
- **B)** Treat immediately for a brood disease, since a cluster that has stopped moving toward its stores in midwinter is most often suffering from an untreated infection of the brood
- **C)** Feed thin syrup at the entrance so the colony can take it without breaking cluster, which is the standard emergency measure for a colony found short of stores in winter
- **D)** Open the hive fully and inspect every frame to determine the extent of the remaining stores and the condition of the queen before deciding what intervention is required

130. (MC) A queen excluder is generally removed before winter because:

- **A)** State apiary regulations in most jurisdictions prohibit the use of queen excluders during the period when colonies are clustered for the winter months
- **B)** The excluder becomes brittle in cold weather and can fracture, allowing pieces of wire or plastic to fall into the cluster and injure the bees below it
- **C)** The excluder restricts ventilation between the boxes, so that condensation accumulates beneath it and drips back down onto the cluster during cold weather
- **D)** As the cluster moves upward into stores, the queen may be unable to follow through the excluder and can be left behind below it and die

131. (SA) A beekeeper asks how much honey to leave for winter in the southeastern US. Explain why a single figure is inadequate and describe how to arrive at a local target.

132. (TF) Liquid syrup can be fed throughout the winter, since bees will take and ripen it whenever they can reach the feeder, and it is preferable to solid feed for emergency winter feeding.

True / False

133. (MC) Equalizing colonies by moving frames of brood from strong to weak hives carries which principal risk?

- **A)** It invariably causes the recipient colony to swarm, since the sudden addition of sealed brood produces a population surge that congests the brood nest within a week or two
- **B)** It can distribute disease, mites and pests through the apiary, and may prop up a colony whose weakness has a cause, such as a failing queen, that added brood does not address
- **C)** The practice is prohibited by federal law and by most state apiary acts, because of the risk that it will spread notifiable brood disease between colonies and apiaries
- **D)** Brood combs cannot survive transfer between colonies, because the receiving bees do not recognize brood from another queen and remove it before it has time to emerge

134. (SA) Explain what spring dwindling is, why it occurs, and how a beekeeper should diagnose it.

135. (MC) Colonies rented for pollination are assessed by frame strength, which means:

- **A)** The number of frames covered by adult bees, assessed under specified conditions as a measure of foraging force, so the conditions of assessment belong in the contract
- **B)** The total weight of the colony including its stores, which correlates closely enough with population that it is the measure most growers and brokers now rely upon
- **C)** The number of frames present in the brood chamber, which is why eight-frame equipment is graded differently from ten-frame equipment in most pollination agreements
- **D)** The number of frames containing sealed brood, since brood drives pollen foraging and is therefore the measure most closely tied to the colony's pollination performance

136. (SA) A colony must be moved 500 yards to another part of the same property. Explain the problem and describe the three standard ways to solve it, and say which are practical at this distance.

137. (MC) The principal physiological hazard when transporting colonies in a closed load during warm weather is:

- **A)** Fermentation of the stored honey, since vibration and warmth during transport accelerate yeast growth in uncapped cells and can spoil an entire load of supers in transit
- **B)** Overheating, because a confined colony cannot ventilate or use evaporative cooling effectively, and an overheated hive can melt comb and kill the colony within hours
- **C)** Loss of queen pheromone circulation, since the bees cannot move normally on the combs during transport and the colony arrives functionally queenless and begins cells
- **D)** Chilling of the brood nest, since airflow through a moving load strips heat from the cluster faster than the bees can generate it, particularly on an overnight journey

138. (SA) Explain why a beekeeper should build a local bloom calendar rather than relying on a published regional one, and describe how to do it.

139. (MC) Hefting a hive, by lifting the back slightly from the stand, is used to:

- **A)** Estimate the weight of stored honey, and therefore whether feeding is needed, without opening the hive and disturbing the cluster in cold weather
- **B)** Determine whether the queen is present, since a queenright colony resists the disturbance more strongly than a queenless one and the difference is readily felt
- **C)** Dislodge small hive beetles from the bottom board so that they fall into an oil tray beneath the screen, which is why the practice is repeated at each apiary visit
- **D)** Level the hive on its stand, so that condensation runs to the front and drains from the entrance rather than collecting on the bottom board beneath the cluster

Part B — Answer Key: Section 7

115. (SA) Describe the shape of the beekeeping year in the southeastern US, naming the major periods of surplus, the major dearth, and the character of the winter.

Model answer: An early build-up beginning in mid to late winter as red maple, willow, henbit and early fruit bloom supply the first substantial pollen, which starts brood rearing well before the calendar spring. A main surplus flow in spring on tulip poplar, blackberry and dewberry, clover, holly, black locust and privet, with gallberry adding a coastal plain flow slightly later and tupelo producing a narrow, high-value crop in certain river swamps. A mountain flow on sourwood in early summer in the higher

elevations of the region. A pronounced dearth through the hottest part of summer. A modest autumn flow on goldenrod and aster whose principal value is nutritional rather than commercial. A mild winter with little or no true broodless period.

Rationale: The two features that most distinguish this calendar from northern practice are how early spring begins, which advances swarm season by a month or more, and the severity of the midsummer dearth, which drives robbing, starvation, small hive beetle pressure and mite build-up at a time when northern colonies are still storing surplus.

References: *Cooperative Extension nectar flow calendars, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

116. (MC) In much of the southeastern US, swarm-season inspections at roughly 7-day intervals should begin:

Answer: A) In late winter or very early spring, since colonies reach swarming condition far earlier than in northern states and cells are capped about eight days from the egg

Rationale: Timing is the whole of swarm control. A beekeeper following a calendar written for a northern climate will begin inspections after colonies have already built, capped cells and departed. The corresponding manipulations, whether splitting, a Demaree, adding drawn comb or supering, must be prepared before the colony makes its decision, which means having equipment ready in winter.

References: *Cooperative Extension apiculture publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

117. (SA) Explain why the midsummer dearth in the southeastern US is the most demanding period of the management year, listing at least five distinct risks it creates.

Model answer: Nectar and pollen availability collapse while temperatures are at their highest, so colonies consume stores faster than they replace them. The risks are: starvation, particularly in colonies from which honey has just been removed; robbing, which escalates rapidly because foragers are searching and colonies are defending, and which can strip a weak colony in hours; small hive beetle build-up, since colonies are contracting while beetles are at their seasonal peak and any undefended comb is vulnerable; Varroa population growth reaching its seasonal maximum just as the bees that will become the winter population are being reared; heat stress and the possibility of absconding in unshaded apiaries; and queen supersedure or reduced laying under nutritional stress.

Rationale: Every one of these is anticipated rather than reacted to: supers off and extracted promptly, entrances reduced, feeding planned, beetle traps serviced, mites monitored, shade and water provided.

References: *Cooperative Extension apiculture publications, southeastern US; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

118. (MC) The single most consequential monitoring point in the management year is:

Answer: B) Late summer, because the bees reared then become the overwintering population, and mites feeding on them during pupation and the viruses transmitted produce compromised bees

Rationale: This is the central timing concept in modern colony management, and it explains the frustrating pattern in which a colony looks strong and productive in late summer and dies in midwinter: the damage was done months earlier during pupation. The corollary is that the decision must be driven by a measured mite count, not by the appearance of the colony, and that treatment must be completed before the winter bees are reared rather than after damage becomes visible.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Dainat, Evans, Chen, Gauthier & Neumann, PLoS ONE 7:e32151 (2012).*

119. (SA) A colony has filled its brood nest with nectar during a heavy spring flow and the queen has little room to lay. Explain what is happening and how you would respond.

Model answer: The colony is becoming honey-bound: incoming nectar is being stored in the brood nest because storage space above is insufficient or inaccessible, which restricts the queen's laying and contributes to the swarming impulse. The response is to give storage space immediately, adding supers of drawn comb where available since foundation is drawn more slowly, and to restore laying space by adding empty drawn frames within the brood nest or by moving nectar-filled frames up into a super. Check that a queen excluder, if used, is sound and not impeding movement, and confirm ventilation is adequate.

Rationale: The related condition of a pollen-bound nest presents similarly but with combs packed with beebread, and calls for the same remedy of providing laying space. Both must be distinguished from a failing queen, since the visible sign, restricted brood, is the same.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

120. (MC) Reversing brood boxes in late winter is appropriate when:

Answer: C) The cluster has moved up into the top box leaving the lower one empty, so placing the empty box above restores expansion room; not if brood spans both boxes in cold weather

Rationale: The manipulation is conditional on the actual distribution of brood rather than on the calendar. In the southeastern US, where warm spells alternate with late cold snaps, the caution matters: a colony reversed in February and then exposed to a hard freeze can lose a divided brood nest. If in doubt, add space above rather than reversing.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

121. (SA) Explain the difference between 1:1 and 2:1 sugar syrup in composition and purpose, and give two cautions about feeding.

Model answer: 1:1 syrup, roughly equal parts sugar and water by weight, approximates nectar concentration and functions as a stimulative feed, encouraging brood rearing, wax secretion and comb building, so it is used in late winter and spring and when drawing foundation. 2:1 syrup, roughly two parts sugar to one of water, supplies more carbohydrate per unit of water so bees expend less energy evaporating it and can store it quickly, which suits autumn feeding to build winter stores. Cautions:

syrup should never be fed while honey supers intended for sale are on the colony, since stored syrup extracted as honey is adulteration; and syrup should be made with plain white granulated sugar, dissolved in warm rather than boiling water and not acid-inverted, because heating sugar solutions generates hydroxymethylfurfural, which is harmful to bees.

Rationale: A further caution is that stored syrup must be ripened and capped before cold weather, so late feeding of thin syrup can leave high-moisture stores that ferment.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; LeBlanc et al., J. Agric. Food Chem. 57:7369-7376 (2009).*

122. (MC) Feeding a protein patty to a colony in the southeastern US carries a specific regional risk:

Answer: B) Protein patties are an excellent substrate for small hive beetle larvae, so patties should be sized for a few days' consumption and withheld from colonies too weak to patrol

Rationale: An oversized patty on a colony without the population to cover it becomes a beetle nursery, which converts a nutritional intervention into a pest problem. The practical rules are small portions matched to consumption rate, removal of the paper backing, placement directly over the cluster, and no protein feeding of colonies too weak to patrol it. Every supplemental feeding decision in the region must be evaluated against beetle pressure.

References: *Neumann & Elzen, Apidologie 35:229-247 (2004); Cooperative Extension small hive beetle publications, southeastern US.*

123. (SA) Describe the actions a beekeeper should take in the weeks immediately after the main spring flow ends, and give the reason for each.

Model answer: Remove and extract honey supers promptly, both to protect honey quality and to avoid leaving undefended comb that small hive beetle will destroy and that the colony will consume during the dearth. Reduce entrances to a defensible size, because robbing pressure rises as forage fails. Assess colony weight and prepare to feed, since colonies that have just had honey removed can starve within weeks. Complete a Varroa assessment and treat if thresholds are exceeded, taking advantage of the window when supers are off and before the winter bee cohort is reared. Service or deploy beetle traps. Assess queen status and requeen failing colonies while there is still season enough for a new queen to establish. Consolidate or combine any colony too weak to defend itself.

Rationale: The organizing idea is that the end of the flow is a transition point at which the colony changes from expansion to contraction, and the beekeeper's management should change with it.

References: *Cooperative Extension apiculture publications, southeastern US; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

124. (TF) Because colonies in much of the southeastern US experience a long and reliable broodless period in midwinter, treatments that reach only the mites on adult bees are more dependable there than in northern states.

Answer: False

Rationale: The regional fact is reversed. Colonies in much of the region rear brood through most or all of the winter and rarely have a long broodless window, which makes treatments that do not penetrate cappings less dependable there, not more. Northern beekeepers can plan a single midwinter oxalic acid application against a reliably broodless colony; in this region broodlessness must be verified, created deliberately, or worked around.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Rademacher & Harz, Apidologie 37:98-120 (2006).*

125. (MC) Splitting colonies in the southeastern US is most commonly done in spring because it simultaneously:

Answer: B) Controls swarming, makes increase, replaces expected losses and creates a brood break useful in mite management, while the season is long enough for both halves to build

Rationale: The trade-off is that splitting during the flow costs surplus, which is why some beekeepers split after the main flow or use manipulations such as the Demaree that preserve the foraging force. Splits made during the midsummer dearth need feeding and beetle protection and are much more likely to fail, so timing matters as much as technique.

References: *Cooperative Extension apiculture publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

126. (SA) Describe how a beekeeper produces a distinct varietal honey such as a sourwood or tupelo crop, and identify the single most important step.

Model answer: Build colonies to strength ahead of the target bloom and manage swarming so the foraging force stays intact. Remove and extract all previously stored surplus before the target bloom begins, leaving each colony with clean, empty drawn supers. Complete any needed mite treatment before those supers go on, since many products, including amitraz, the thymol products and the pyrethroid and coumaphos strips, require supers to be off. Place the clean supers immediately before or at the start of the target bloom. Remove and extract them promptly when that bloom ends, before the bees add honey from subsequent sources. Keep the crop segregated through extraction, settling, storage and bottling. The single most important step is clearing the supers of other honey before the target bloom begins, because anything already in the comb will be extracted along with the varietal.

Rationale: This discipline pays twice: it also prevents strongly flavored honey from a source such as privet or a late goldenrod flow from contaminating a table crop. Formic acid, the oxalic acid products (VarroXSan only if at least one box separates the treated brood chamber from any honey to be extracted), HopGuard 3, and the newer MBG2X5G (l-glutamic acid) and OrganiShield (sucrose octanoate) products are labeled for use with supers on within their temperature limits, but completing treatment before the target supers go on keeps the varietal crop clear of any question.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

127. (MC) Autumn goldenrod and aster bloom in the southeastern US is chiefly valuable because it:

Answer: D) Supplies the late nectar and, more importantly, the pollen that allows colonies to rear the healthy, well-provisioned bees that will overwinter successfully

Rationale: There is a legitimate market for goldenrod honey, but its principal role in the region is nutritional. A poor autumn bloom is therefore a management signal: the colony may need protein supplementation to produce a sound winter population. Goldenrod honey also has a strong odor while curing, which beekeepers commonly notice at the hive.

References: *Cooperative Extension nectar plant publications, southeastern US; Somerville, Fat Bees Skinny Bees, RIRDC Publication 05/054, 2005.*

128. (SA) List the actions that should be completed in early to mid autumn to prepare colonies for winter in the southeastern US, and note how the emphasis differs from northern practice.

Model answer: Confirm each colony is queenright with a good pattern and requeen those failing; complete mite monitoring and any needed treatment early enough to protect the bees being reared for winter, then verify efficacy with a follow-up count; assess and build stores, feeding heavier syrup while temperatures still allow the bees to ripen and cap it; combine colonies too weak to winter, after confirming they are free of disease; reduce entrances and fit mouse guards where rodents occur; remove queen excluders so the cluster can move upward; ensure covers are sound and the hive is tilted slightly forward with adequate ventilation to manage condensation; and remove and properly store surplus supers to protect them from wax moth and beetles. The emphasis differs from northern practice in that insulation and wrapping are generally unnecessary, while mite control, small hive beetle management and moisture control matter as much or more.

Rationale: A further regional difference is that colonies break cluster and rear brood during mild spells, so they consume stores faster than a continuously clustered northern colony of the same size.

References: *Cooperative Extension apiculture publications, southeastern US; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

129. (MC) A colony is found in midwinter with a small cluster on empty comb and capped honey two frames away. The most appropriate immediate action is to:

Answer: A) Place fondant or dry sugar directly above the cluster, and if weather permits a brief manipulation, move capped honey adjacent, since the risk is isolation starvation

Rationale: Isolation starvation kills colonies that have adequate total stores. Solid feed placed where the cluster can reach it without moving is the fastest and safest intervention; thin syrup in cold weather adds moisture the colony must evaporate and may not be taken at all. The follow-up question is why the cluster was too small to reach its stores, which frequently leads back to mite and virus damage to the autumn bees.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

130. (MC) A queen excluder is generally removed before winter because:

Answer: D) As the cluster moves upward into stores, the queen may be unable to follow through the excluder and can be left behind below it and die

Rationale: Winter cluster movement is predominantly upward as the stores directly above are consumed. Any device that restricts that movement is a liability in prolonged cold. Where an excluder must remain for another purpose, the mitigation is to ensure the queen is above it before winter or to leave a passage around it.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Root, ABC and XYZ of Bee Culture, 41st ed., A.I. Root Co., 2007.*

131. (SA) A beekeeper asks how much honey to leave for winter in the southeastern US. Explain why a single figure is inadequate and describe how to arrive at a local target.

Model answer: The requirement is set by total metabolic demand over the period between the end of autumn forage and the return of reliable spring forage, which varies with the length and severity of winter at that location and elevation, colony size and configuration, hive type and exposure, and how early the first dependable pollen and nectar arrive. Southeastern colonies generally need less than colonies in the upper Midwest, but they break cluster and rear brood during mild spells, which consumes stores faster than continuous clustering. The way to arrive at a local target is to weigh or heft hives through several winters at the specific site, record consumption, note the arrival date of the first reliable spring forage, and set a target with a margin for a late spring, then monitor through the winter and be prepared to feed.

Rationale: The examinable point is the method rather than a number: measurement at the site beats a figure copied from a book written for another region.

References: *Meikle & Holst, Apidologie 46:10-22 (2015); Cooperative Extension apiculture publications, southeastern US.*

132. (TF) Liquid syrup can be fed throughout the winter, since bees will take and ripen it whenever they can reach the feeder, and it is preferable to solid feed for emergency winter feeding.

Answer: False

Rationale: Bees will not process syrup they cannot ripen. Below roughly the mid-50s degrees Fahrenheit uptake becomes unreliable, cold syrup standing in a feeder ferments, and the added moisture is itself a burden on a clustered colony. Liquid feeding should be completed while temperatures still permit ripening and capping; thereafter fondant, sugar cakes or dry sugar placed directly above the cluster is the appropriate emergency feed.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

133. (MC) Equalizing colonies by moving frames of brood from strong to weak hives carries which principal risk?

Answer: B) It can distribute disease, mites and pests through the apiary, and may prop up a colony whose weakness has a cause, such as a failing queen, that added brood does not address

Rationale: Equalization is a legitimate tool before a flow or a pollination contract, but it should follow diagnosis rather than precede it. The disciplined sequence is to establish why the weak colony is weak, address that cause, take brood only from colonies of verified health, and avoid weakening the donor below its own requirements. Blind equalization is an efficient way to distribute foulbrood through an apiary.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

134. (SA) Explain what spring dwindling is, why it occurs, and how a beekeeper should diagnose it.

Model answer: Spring dwindling is the sharp decline of a colony that appeared to overwinter successfully, occurring as winter ends. The mechanism is a demographic race: the overwintered bees are reaching the end of their lives and dying faster than emerging brood replaces them. Anything that suppresses brood rearing, such as a failing queen, poor early pollen availability or *Vairimorpha* (*Nosema*), or that accelerates adult mortality, such as residual mite and virus load, tips the balance. Diagnosis proceeds by checking for eggs and assessing brood pattern and quantity to evaluate the queen, assessing honey and pollen stores, sampling for *Nosema*, taking a mite count, and reviewing the previous autumn's mite management, then acting on the specific finding rather than simply feeding.

Rationale: In the southeastern US the early build-up means dwindling can appear surprisingly early in the year, and it is frequently traced back to inadequate late-summer mite control the previous season.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Fries, J. Invertebr. Pathol. 103:S73-S79 (2010).*

135. (MC) Colonies rented for pollination are assessed by frame strength, which means:

Answer: A) The number of frames covered by adult bees, assessed under specified conditions as a measure of foraging force, so the conditions of assessment belong in the contract

Rationale: Population determines foraging force, which is what the grower is buying. The contract should also specify delivery and removal dates keyed to bloom stage, placement and access, price and payment terms, pesticide notification and application timing, and how disagreements about strength will be resolved. A beekeeper who cannot meet the standard should renegotiate rather than deliver substandard colonies.

References: *Delaplane & Mayer, Crop Pollination by Bees, CABI, 2000; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

136. (SA) A colony must be moved 500 yards to another part of the same property. Explain the problem and describe the three standard ways to solve it, and say which are practical at this distance.

Model answer: The problem is that foragers navigate to the precise location of their hive. A move of a few feet is small enough for them to find the entrance, and a move of several miles places the hive

outside their familiar range so that they reorient on their first flight, but an intermediate move leaves foragers returning to the empty original site where they are lost. Solutions: relocate the colony more than about three miles away for two to three weeks and then bring it to the new site; move it a few feet at a time over successive days, which suits only moves of a few yards to a few tens of yards and would take most of a year at 500 yards, so it is not practical here; or move it directly and force reorientation by obstructing the entrance with leafy branches or similar material, accepting some forager loss. Placing a nucleus or a trap at the old site to collect returning foragers is a useful supplement.

Rationale: The underlying rule of thumb is less than about three feet or more than about three miles, and the intermediate distance is the case that requires a technique.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

137. (MC) The principal physiological hazard when transporting colonies in a closed load during warm weather is:

Answer: B) Overheating, because a confined colony cannot ventilate or use evaporative cooling effectively, and an overheated hive can melt comb and kill the colony within hours

Rationale: Mitigations are ample screened ventilation with unobstructed airflow through the load even when netted, travel at night or in cool conditions, avoidance of prolonged stops in sun, securing the load against shifting, removal of very heavy supers that stress combs, and prompt unloading with water available on arrival. In the southeastern US the thermal risk dominates every other transport consideration for much of the year.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Simone-Finstrom et al., Sci. Rep. 6:32023 (2016).*

138. (SA) Explain why a beekeeper should build a local bloom calendar rather than relying on a published regional one, and describe how to do it.

Model answer: Published regional calendars describe a broad area, but bloom timing shifts by weeks with latitude, elevation, land use, soil and year-to-year weather, and nectar secretion varies with rainfall and temperature even when a plant is in bloom. A calendar built at the specific site is therefore far more useful. To build one, record the first, peak and last bloom dates of the major nectar and pollen plants within about two miles of the apiary each year; record the colors of incoming pollen and match them to plants; keep hive weight records or consistent hefting notes so that gains and losses are documented; note when white new wax appears and how quickly supers fill; and correlate the sequence with weather rather than with fixed dates.

Rationale: The most valuable output is not the list of flows but the identification of the dearth periods, since those determine feeding, robbing precautions, mite treatment windows and split timing.

References: *Meikle & Holst, Apidologie 46:10-22 (2015); Cooperative Extension apiculture publications, southeastern US.*

139. (MC) Hefting a hive, by lifting the back slightly from the stand, is used to:

Answer: A) Estimate the weight of stored honey, and therefore whether feeding is needed, without opening the hive and disturbing the cluster in cold weather

Rationale: Hefting is fast, non-invasive and can be done when opening the hive would be harmful, and it becomes reliable once a beekeeper has calibrated their own sense of what an adequately provisioned colony feels like. A hive scale provides the same information continuously and more precisely, and either is far better than assuming that a colony that was heavy in autumn is still heavy in late winter.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Meikle & Holst, Apidologie 46:10-22 (2015).*

Section 8: Nutrition, Feeding & Pollination (Q140–158)

Part A — Questions

140. (MC) Which statement about honey bee nutritional requirements is correct?

- **A)** Nectar supplies carbohydrate while pollen supplies protein, lipids, sterols, vitamins and minerals; bees require ten essential amino acids and cannot synthesize sterols
- **B)** Sugar syrup supplies all of a colony's nutritional needs, which is why colonies fed continuously through a dearth show no decline in brood rearing or in adult longevity
- **C)** Bees obtain their protein requirement from water and from the microbial flora of the gut, which is why pollen is collected chiefly as a source of trace minerals and lipids
- **D)** Pollen supplies energy for flight while nectar supplies the protein used in brood food, which is why a colony short of nectar cannot rear brood even with beebread stored

141. (SA) Explain why crude protein content alone is an inadequate way to judge a pollen substitute, and give three additional criteria.

142. (MC) Pollen diversity matters to colony health because:

- **A)** Bees lose interest in a single pollen type after a few days and cease collecting it, so diversity is needed simply to maintain the colony's rate of pollen collection
- **B)** Pollen diversity affects only the flavor and color of the resulting honey and has no measurable consequence for brood rearing, adult longevity or disease resistance
- **C)** Pollens differ in protein, amino acid balance and lipid content, so a mixed diet more likely meets the full requirement; diverse diets improve immune measures and, under pathogen challenge, give survival as good as the best single pollen and better than poorer ones
- **D)** Diverse pollen is physically easier for foragers to pack into the corbicula, so a colony with access to several sources returns larger loads and stores more beebread

143. (SA) Name four methods of feeding syrup and give the principal advantage and drawback of each, with attention to conditions in the southeastern US.

144. (TF) Feeding honey of unknown origin, including retail honey, to bees is a recognized route for introducing American foulbrood spores, because the spores survive in honey indefinitely.

True / False

145. (MC) Hydroxymethylfurfural is relevant to bee feeding because:

- **A)** It is produced by bees during nectar ripening and acts as a preservative, which is why honey with a higher concentration of it resists fermentation more effectively
- **B)** It is a vitamin that bees require in small quantities and cannot synthesize, which is why commercial syrups are supplemented with it before being sold for bee feed
- **C)** It forms when sugar solutions are heated, especially under acid conditions, and accumulates in warm storage; at elevated concentrations it is toxic to bees
- **D)** It improves the shelf life of stored syrup by inhibiting yeast growth, which is why acid inversion of sucrose syrup is recommended before extended warm-weather storage

146. (SA) State the periods during which a colony in the southeastern US is most likely to need protein supplementation, and explain the reason for each.

147. (MC) Honey bees are relatively inefficient pollinators of crops with poricidal anthers, such as blueberry and tomato, because:

- **A)** Honey bees cannot perceive the flowers of those crops, since the corollas reflect little ultraviolet light and fall outside the range of the honey bee's color vision
- **B)** The nectar of those crops contains compounds mildly toxic to honey bees, so foragers abandon the crop after a few visits and recruitment to it collapses within a day
- **C)** Those crops bloom principally at night and close their flowers by mid-morning, so honey bees are active for only a small part of the period when pollen is available
- **D)** Those anthers release pollen most efficiently in response to buzz pollination, a vibration produced by bumble bees and various native bees that honey bees do not perform

148. (SA) Distinguish per-visit pollinator efficiency from overall pollination effectiveness, and explain why honey bees dominate commercial pollination despite being modest on the first measure for many crops.

149. (MC) Colonies are usually delivered to a crop at the beginning of bloom rather than well in advance because:

- **A)** Colonies placed early establish on competing forage and continue working it, whereas colonies arriving as the crop opens orient onto the most abundant nearby resource
- **B)** Bees must be deprived of forage for several days before a contract so that they work the target crop intensively as soon as they are released into the orchard or field
- **C)** Colonies cannot survive more than a few days in a cropped field, so delivery is delayed as long as possible to limit their exposure to the conditions there
- **D)** Growers pay a lower rate for colonies delivered before bloom, since the beekeeper benefits from the forage available during the period preceding the contracted bloom

150. (SA) List the terms that should appear in a written pollination contract and explain why each protects both parties.

151. (TF) Foragers prefer more concentrated nectar, and because uptake rate is unaffected by viscosity, the net rate of energy gain continues to rise as concentration increases toward saturation.

True / False

152. (MC) Water collection serves which combination of colony functions?

- **A)** Dilution of stored honey alone, since the colony cools itself by fanning rather than by evaporation and therefore needs water only for the preparation of brood food
- **B)** Provision of the mineral content that pollen does not supply, which is why colonies prefer water sources containing dissolved salts to sources of clean rainwater
- **C)** Evaporative cooling alone, which is why water collection ceases entirely once ambient temperatures fall below the level at which the colony needs to cool its nest
- **D)** Evaporative cooling, dilution of concentrated or crystallized stores for feeding brood and adults, and maintenance of brood nest humidity

153. (SA) Describe the signs that a colony is starving and state what should be done immediately.

154. (MC) Open feeding, in which syrup is provided in a communal container away from the hives, is generally discouraged because it:

- **A)** Is prohibited by federal law and by the apiary statutes of most states because of the risk that it will transmit notifiable brood diseases between neighboring operations
- **B)** Causes bees to lose the ability to locate natural forage, since colonies that have been open fed cease responding to recruitment dances for floral sources thereafter
- **C)** Distributes feed unevenly in favor of the strongest colonies, spreads disease between colonies and apiaries, and readily triggers apiary-wide robbing behavior
- **D)** Cannot be taken by bees from an open container, since foragers will not collect from a still surface and the syrup ferments before it is consumed in any quantity

155. (TF) A colony fed sugar syrup while honey supers intended for sale are on the hive may store that syrup in the supers, and selling the resulting product as honey would be adulteration.

True / False

156. (MC) The best single indicator that a colony is short of protein is:

- **A)** The presence of drones in the colony, since a colony under protein stress evicts its drones first and their continued presence indicates that reserves are adequate
- **B)** Little capped honey in the supers, since a colony short of protein diverts its foragers from nectar to pollen and therefore stores less surplus than its neighbors
- **C)** Little or no stored bee bread in and around the brood area, with brood rearing contracted despite warm weather and a laying queen present
- **D)** Bees bearding on the front of the hive, since protein-deficient bees generate more metabolic heat and the colony must move part of its population outside to cool

157. (SA) Explain what a beekeeper can and cannot do to improve the forage available to their colonies.

158. (MC) Apiary carrying capacity refers to:

- **A)** The number of colonies that can be placed on a single hive stand or pallet without the structure becoming unstable or the hives interfering with one another's entrances
- **B)** The number of colonies a location can support without forage competition depressing per-colony productivity and condition, set by forage abundance, diversity and timing
- **C)** The maximum number of colonies permitted at one location under the apiary statutes and local ordinances that apply in the jurisdiction where the yard is situated
- **D)** The number of colonies one beekeeper can inspect thoroughly in a single working day, which determines how large an apiary can be managed on a seven-day inspection cycle

Part B — Answer Key: Section 8

140. (MC) Which statement about honey bee nutritional requirements is correct?

Answer: A) Nectar supplies carbohydrate while pollen supplies protein, lipids, sterols, vitamins and minerals; bees require ten essential amino acids and cannot synthesize sterols

Rationale: The consequence is that a colony with abundant honey and no pollen cannot rear brood, and feeding syrup will not correct a protein shortage. The sterol requirement is why extended feeding of a substitute lacking an adequate sterol source produces declining brood rearing even when the protein content looks adequate on paper, and it is one reason no substitute fully replaces diverse natural pollen over long periods.

References: *De Groot, Physiol. Comp. Oecol. 3:197-285 (1953); Somerville, Fat Bees Skinny Bees, RIRDC Publication 05/054, 2005.*

141. (SA) Explain why crude protein content alone is an inadequate way to judge a pollen substitute, and give three additional criteria.

Model answer: Crude protein measures nitrogen content without regard to whether the amino acid profile matches the bee's requirement, so a substitute can be high in protein yet limiting in one essential amino acid and therefore of low biological value. Additional criteria: the amino acid profile, and particularly which amino acid is first limiting; the presence of an adequate sterol source, since bees cannot synthesize sterols; palatability and actual consumption rate under field conditions, since an uneaten patty has no value; digestibility and freedom from antinutritional or toxic components; and lipid content, since foraging preference in bees tracks the protein-to-lipid ratio of pollen rather than protein content alone.

Rationale: The practical test is a feeding trial measuring brood area produced per unit of substitute consumed, rather than laboratory composition alone.

References: *De Groot, Physiol. Comp. Oecol. 3:197-285 (1953); Vaudo et al., PNAS 113:E4035-E4042 (2016).*

142. (MC) Pollen diversity matters to colony health because:

Answer: C) Pollens differ in protein, amino acid balance and lipid content, so a mixed diet more likely meets the full requirement; diverse diets improve immune measures and, under pathogen challenge, give survival as good as the best single pollen and better than poorer ones

Rationale: This is why forage quality is assessed by diversity as well as quantity, and why a landscape dominated by a single crop can be nutritionally poor even when pollen is abundant. It also supports the practical emphasis on siting apiaries where the surrounding landscape offers a succession of blooms, and on encouraging hedgerows, field margins and cover crops.

References: *Alaux, Ducloz, Crauser & Le Conte, Biol. Lett. 6:562-565 (2010); Di Pasquale et al., PLoS ONE 8:e72016 (2013).*

143. (SA) Name four methods of feeding syrup and give the principal advantage and drawback of each, with attention to conditions in the southeastern US.

Model answer: Entrance or Boardman feeder: simple and the level is visible without opening the hive, but it sits at the entrance where it readily provokes robbing and heats in the sun, making it poorly suited to the region. Frame or division board feeder: holds a substantial volume inside the hive safe from robbing, but requires opening the hive to refill and can drown bees without a ladder or floats. Hive-top

feeder: large capacity, refilled with minimal disturbance and well protected from robbing, but adds height and weight and can harbor beetles if not maintained. Inverted pail or jar over the inner cover hole: cheap and effective with the feeding rate set by hole size, but limited in capacity and needs an empty box around it. Open or barrel feeding away from the apiary: fast for many colonies but distributes feed unevenly, spreads disease between colonies and readily triggers apiary-wide robbing.

Rationale: Because robbing risk dominates during the midsummer dearth, internal feeders are strongly preferred in the region and open feeding is generally discouraged.

References: *Graham (ed.), The Hive and the Honey Bee*, Dadant, 2015; *Sammataro & Avitabile, The Beekeeper's Handbook*, 5th ed., Cornell Univ. Press, 2021.

144. (TF) Feeding honey of unknown origin, including retail honey, to bees is a recognized route for introducing American foulbrood spores, because the spores survive in honey indefinitely.

Answer: True

Rationale: Retail honey may originate anywhere, and spores remain viable in it for decades. Feeding back honey from a beekeeper's own colonies is a different matter, but even then the source colony's health status must be known. This is one of the most consistently repeated biosecurity rules in beekeeping and one of the most frequently ignored, often by beekeepers using old jars of crystallized honey they do not want to waste.

References: *Genersch, J. Invertebr. Pathol.* 103:S10-S19 (2010); *Shimanuki & Knox, Diagnosis of Honey Bee Diseases*, USDA Agriculture Handbook 690, 2000.

145. (MC) Hydroxymethylfurfural is relevant to bee feeding because:

Answer: C) It forms when sugar solutions are heated, especially under acid conditions, and accumulates in warm storage; at elevated concentrations it is toxic to bees

Rationale: The practical rules follow directly: dissolve sugar in warm rather than boiling water, do not invert syrup with acid, store syrup cool and use it promptly, and be aware that corn syrup products stored warm for extended periods accumulate HMF. The same chemistry underlies the use of HMF as a quality indicator in honey, where it signals heat abuse or age.

References: *LeBlanc et al., J. Agric. Food Chem.* 57:7369-7376 (2009); *Jachimowicz & El Sherbiny, Apidologie* 6:121-143 (1975).

146. (SA) State the periods during which a colony in the southeastern US is most likely to need protein supplementation, and explain the reason for each.

Model answer: During the midsummer dearth, when little pollen is coming in but the colony is still rearing brood and drawing on stored beebread that may be exhausted. In autumn if the goldenrod and aster bloom is poor, because the autumn pollen supply determines the quality of the winter bee population and therefore whether the colony survives to spring. In late winter when stimulating early build-up ahead of the main flow or ahead of a pollination contract, since brood rearing at that point is

limited by protein rather than by nectar. Additionally, whenever colonies are placed on a monoculture crop that supplies a narrow and nutritionally poor pollen.

Rationale: A caution worth stating is that a colony with abundant natural pollen coming in will often ignore a patty, and that in this region patties must be sized and placed to avoid feeding small hive beetle larvae instead of bees.

References: *Somerville, Fat Bees Skinny Bees, RIRDC Publication 05/054, 2005; Cooperative Extension apiculture publications, southeastern US.*

147. (MC) Honey bees are relatively inefficient pollinators of crops with poricidal anthers, such as blueberry and tomato, because:

Answer: D) Those anthers release pollen most efficiently in response to buzz pollination, a vibration produced by bumble bees and various native bees that honey bees do not perform

Rationale: Honey bees still visit such crops for nectar and effect some pollination, and high stocking density is used to compensate, but per-visit efficiency is low relative to *Bombus*. Growers of these crops in the southeastern US commonly rely on a combination of honey bee stocking, managed bumble bees where appropriate, and habitat supporting native species, and a beekeeper offering pollination should understand where honey bees excel and where they supplement.

References: *Buchmann, in Handbook of Experimental Pollination Biology, Van Nostrand Reinhold, 1983; Delaplane & Mayer, Crop Pollination by Bees, CABI, 2000.*

148. (SA) Distinguish per-visit pollinator efficiency from overall pollination effectiveness, and explain why honey bees dominate commercial pollination despite being modest on the first measure for many crops.

Model answer: Per-visit efficiency is the amount of pollen deposited on a receptive stigma, or the fruit set achieved, per individual flower visit. Overall effectiveness at the crop level is the product of that per-visit performance and the number of visits delivered, which depends on the number of foragers present, the duration of foraging, tolerance of weather, and manageability. For some crops, particularly buzz-pollinated or specialist-served flowers such as blueberry and squash, specialized native bees deposit more pollen per visit. Across crops generally, a honey bee visit deposits plenty of pollen but tends to produce less fruit set than a wild-insect visit, because the weakness lies in the quality of transfer, chiefly cross-pollination, rather than the quantity of pollen moved. Honey bees can, however, be delivered to a field in enormous, timed, manageable numbers, so their aggregate contribution dominates in large-scale commercial systems.

Rationale: The corollary is that where per-visit efficiency is very low, as with crops requiring sonication, numerical advantage may not fully compensate, and integrated approaches are appropriate.

References: *Delaplane & Mayer, Crop Pollination by Bees, CABI, 2000; Garibaldi et al., Science 339:1608-1611 (2013).*

149. (MC) Colonies are usually delivered to a crop at the beginning of bloom rather than well in advance because:

Answer: A) Colonies placed early establish on competing forage and continue working it, whereas colonies arriving as the crop opens orient onto the most abundant nearby resource

Rationale: Delivery is commonly timed to roughly 5 to 25 percent bloom as a compromise between fidelity and giving colonies time to settle. Exceptions arise where the crop is the overwhelming dominant forage with no competitor, or where access roads become impassable later, both of which are real considerations in the southeastern US during a wet spring.

References: *Delaplane & Mayer, Crop Pollination by Bees, CABI, 2000; Free, Insect Pollination of Crops, 2nd ed., Academic Press, 1993.*

150. (SA) List the terms that should appear in a written pollination contract and explain why each protects both parties.

Model answer: Colony strength standard and the method, timing and conditions of its assessment; the number of colonies and the stocking rate per acre; delivery and removal dates keyed to bloom stage; placement locations, drop sites and access arrangements; price per colony, payment terms and any adjustment for colonies failing the standard; pesticide undertakings, including advance notification, application timing restrictions and disclosure of tank mixes; responsibility for water provision and for damage to colonies; liability and insurance; and how disputes over strength or performance will be resolved. Each protects both sides because the recurring disputes concern exactly these points: what a colony must contain, when it arrives and leaves, what may be sprayed while it is there, and who bears a loss.

Rationale: Pesticide notification is the term most often omitted and most often regretted, and the strength standard must specify assessment conditions, since colonies graded cold (tightly clustered) or at midday (foragers out) both undergrade; grading is best done when the bees are expanded but not yet flying, commonly above about 60 degrees F in the early morning or on a cool overcast day.

References: *Delaplane & Mayer, Crop Pollination by Bees, CABI, 2000; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

151. (TF) Foragers prefer more concentrated nectar, and because uptake rate is unaffected by viscosity, the net rate of energy gain continues to rise as concentration increases toward saturation.

Answer: False

Rationale: Viscosity is precisely what limits the relationship. Intake rate is the product of concentration and volumetric uptake, and uptake falls steeply as the solution thickens, so the net rate of energy gain peaks at an intermediate concentration rather than rising indefinitely. This is why bees abandon flowers whose nectar has become highly concentrated in hot dry weather, and why very heavy syrup can be taken more slowly than expected.

References: *Roubik & Buchmann, Oecologia 61:1-10 (1984); Seeley, The Wisdom of the Hive, Harvard Univ. Press, 1995.*

152. (MC) Water collection serves which combination of colony functions?

Answer: D) Evaporative cooling, dilution of concentrated or crystallized stores for feeding brood and adults, and maintenance of brood nest humidity

Rationale: All three operate, and their relative weight shifts with season. In the southeastern US, where brood rearing begins in mid to late winter, water is needed early in the year as well as in the heat. This is why a dependable water source is a year-round apiary requirement, and why establishing it before bees find a neighbor's pool is far easier than redirecting them afterward.

References: *Lindauer, Z. vergl. Physiol. 36:391-432 (1954); Human, Nicolson & Dietemann, Naturwissenschaften 93:397-401 (2006).*

153. (SA) Describe the signs that a colony is starving and state what should be done immediately.

Model answer: Signs include very light hive weight on hefting; no capped or uncapped stores visible in the combs; brood being removed or cannibalized; dead bees head-first in empty cells, indicating they died reaching for the last food; lethargic or trembling bees; a small tight cluster with no reserves adjacent; and, in warm weather, unusual aggression or the onset of robbing. The immediate action is to supply feed at once: syrup if conditions permit the bees to take and process it, or fondant, sugar cakes or dry sugar placed directly above the cluster in cold weather, or a frame of capped honey from a colony of verified good health placed adjacent to the cluster.

Rationale: Speed matters more than method, since a starving colony can die within a day or two. In the southeastern US starvation occurs most often during the midsummer dearth, particularly just after honey removal, and in late winter when brood rearing has resumed and consumption has risen sharply.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

154. (MC) Open feeding, in which syrup is provided in a communal container away from the hives, is generally discouraged because it:

Answer: C) Distributes feed unevenly in favor of the strongest colonies, spreads disease between colonies and apiaries, and readily triggers apiary-wide robbing behavior

Rationale: It also draws bees from neighboring apiaries, which compounds the disease transmission concern and may not be appreciated by the neighbor. Some commercial operators use it deliberately in specific situations, but for a small or sideline beekeeper in a region with a severe midsummer dearth, individual internal feeders are almost always the better choice.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

155. (TF) A colony fed sugar syrup while honey supers intended for sale are on the hive may store that syrup in the supers, and selling the resulting product as honey would be adulteration.

Answer: True

Rationale: Honey is defined as the natural product produced by bees from nectar or honeydew, so a product containing stored sugar syrup is not honey. The operating rule is to remove supers intended for

harvest before feeding, and if an emergency requires feeding during a flow, to keep the resulting stores out of the harvested crop. This is both a legal and an ethical matter and is entirely within the beekeeper's control.

References: *US FDA Guidance for Industry: Proper Labeling of Honey and Honey Products (2018)*; *Codex Alimentarius Standard for Honey CXS 12-1981*.

156. (MC) The best single indicator that a colony is short of protein is:

Answer: C) Little or no stored beebread in and around the brood area, with brood rearing contracted despite warm weather and a laying queen present

Rationale: Assessing stored beebread is a routine part of inspection that is frequently skipped. The essential discrimination is between a pollen dearth, in which cells are empty and available, and a pollen-bound brood nest, in which combs are packed with beebread and the queen has no laying space. Both reduce brood but call for opposite interventions.

References: *Somerville, Fat Bees Skinny Bees, RIRDC Publication 05/054, 2005*; *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015*.

157. (SA) Explain what a beekeeper can and cannot do to improve the forage available to their colonies.

Model answer: What a beekeeper can do: choose apiary sites where the surrounding landscape offers a succession of blooms rather than a single crop or a monotonous cover; negotiate with landowners over mowing timing, cover cropping and field margins; plant supplemental forage that fills gaps in the local calendar, particularly plants blooming during the midsummer dearth; provide a dependable water source; and avoid overstocking a site beyond its carrying capacity, which simply divides a fixed resource among more colonies. What a beekeeper cannot do: meaningfully feed a colony from their own planting, since a colony forages over several square miles and a small planting is a token; or increase the nectar a plant secretes, which is set by species, genotype, weather and soil moisture.

Rationale: Site selection therefore matters far more than planting, and honest advice to a new beekeeper should say so rather than encouraging the belief that a pollinator garden will support an apiary.

References: *Visscher & Seeley, Ecology 63:1790-1801 (1982)*; *Cooperative Extension pollinator habitat publications, southeastern US*.

158. (MC) Apiary carrying capacity refers to:

Answer: B) The number of colonies a location can support without forage competition depressing per-colony productivity and condition, set by forage abundance, diversity and timing

Rationale: Because carrying capacity varies between years with rainfall and land management, it is a moving target rather than a fixed property of a site. The defensible way to estimate it is to place a small number of colonies with weight records for a season, survey the landscape within roughly a three-mile radius for major sources and their bloom periods, ascertain whether other apiaries are present, and scale up incrementally while monitoring per-colony yield.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Meikle & Holst, Apidologie 46:10-22 (2015).*

Section 9: Regional Bee Botany & Honey Plants (Q159–175)

Part A — Questions

159. (MC) Tulip poplar (*Liriodendron tulipifera*) is significant across much of the southeastern US because it:

- **A)** Blooms in autumn and provides the late nectar and pollen on which colonies rear their winter bees, which is why the crop is normally left on rather than harvested
- **B)** Produces abundant pollen but no nectar, so its value lies entirely in supporting brood rearing during the period of most rapid spring build-up in the region
- **C)** Produces nectar containing compounds toxic to brood, which is why colonies are moved away from stands of it during the period when the trees are in full bloom
- **D)** Blooms in spring and can yield a heavy, dark, reddish-amber honey and a substantial surplus, provided colonies are built up and supered before it opens

160. (SA) Name the plant that produces genuine tupelo honey, describe where it grows and when it blooms, and explain the chemical property that gives the honey its commercial value.

161. (MC) Sourwood (*Oxydendrum arboreum*) honey is produced in which part of the southeastern US, and when?

- **A)** The coastal plain and pine flatwoods of the region, blooming in early spring at about the same time as the first substantial pollen sources become available
- **B)** The river swamps of the Gulf coastal portion of the region, blooming for a narrow window in early to mid spring and yielding a honey that resists granulation
- **C)** Throughout the region wherever the tree occurs, blooming in autumn alongside goldenrod and aster and contributing to the colony's winter stores
- **D)** The southern Appalachian mountains and foothills of the region, blooming in early summer after the main spring flow has ended

162. (SA) Describe gallberry (*Ilex glabra*) as a honey plant: where it grows, when it blooms, the character of its honey, and one factor affecting the reliability of the crop.

163. (MC) Purple brood, seen in some southeastern US apiaries, is caused by:

- **A)** Larvae being fed nectar or honey from summer titi (*Cyrilla racemiflora*) during its bloom, producing purple to blue-purple discoloration and brood mortality
- **B)** Accumulated miticide residue in old brood comb, which is absorbed by developing larvae and produces a purple discoloration together with elevated brood mortality
- **C)** A bacterial infection closely related to European foulbrood, distinguished from it by the purple discoloration and by its confinement to the coastal plain of the region
- **D)** Overheating of the brood nest during summer, which denatures pigments in the larval tissue and produces the characteristic discoloration in the affected cells

164. (MC) Buckeye (*Aesculus* species) is of concern to beekeepers because:

- **A)** It attracts bears to apiaries in autumn when its nuts fall, which is why apiaries in the mountainous parts of the region are sited away from stands of the tree
- **B)** Its nectar and pollen have been associated with brood mortality and deformed adults during its spring bloom, with no remedy other than moving colonies for the duration
- **C)** It harbors overwintering small hive beetle adults in bark crevices, so apiaries sited in stands of it experience much heavier beetle pressure the following season
- **D)** Its wood is unsuitable for hive construction because it warps badly in humid conditions and will not hold paint, which is why it is never used for boxes or frames

165. (SA) Explain why some honeys granulate quickly and others remain liquid, and name one regional honey of each type.

166. (TF) Chinese privet and Chinese tallow are valuable nectar sources in parts of the southeastern US, and because they benefit beekeepers, planting them is encouraged where they are not yet established.

True / False

167. (MC) Cotton is relevant to beekeepers in the region because:

- **A)** It is entirely wind pollinated and offers only pollen, which bees collect in quantity during the period when the crop is shedding and no other pollen is available
- **B)** It produces no nectar of any kind and is never visited by honey bees, so applications made to it pose no risk to colonies placed anywhere in the surrounding landscape
- **C)** It produces nectar from both floral and extrafloral nectaries, so bees may work it outside its bloom, which matters for pesticide exposure and for a possible honey crop
- **D)** It blooms only at night and closes its flowers by dawn, so honey bees have no opportunity to work it and any crop attributed to it is in fact from other sources

168. (SA) Define an extrafloral nectary, explain its usual ecological role, and state why it matters to a beekeeper.

169. (MC) Corn in a regional landscape is best characterized for bees as:

- **A)** A source of nectar, pollen and the plant resin that bees collect as propolis, which is why colonies near large acreages of it accumulate propolis unusually rapidly
- **B)** A crop that honey bees do not visit at all, since it offers neither nectar nor pollen that bees can use, so applications to it pose no exposure risk to colonies
- **C)** A wind-pollinated crop offering no nectar but abundant pollen, which bees collect in quantity, creating exposure to systemic insecticides and to planting-time dust
- **D)** A significant nectar source yielding a light honey in years when soil moisture is adequate, which is why apiaries are placed in row-crop districts during tasseling

170. (SA) Name three plants that supply important early-season pollen in the southeastern US and explain why early pollen matters more than early nectar.

171. (MC) Which statement about nectar secretion is correct?

- **A)** Secretion depends only on day length, which is why the timing and magnitude of a given flow are consistent from year to year at any one latitude within the region

- **B)** Secretion varies with species and genotype, plant age and vigor, soil moisture and rainfall, and temperature, so the same species may yield well one year and not the next
- **C)** Secretion increases in proportion to the number of colonies placed nearby, since removal of standing nectar stimulates the plant to replace it more rapidly than otherwise
- **D)** A plant in bloom secretes nectar at a rate characteristic of its species, so that a reliable estimate of the crop can be made from the acreage of that species in bloom

172. (SA) A beekeeper reports that their honey sometimes has an unpleasant bitter or weedy flavor. Give two plausible botanical explanations for the region and describe how to prevent the problem.

173. (MC) Pine-dominated landscapes in the southeastern US should be evaluated for beekeeping on the basis that:

- **A)** Pine pollen is the highest-value protein source available in the region, so colonies in pine-dominated landscapes require no protein supplementation at any season
- **B)** Pines yield no nectar and only low-value pollen, so a site's worth depends on the understory and surrounding land use, which ranges from excellent to very poor
- **C)** Pines are toxic to honey bees through resin compounds collected as propolis, so apiaries should not be placed within flight range of extensive pine plantation
- **D)** Pines are a major nectar source producing a dark, strongly flavored honey, so extensive pine acreage is among the most reliable indicators of a productive apiary site

174. (TF) Blackberry and dewberry (*Rubus* species) are among the most dependable spring nectar and pollen sources across much of the southeastern US, and their bloom typically coincides with peak colony population and peak swarming risk.

True / False

175. (SA) Mountain laurel and several rhododendrons are abundant in parts of the southern Appalachian mountains of the region. Explain the concern they raise for honey harvested there, what they do and do not do to bees, and how a beekeeper manages the risk.

Part B — Answer Key: Section 9

159. (MC) Tulip poplar (*Liriodendron tulipifera*) is significant across much of the southeastern US because it:

Answer: D) Blooms in spring and can yield a heavy, dark, reddish-amber honey and a substantial surplus, provided colonies are built up and supered before it opens

Rationale: Because poplar comes early, the beekeeper must have colonies at strength and supers in place before it begins, which in practice means building through the late-winter and early-spring period. This is a recurring theme in the region: the main opportunity arrives before a beekeeper following a northern calendar is ready. Poplar honey is dark with a distinctive flavor and is frequently sold as a varietal or used as a base for blending.

References: *Cooperative Extension nectar plant publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

160. (SA) Name the plant that produces genuine tupelo honey, describe where it grows and when it blooms, and explain the chemical property that gives the honey its commercial value.

Model answer: Ogeechee tupelo, *Nyssa ogeche*, growing in river swamps and floodplain edges of the coastal plain from South Carolina through Georgia to northwest Florida, with the commercial crop concentrated on a few river systems such as the Apalachicola, blooming in early to mid spring (roughly late March to early May) over a window of only about two to three weeks. Its commercial value rests on an unusually high ratio of fructose to glucose, which means the honey resists granulation and remains liquid for very long periods; it is also light in color with a delicate flavor, and it commands a substantial premium.

Rationale: Producing it requires the full varietal discipline of clearing supers of other honey before the short bloom and pulling them promptly afterward, and the crop is vulnerable to river flooding and to weather during the bloom, which makes it a high-risk, high-value proposition confined to a small geography.

References: *Crane, Honey: A Comprehensive Survey, Heinemann, 1975; White, in Crane (ed.), Honey: A Comprehensive Survey, Heinemann, 1975.*

161. (MC) Sourwood (*Oxydendrum arboreum*) honey is produced in which part of the southeastern US, and when?

Answer: D) The southern Appalachian mountains and foothills of the region, blooming in early summer after the main spring flow has ended

Rationale: Sourwood is a premium light varietal that commands a high price, and producing it requires clean supers placed specifically for that bloom after earlier honey has been removed, so the crop is not diluted with poplar or clover honey. It is a mountain crop determined by the tree's distribution and by elevation, so a beekeeper in the coastal plain of the region will not produce it regardless of management.

References: *Cooperative Extension apiculture publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

162. (SA) Describe gallberry (*Ilex glabra*) as a honey plant: where it grows, when it blooms, the character of its honey, and one factor affecting the reliability of the crop.

Model answer: Gallberry is a low evergreen shrub of the wet pine flatwoods and coastal plain of the southeastern US, blooming in late spring into early summer, after or overlapping the end of the main poplar and blackberry flow. It yields a light amber honey with good body that is slow to granulate and has historically been one of the region's important commercial honeys. The reliability of the crop depends heavily on land management: gallberry thrives in open, periodically burned pine flatwoods with a maintained understory, so changes in forestry practice, fire suppression, canopy closure and land conversion directly reduce the resource.

Rationale: This connection between a honey crop and land management is worth understanding generally, since it applies equally to clover in pasture, to roadside and field-margin bloom, and to the effect of development on any regional flow.

References: *Cooperative Extension nectar plant publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

163. (MC) Purple brood, seen in some southeastern US apiaries, is caused by:

Answer: A) Larvae being fed nectar or honey from summer titi (*Cyrilla racemiflora*) during its bloom, producing purple to blue-purple discoloration and brood mortality

Rationale: Purple brood is a plant-toxin brood disorder, not an infectious disease, and it is confined to the titi bloom in areas where the plant is abundant. Recognizing it prevents both unnecessary treatment and misdiagnosis as foulbrood. Since nothing can be treated, the management response where the problem is severe is to move colonies away from heavy titi during the bloom period.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Morse & Flottum (eds.), Honey Bee Pests, Predators, and Diseases, 3rd ed., A.I. Root, 1997.*

164. (MC) Buckeye (*Aesculus* species) is of concern to beekeepers because:

Answer: B) Its nectar and pollen have been associated with brood mortality and deformed adults during its spring bloom, with no remedy other than moving colonies for the duration

Rationale: Like purple brood from titi, buckeye poisoning is a botanical brood disorder rather than a disease. The diagnostic clues are coincidence with a specific bloom period, absence of infectious disease signs such as ropiness, odor and adherent scale, and local abundance of the plant. Recognizing it prevents a beekeeper from treating a colony for a disease it does not have.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Morse & Flottum (eds.), Honey Bee Pests, Predators, and Diseases, 3rd ed., A.I. Root, 1997.*

165. (SA) Explain why some honeys granulate quickly and others remain liquid, and name one regional honey of each type.

Model answer: Granulation is driven chiefly by the ratio of glucose to fructose and by the glucose-to-water ratio, since glucose is the sugar that crystallizes; honeys with a high glucose fraction granulate quickly, while honeys high in fructose remain liquid. The presence of nucleation particles such as pollen and fine wax fragments accelerates the onset, and storage temperature affects the rate, with crystallization fastest near 57 degrees F and slowed by both warmer and much colder storage. Tupelo is the regional honey known for resisting granulation because of its high fructose content; cotton honey and clover honey are examples that granulate relatively readily.

Rationale: The practical consequences are that fast-granulating honeys should be extracted promptly and are good candidates for creamed honey production, while slow-granulating honeys command a premium as a liquid product.

References: *White, in Crane (ed.), Honey: A Comprehensive Survey, Heinemann, 1975; Bogdanov, Honey Composition, Bee Product Science.*

166. (TF) Chinese privet and Chinese tallow are valuable nectar sources in parts of the southeastern US, and because they benefit beekeepers, planting them is encouraged where they are not yet established.

Answer: False

Rationale: The first clause is accurate and the conclusion is not. Both are invasive species that displace native vegetation, and their value as nectar sources does not offset the ecological cost or license planting them. The honest position is to acknowledge both facts: a beekeeper may benefit from an invasive already present in the landscape while still supporting its control and never propagating it.

References: *Cooperative Extension nectar plant and invasive species publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

167. (MC) Cotton is relevant to beekeepers in the region because:

Answer: C) It produces nectar from both floral and extrafloral nectaries, so bees may work it outside its bloom, which matters for pesticide exposure and for a possible honey crop

Rationale: Extrafloral nectaries secrete outside the flowering period, so an applicator who believes bees are absent because the crop is not blooming may be mistaken. This is a specific, useful point to raise with a grower planning an application to a non-flowering crop near an apiary, and it generalizes to other crops with extrafloral nectaries.

References: *Free, Insect Pollination of Crops, 2nd ed., Academic Press, 1993; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

168. (SA) Define an extrafloral nectary, explain its usual ecological role, and state why it matters to a beekeeper.

Model answer: An extrafloral nectary is a nectar-secreting structure located outside the flower, on leaves, petioles, stipules or bracts. Its usual ecological role is to attract ants and other arthropods that defend the plant against herbivores, rather than to attract pollinators. It matters to a beekeeper for two reasons: bees will work extrafloral nectar, so a crop can be attractive to bees outside its bloom period and can in some cases contribute to a honey crop; and, more importantly, a grower or applicator may reasonably but wrongly assume that a non-flowering crop carries no risk to pollinators, so the beekeeper should raise the point when discussing spray timing.

Rationale: Cotton is the best-known example in the region, and several *Vicia* species and some *Prunus* also bear them.

References: *Free, Insect Pollination of Crops, 2nd ed., Academic Press, 1993; Crane, Honey: A Comprehensive Survey, Heinemann, 1975.*

169. (MC) Corn in a regional landscape is best characterized for bees as:

Answer: C) A wind-pollinated crop offering no nectar but abundant pollen, which bees collect in quantity, creating exposure to systemic insecticides and to planting-time dust

Rationale: This is a practically important point about pesticide exposure: a crop not considered bee-attractive because it offers no nectar may nonetheless be a major pollen source and may be treated without pollinator precautions while bees are working it. Beekeepers near substantial row-crop acreage should know local planting and tasseling periods and discuss them with growers.

References: *Krupke, Hunt, Eitzer, Andino & Given, PLoS ONE 7:e29268 (2012); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

170. (SA) Name three plants that supply important early-season pollen in the southeastern US and explain why early pollen matters more than early nectar.

Model answer: Red maple, willow, henbit and purple dead nettle, dandelion, elm, alder, and early fruit bloom such as pear and plum. Early pollen matters more than early nectar because the colony usually still holds honey from the previous season or is being fed, whereas it has no comparable protein reserve; incoming pollen is what enables nurse bees to produce brood food and therefore what triggers and sustains expansion of the brood nest ahead of the main flow.

Rationale: The practical corollary is that a beekeeper wanting colonies at strength for the spring flow should ensure protein is available in the weeks before it, from natural forage or a substitute, and should watch incoming pollen loads as the signal that build-up has begun.

References: *Somerville, Fat Bees Skinny Bees, RIRDC Publication 05/054, 2005; Cooperative Extension nectar plant publications, southeastern US.*

171. (MC) Which statement about nectar secretion is correct?

Answer: B) Secretion varies with species and genotype, plant age and vigor, soil moisture and rainfall, and temperature, so the same species may yield well one year and not the next

Rationale: This is why a plant list is a weaker guide than a beekeeper's own weight records, and why local experience of which flows are dependable matters so much. It is also why colony density does not increase the resource: placing more colonies divides a fixed supply, which is the basis of apiary carrying capacity.

References: *Crane, Honey: A Comprehensive Survey, Heinemann, 1975; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

172. (SA) A beekeeper reports that their honey sometimes has an unpleasant bitter or weedy flavor. Give two plausible botanical explanations for the region and describe how to prevent the problem.

Model answer: Bitterweed or sneezeweed (*Helenium* species), common in pastures and disturbed ground, which imparts a bitter flavor; and strongly flavored sources such as privet, or a late-season goldenrod and aster crop, both of which have distinctive odors and flavors that many table buyers dislike. Onion and certain other sources can also taint a crop. Prevention rests on knowing the local bloom sequence and harvesting by flow rather than accumulating honey through the season in the same

supers: remove and extract at the end of each distinct flow, keep crops segregated, and taste each batch before blending or bottling, holding strongly flavored honey aside for baking markets or leaving it on the colonies as winter stores.

Rationale: The same discipline of segregating crops by flow is what makes varietal production possible, so it pays twice.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

173. (MC) Pine-dominated landscapes in the southeastern US should be evaluated for beekeeping on the basis that:

Answer: B) Pines yield no nectar and only low-value pollen, so a site's worth depends on the understory and surrounding land use, which ranges from excellent to very poor

Rationale: This distinction matters for apiary siting in a region where pine plantation is a dominant land cover. The beekeeper evaluating a site should look at the understory, the management regime, and the surrounding two to three miles rather than at the canopy species. The same principle applies to any landscape: what matters is the sequence of blooms available within flight range.

References: *Cooperative Extension apiculture publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

174. (TF) Blackberry and dewberry (*Rubus* species) are among the most dependable spring nectar and pollen sources across much of the southeastern US, and their bloom typically coincides with peak colony population and peak swarming risk.

Answer: True

Rationale: *Rubus* is widespread on roadsides, field edges, fencerows and cutover land, which makes it dependable across a wide range of sites. Its coincidence with peak population is precisely why the main spring period is simultaneously the best surplus opportunity and the highest swarm risk, and why supers and swarm management must both be in hand at the same moment.

References: *Cooperative Extension nectar flow calendars, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

175. (SA) Mountain laurel and several rhododendrons are abundant in parts of the southern Appalachian mountains of the region. Explain the concern they raise for honey harvested there, what they do and do not do to bees, and how a beekeeper manages the risk.

Model answer: Their nectar contains grayanotoxins, diterpenes that hold the sodium channels of nerve and muscle open. Honey made predominantly from that nectar can cause grayanotoxin poisoning, historically called mad honey poisoning: dizziness, nausea, salivation, blurred vision, weakness and, characteristically, a slow heart rate and low blood pressure, occasionally severe enough to need medical care. Bees work these plants and show no obvious harm in the field, although laboratory work has found grayanotoxin harmful to bees at some concentrations; the colony is not a filter, and the toxin passes into

the honey essentially unaltered. The risk is practical only where these plants dominate the forage during their late-spring and early-summer bloom, since elsewhere their nectar is diluted by other sources.

Management: know the local stands and when they bloom; harvest by flow, so that honey stored while laurel or rhododendron was the main source is kept separate; leave that honey on the colonies as stores rather than bottling it; and never sell honey of doubtful source, least of all as a single-source product.

Rationale: The item tests a general principle as well as a regional fact: plant secondary compounds such as grayanotoxins pass from nectar into honey largely unchanged, and bees do not screen them out.

Honey blended from many sources is rarely a problem; the cases that reach medical attention usually involve honey from a stand of little else, or honey sought deliberately for its effect. Candidates should be able to explain the hazard accurately to a customer without either dismissing it or exaggerating it.

References: *Jansen et al., Cardiovasc. Toxicol. 12:208-215 (2012); Cooperative Extension nectar plant publications, southeastern US.*

Section 10: Brood Diseases – Bacterial & Fungal (Q176–198)

Part A – Questions

176. (MC) American foulbrood is caused by *Paenibacillus* larvae. Which statement about its biology is correct?

- **A)** Only the spore stage is infective, larvae are susceptible for roughly the first day or two after hatching, very few spores suffice, and adults distribute spores unaffected
- **B)** Infection passes from queen to offspring through the egg, so replacing the queen with one from a clean source eliminates the disease from the colony within one brood cycle
- **C)** The bacterium does not form spores and dies within days outside the host, so contaminated equipment becomes safe to reuse after a single season standing empty
- **D)** Adult bees are the susceptible stage and larvae are unaffected, which is why the disease produces a rapid decline in the adult population before any brood signs appear

177. (SA) State approximately how many spores a single dead larva can contain and how long those spores remain viable, then explain what these two figures imply for management.

178. (SA) Describe the field signs of American foulbrood, giving at least six specific observations.

179. (MC) On finding presumptive American foulbrood in one colony of an apiary, the first action should be to:

- **A)** Stop all movement of frames, bees, tools and equipment between colonies, close the suspect hive, disinfect tools, and contact the state apiary inspector for direction
- **B)** Move a frame from the suspect colony into a strong neighboring colony to see whether the disease develops there, which confirms the diagnosis before an inspector is called
- **C)** Feed the colony an antibiotic obtained over the counter and reassess the brood pattern in about a month, requeening if the condition has not resolved by that point
- **D)** Extract the colony's honey immediately, before the colony collapses and the crop is lost, then destroy the bees and comb once the honey has been safely removed

180. (SA) Describe how to collect and submit a brood sample for laboratory diagnosis of foulbrood, and state the packaging error that most often ruins samples.

181. (MC) Scorching hive bodies for disease control is effective only if:

- **A)** A brief pass with a flame is made over the surface, which is sufficient because spores are destroyed by any direct contact with flame regardless of the wood's condition
- **B)** The wax and propolis are left in place to help the surface burn evenly, since the fuel they provide raises the surface temperature well beyond what bare wood achieves
- **C)** The interior is first scraped free of wax and propolis, which insulate the wood, and heat applied until uniformly charred; frames and comb must be destroyed instead
- **D)** The boxes are soaked in water first so that the wood does not ignite, allowing prolonged heating of the surface without the risk of losing the equipment to fire

182. (MC) European foulbrood differs fundamentally from American foulbrood in that its causative organism:

- **A)** Is *Melissococcus plutonius*, which competes with the larva for food in the midgut, so larvae die before capping, appear twisted, and leave non-adherent remains
- **B)** Forms durable spores that persist in comb and woodenware for decades, so infected equipment must be destroyed and no colony-level management is capable of resolving it
- **C)** Is a fungus rather than a bacterium, which is why the affected larvae mummify and can be found as hardened remains both in the cells and at the entrance of the hive
- **D)** Attacks adult bees rather than brood, so the colony declines through adult mortality while the brood pattern and the appearance of the larvae remain entirely normal

183. (SA) Contrast the remains left by American and European foulbrood in terms of position, appearance and adherence, and state why this comparison is useful.

184. (TF) European foulbrood commonly appears during rapid spring build-up, and because the organism forms durable spores, an affected colony's comb and woodenware must be destroyed as for American foulbrood.

True / False

185. (MC) A shook swarm, in which all adult bees are shaken onto fresh foundation and the old comb is destroyed, is an accepted management option for:

- **A)** Varroa infestation as a complete control, since shaking the bees removes every mite along with the brood and leaves the colony effectively free of the parasite
- **B)** European foulbrood and heavy comb contamination, in strong colonies during a flow or with feeding, because it removes the pathogen reservoir held in comb and brood
- **C)** Chilled brood, since transferring the adult bees to fresh foundation allows them to restart brood rearing in a compact nest that they can cover and keep warm
- **D)** Confirmed American foulbrood, as an accepted substitute for destruction, since removing the comb eliminates the spore reservoir and allows the bees to be saved

186. (MC) Chalkbrood is caused by *Ascosphaera apis* and is recognized by:

- **A)** Ropy brown larval remains beneath sunken cappings, drawn out in a strand of an inch or more, accompanied by a characteristic odor and by scale adhering to the cell wall
- **B)** Larvae that fail to pupate after capping and form a fluid-filled sac when lifted from the cell, with the dried remains curling upward at the head end into a brittle scale
- **C)** Hard, chalky mummified larvae from white to grey or black, in cells, on the bottom board and at the entrance, the darker ones indicating spore-bearing bodies have formed
- **D)** Adult bees emerging with shrivelled and useless wings and shortened abdomens, crawling at the entrance and unable to fly, together with a spotty and irregular brood pattern

187. (SA) A colony in a shaded, poorly drained apiary shows persistent chalkbrood each spring. Set out your management response and explain why no chemical treatment is proposed.

188. (MC) Stonebrood warrants a specific handling precaution because:

- **A)** The hardened mummies have sharp edges that can cut the hands when frames are handled, which is why the condition is dealt with using a hive tool rather than by hand
- **B)** It is caused by *Aspergillus* species, which are opportunistic human pathogens and produce mycotoxins, so gloves and respiratory protection are prudent when handling it
- **C)** It is highly contagious between apiaries through robbing and drifting, so an affected colony must be closed and moved out of the area before any further inspection
- **D)** It is a notifiable condition in every state and the inspector must be called before any equipment is moved, since the spores persist indefinitely in comb and woodenware

189. (TF) Chilled brood produces mortality scattered through the brood nest according to the susceptibility of individual larvae, whereas infectious brood disease kills all stages within a sharply bounded area.

True / False

190. (SA) List at least six conditions that can produce a spotty brood pattern and explain why the list matters.

191. (MC) The current status of antibiotic use for foulbrood in United States beekeeping is that:

- **A)** Antibiotics may be purchased over the counter and fed prophylactically each spring and autumn, which remains the standard recommendation for preventing foulbrood outbreaks entirely
- **B)** Medically important antimicrobials require veterinary oversight through a directive or prescription, and routine prophylactic use is no longer lawful, as it masks disease and selects resistance
- **C)** All antibiotic use in honey bee colonies is now prohibited nationwide, so a beekeeper with a confirmed foulbrood diagnosis has no lawful chemical option available at all
- **D)** Antibiotics eliminate American foulbrood spores from comb and equipment, so a treated colony and its woodenware can be returned to normal use once the course is completed

192. (SA) Explain comb rotation, state a common target rate, and give three reasons for the practice.

193. (MC) Why can a colony with an advancing American foulbrood infection still look strong from the outside?

- **A)** The bacterium remains dormant during the active season and becomes pathogenic only in autumn, which is why colonies appear healthy through the summer months
- **B)** The disease affects the queen rather than the workers, so the colony continues to function normally until her laying rate falls and the population begins to decline
- **C)** Adults are not susceptible; only very young larvae are infected, so the adult population appears normal until brood mortality accumulates and replacement begins to fail
- **D)** Infected colonies compensate by increasing their foraging effort, so entrance activity actually rises during the early stages of an infection and masks the developing problem

194. (TF) Acquiring used beekeeping equipment, particularly drawn comb of unknown history, is among the highest-risk activities in beekeeping because American foulbrood spores persist in comb and woodenware for decades.

True / False

195. (MC) Hygienic behavior contributes to brood disease resistance because:

- **A)** The colony abandons infected comb and relocates the brood nest to clean comb elsewhere in the hive, isolating the affected area until the beekeeper removes those frames
- **B)** Workers secrete an antimicrobial compound into affected cells that kills the pathogen directly, which is why hygienic colonies can retain infected brood without harm
- **C)** Workers detect and remove diseased brood from sealed cells before the pathogen completes development and produces its infective stage, reducing incidence without immunity
- **D)** The behavior prevents pathogens from entering the hive in the first place, since hygienic colonies groom incoming foragers and remove contaminated material at the entrance

196. (SA) Explain why moving frames of brood between colonies to equalize them carries disease risk, and describe how to do it responsibly.

197. (MC) Which observation would most strongly favor European foulbrood over American foulbrood?

- **A)** Larvae dying uncapped, twisted or displaced, discolored yellow to brown, with remains that lift out easily and a sour odor, in a colony under nutritional stress
- **B)** A brown ropy strand of about an inch drawn from a capped cell on the matchstick test, together with sunken and irregularly perforated cappings across the brood area
- **C)** A fine tongue-like projection of the pupal proboscis extending from the base of the cell across toward the roof, visible when the comb is held to the light at an angle
- **D)** Hard black scales adhering firmly to the lower cell wall and impossible to remove intact, accompanied by a distinct glue-pot odor noticeable on opening the colony

198. (SA) Set out the decision sequence a beekeeper should follow on finding an abnormal brood pattern, and state the rule that applies throughout.

Part B — Answer Key: Section 10

176. (MC) American foulbrood is caused by *Paenibacillus* larvae. Which statement about its biology is correct?

Answer: A) Only the spore stage is infective, larvae are susceptible for roughly the first day or two after hatching, very few spores suffice, and adults distribute spores unaffected

Rationale: Each element has a management consequence. The narrow susceptibility window means the disease is a brood disease with no adult signs. The very low infective dose means small amounts of contamination matter. The role of adults as carriers means a colony spreads spores internally even before disease is visible, and that beekeepers spread it between colonies on frames, tools and gloves.

References: *Genersch, J. Invertebr. Pathol. 103:S10-S19 (2010); Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

177. (SA) State approximately how many spores a single dead larva can contain and how long those spores remain viable, then explain what these two figures imply for management.

Model answer: A single infected larva can contain on the order of a billion or more spores, and spores remain viable in comb, honey, wax and woodenware for decades, commonly cited as 35 years or more. Together these mean that one scale represents an inoculum vastly greater than the infective dose for an entire apiary, and that no practical cleaning removes spores from comb. Management therefore cannot

be colony-level improvement or treatment; it must be destruction of the infected material or, where permitted, a strictly controlled alternative such as gamma irradiation, combined with rigorous prevention of equipment sharing.

Rationale: This arithmetic is what makes American foulbrood categorically different from every other brood disease, and it is why the regulatory response is more severe and why the beekeeper's containment behavior between suspicion and confirmation matters so much.

References: *Genersch, J. Invertebr. Pathol. 103:S10-S19 (2010); Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

178. (SA) Describe the field signs of American foulbrood, giving at least six specific observations.

Model answer: A spotty, irregular brood pattern with capped cells scattered among empty ones; cappings that are sunken, darkened, greasy or moist looking and often irregularly perforated; a foul, glue-pot odor; larvae that died after capping, discolored progressively from creamy white through tan to dark brown; a brown ropy strand of about an inch or more drawn out when a small stick is inserted and slowly withdrawn; hard, dark, brittle scales lying flat along the lower cell wall that adhere so tightly they cannot be lifted out intact; and, in some cells, a fine tongue-like projection of the pupal proboscis extending across the cell toward the roof.

Rationale: Scale adherence and the ropy strand are the two most useful discriminators from European foulbrood. Because the stakes are high, field impression should trigger containment and laboratory confirmation rather than a decision.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Genersch, J. Invertebr. Pathol. 103:S10-S19 (2010).*

179. (MC) On finding presumptive American foulbrood in one colony of an apiary, the first action should be to:

Answer: A) Stop all movement of frames, bees, tools and equipment between colonies, close the suspect hive, disinfect tools, and contact the state apiary inspector for direction

Rationale: Most apiary-wide outbreaks are created by the beekeeper's own equipment handling in the interval between suspicion and diagnosis. Antibiotic feeding suppresses clinical signs without eliminating spores, so it masks the infection while it continues to spread, and in the United States such use now requires veterinary oversight. Extracting honey from a suspect colony risks distributing spores widely.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; FDA Guidance for Industry 213 and the Veterinary Feed Directive rule (2017).*

180. (SA) Describe how to collect and submit a brood sample for laboratory diagnosis of foulbrood, and state the packaging error that most often ruins samples.

Model answer: Cut a piece of comb, commonly about 4 square inches (roughly 2 by 2 inches) or the size the laboratory specifies, containing as much suspect brood as possible and including cells with sunken or perforated cappings and any scale. Do not include honey. Wrap the sample in paper such as newspaper

or a paper bag, place it in a sturdy cardboard box, and include a note with the sender's name and address, hive identification, date, location and a description of the observations. Contact the state apiary inspector first, who knows which laboratory is currently receiving samples, and send the sample as directed. The packaging error that most often ruins samples is wrapping in plastic, foil or an airtight container, which traps moisture and allows mold to overgrow the sample so that it cannot be read.

Rationale: A candidate should also note that where regulatory action may follow, the inspector's instructions on sampling and chain of custody take precedence over any general procedure. The USDA Bee Research Laboratory at Beltsville long provided free diagnosis to US beekeepers, but in July 2025 USDA announced that the Beltsville Agricultural Research Center will be closed over several years, leaving the service's future unsettled in 2026, and several state departments of agriculture and university laboratories now accept foulbrood samples.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; state apiary inspection program sample submission instructions; USDA Bee Research Laboratory sample submission guidance.*

181. (MC) Scorching hive bodies for disease control is effective only if:

Answer: C) The interior is first scraped free of wax and propolis, which insulate the wood, and heat applied until uniformly charred; frames and comb must be destroyed instead

Rationale: Wax and propolis prevent the wood surface from reaching the temperature needed to destroy spores, which is why scraping first is essential and why the visible standard is uniform charring rather than light browning. Paraffin dipping at high temperature is an established commercial alternative for boxes, and gamma irradiation can treat both boxes and comb where the service is available. Note that scorching cannot be used on polystyrene equipment.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Genersch, J. Invertebr. Pathol. 103:S10-S19 (2010).*

182. (MC) European foulbrood differs fundamentally from American foulbrood in that its causative organism:

Answer: A) *Is Melissococcus plutonius*, which competes with the larva for food in the midgut, so larvae die before capping, appear twisted, and leave non-adherent remains

Rationale: Because the mechanism is competition for larval food, European foulbrood is strongly associated with nutritional stress, rapid brood expansion and colony weakness, and colonies often improve when conditions improve. This is why management options such as improving nutrition, requeening to create a brood break, and comb replacement are legitimate for European foulbrood and are not for American foulbrood.

References: *Forsgren, J. Invertebr. Pathol. 103:S5-S9 (2010); Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

183. (SA) Contrast the remains left by American and European foulbrood in terms of position, appearance and adherence, and state why this comparison is useful.

Model answer: The American foulbrood scale is dark brown to black, brittle, lies flat along the lower wall of the cell extending toward the base, and adheres so tightly that it cannot be removed intact with a probe; a fine tongue-like projection of the pupal proboscis may extend across the cell. European foulbrood remains are typically rubbery or loosely dried, yellow-brown to brown, often twisted or displaced within the cell rather than lying along one wall, and can generally be lifted out. American foulbrood larvae die predominantly after capping, giving sunken and perforated cappings, while European foulbrood larvae usually die uncapped. The comparison is useful because scale adherence is the single most reliable field discriminator, and the two diseases carry entirely different regulatory and management consequences.

Rationale: Field discrimination is nonetheless imperfect, so any suspicion of American foulbrood should still trigger containment and laboratory confirmation.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Forsgren, J. Invertebr. Pathol. 103:S5-S9 (2010).*

184. (TF) European foulbrood commonly appears during rapid spring build-up, and because the organism forms durable spores, an affected colony's comb and woodenware must be destroyed as for American foulbrood.

Answer: False

Rationale: *Melissococcus plutonius* does not form true durable spores, which is the fundamental difference from *Paenibacillus* larvae and the reason the two diseases are managed so differently. European foulbrood often improves when forage improves, when requeening supplies a brood break, or when comb is replaced, and a shook swarm is an accepted option in strong colonies. The organism does persist in the colony environment, so recurrence is common.

References: *Forsgren, J. Invertebr. Pathol. 103:S5-S9 (2010); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

185. (MC) A shook swarm, in which all adult bees are shaken onto fresh foundation and the old comb is destroyed, is an accepted management option for:

Answer: B) European foulbrood and heavy comb contamination, in strong colonies during a flow or with feeding, because it removes the pathogen reservoir held in comb and brood

Rationale: It is not an accepted substitute for destruction in confirmed American foulbrood, where spore persistence and legal requirements normally mandate destruction or a strictly regulated alternative. The manipulation costs the colony all its brood and stores, so it requires a strong colony, warm weather and either a flow or feeding, and it is a substantial intervention rather than a routine one.

References: *Waite, Brown, Thompson & Bew, Apidologie 34:569-575 (2003); Forsgren, J. Invertebr. Pathol. 103:S5-S9 (2010).*

186. (MC) Chalkbrood is caused by *Ascosphaera apis* and is recognized by:

Answer: C) Hard, chalky mummified larvae from white to grey or black, in cells, on the bottom board and at the entrance, the darker ones indicating spore-bearing bodies have formed

Rationale: Mummies at the entrance are often the first sign, since bees remove them. The color difference reflects whether both fungal mating types are present so that spore cysts have developed; dark mummies therefore indicate a heavier infective spore load. The disease is favored by cool damp conditions, chilled brood, poor ventilation, colony weakness and nutritional stress, which points directly to the management response.

References: Aronstein & Murray, *J. Invertebr. Pathol.* 103:S20-S29 (2010); Shimanuki & Knox, *Diagnosis of Honey Bee Diseases*, USDA Agriculture Handbook 690, 2000.

187. (SA) A colony in a shaded, poorly drained apiary shows persistent chalkbrood each spring. Set out your management response and explain why no chemical treatment is proposed.

Model answer: Address the predisposing conditions. Relocate or improve the site: better drainage, morning sun rather than deep full-day shade, hive stands, a slight forward tilt for drainage and adequate ventilation to reduce moisture. Strengthen the colony so it can hold brood nest temperature reliably, and avoid chilling brood by keeping cool-weather inspections brief and not splitting the brood nest across boxes. Requeen with hygienic stock, since hygienic behavior confers real resistance by removing infected brood before the fungus produces spores. Replace heavily affected comb to reduce the spore reservoir, and ensure adequate nutrition. No chemical treatment is proposed because none is registered for chalkbrood, and the disease is fundamentally a consequence of conditions and colony strength.

Rationale: Requeening with hygienic stock and correcting the site are the two interventions with the best support, and both are within reach of an ordinary beekeeper.

References: Aronstein & Murray, *J. Invertebr. Pathol.* 103:S20-S29 (2010); Spivak & Downey, *J. Econ. Entomol.* 91:64-70 (1998).

188. (MC) Stonebrood warrants a specific handling precaution because:

Answer: B) It is caused by *Aspergillus* species, which are opportunistic human pathogens and produce mycotoxins, so gloves and respiratory protection are prudent when handling it

Rationale: Stonebrood is uncommon, but the zoonotic caution is real, particularly for anyone immunocompromised. Clinically the mummies are hard and, when sporulating, are covered with a green to yellow-green powdery growth, distinguishing them from the white to grey-black chalkbrood mummy. Adult bees can also be affected.

References: Shimanuki & Knox, *Diagnosis of Honey Bee Diseases*, USDA Agriculture Handbook 690, 2000; Foley, Fazio, Jensen & Hughes, *Vet. Microbiol.* 169:203-210 (2014).

189. (TF) Chilled brood produces mortality scattered through the brood nest according to the susceptibility of individual larvae, whereas infectious brood disease kills all stages within a sharply bounded area.

Answer: False

Rationale: The two patterns are reversed. Chilling kills whatever is present in the chilled zone regardless of stage or age, producing a sharply bounded area of dead brood at the margins of the nest or on comb that was exposed. Infectious disease produces mortality scattered according to susceptibility and stage. The pattern is the diagnosis, and reading it backwards would send a beekeeper looking for a pathogen after their own cool-weather inspection caused the loss.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

190. (SA) List at least six conditions that can produce a spotty brood pattern and explain why the list matters.

Model answer: American foulbrood; European foulbrood; heavy Varroa infestation with associated viruses; sacbrood; chalkbrood; chilled brood; a failing or poorly mated queen; laying workers; inbreeding producing removal of diploid drone larvae; a pollen- or honey-bound brood nest restricting laying; and a plant-toxin disorder such as purple brood or buckeye poisoning during the relevant bloom. The list matters because a spotty pattern is a sign rather than a diagnosis: a beekeeper who automatically requeens on seeing one may replace a sound queen while leaving the actual problem, such as a mite infestation or a foulbrood infection, entirely untouched.

Rationale: The professional habit is to examine the cells themselves, assess capping appearance, test suspicious larvae, take a mite count, and weigh colony history and season before deciding what the pattern means.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

191. (MC) The current status of antibiotic use for foulbrood in United States beekeeping is that:

Answer: B) Medically important antimicrobials require veterinary oversight through a directive or prescription, and routine prophylactic use is no longer lawful, as it masks disease and selects resistance

Rationale: The substantive point behind the regulatory change is that antibiotics act on vegetative bacteria and do nothing about spores, so a treated colony with American foulbrood remains infectious and its equipment remains contaminated. Resistant strains have also been documented. A beekeeper intending to use an antibiotic must work with a veterinarian, keep records supporting a diagnosis, and still address the underlying disease.

References: *FDA Guidance for Industry 213 and the Veterinary Feed Directive rule (2017); Miyagi et al., J. Invertebr. Pathol. 75:95-96 (2000).*

192. (SA) Explain comb rotation, state a common target rate, and give three reasons for the practice.

Model answer: Comb rotation is the systematic culling and replacement of the oldest brood combs, commonly about 20 percent of brood comb per year so that no comb remains in service for more than about five years. Reasons: accumulation of lipophilic pesticide and miticide residues in beeswax, which persists for years and which recycles into commercial foundation; accumulation of pathogen spores and organisms in old comb, including chalkbrood and *Vairimorpha* (*Nosema*); and progressive narrowing of

cells from accumulated cocoons and debris, together with darkening and structural deterioration that make comb harder to inspect and more attractive to wax moth.

Rationale: Implementation is simple: mark frames with the year they are drawn, move the oldest to the outside of the box during the season, and remove them at the end of it. In the southeastern US, culled dark comb should be rendered promptly rather than stored, since it is prime wax moth and small hive beetle substrate.

References: Mullin et al., *PLoS ONE* 5:e9754 (2010); Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

193. (MC) Why can a colony with an advancing American foulbrood infection still look strong from the outside?

Answer: C) Adults are not susceptible; only very young larvae are infected, so the adult population appears normal until brood mortality accumulates and replacement begins to fail

Rationale: This is why inspection for American foulbrood is a careful, cell-by-cell examination of the brood in good light, and why an assessment based on entrance activity or general colony vigour is worthless for this disease. It is also why regular brood inspection, rather than occasional glances, is a genuine biosecurity practice rather than a formality.

References: Genersch, J. *Invertebr. Pathol.* 103:S10-S19 (2010); Shimanuki & Knox, *Diagnosis of Honey Bee Diseases*, USDA Agriculture Handbook 690, 2000.

194. (TF) Acquiring used beekeeping equipment, particularly drawn comb of unknown history, is among the highest-risk activities in beekeeping because American foulbrood spores persist in comb and woodenware for decades.

Answer: True

Rationale: Used comb of unknown origin is the classic route by which a beekeeper destroys their own apiary, and its low purchase price bears no relation to the potential cost. Reasonable precautions are to establish the seller's health history, inspect comb carefully in good light for scale and perforated cappings, prefer equipment without comb, sterilize woodenware before use, and check whether the state requires inspection or certification for a transfer of used equipment.

References: Genersch, J. *Invertebr. Pathol.* 103:S10-S19 (2010); state apiary acts.

195. (MC) Hygienic behavior contributes to brood disease resistance because:

Answer: C) Workers detect and remove diseased brood from sealed cells before the pathogen completes development and produces its infective stage, reducing incidence without immunity

Rationale: The interruption of the pathogen's life cycle is the mechanism, which is why hygienic stock shows real resistance to American foulbrood and chalkbrood. The realistic framing is reduction rather than immunity, so hygienic stock complements inspection and good management rather than replacing them. The trait is assessed with a freeze-killed brood assay, which is within the reach of a sideline beekeeper.

References: *Spivak & Downey, J. Econ. Entomol. 91:64-70 (1998); Rothenbuhler, Am. Zool. 4:111-123 (1964).*

196. (SA) Explain why moving frames of brood between colonies to equalize them carries disease risk, and describe how to do it responsibly.

Model answer: Moving brood comb moves whatever the donor colony carries: American and European foulbrood, chalkbrood spores, Nosema, viruses and Varroa. Blind equalization can therefore distribute a disease through an entire apiary in a single afternoon. To do it responsibly, first determine why the recipient is weak, since added brood does not remedy a failing queen or a heavy mite load; take brood only from colonies inspected carefully and believed healthy; do not weaken the donor below its own requirements; avoid moving comb between apiaries or from colonies of unknown history; and clean the hive tool between colonies, working any suspect colony last.

Rationale: The general principle is that any manipulation which moves comb between colonies is also an epidemiological event and should be preceded by a health assessment.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

197. (MC) Which observation would most strongly favor European foulbrood over American foulbrood?

Answer: A) Larvae dying uncapped, twisted or displaced, discolored yellow to brown, with remains that lift out easily and a sour odor, in a colony under nutritional stress

Rationale: The ropy strand, the adherent black scale and the pupal tongue projection are all classical American foulbrood findings, so any choice built on them points away from European foulbrood. The European foulbrood picture is death before capping, larval displacement, non-adherent remains, a sour odor and a strong seasonal and nutritional association. Because field discrimination is imperfect and the consequences of error are asymmetric, any suspicion of American foulbrood should trigger containment and laboratory confirmation regardless.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Forsgren, J. Invertebr. Pathol. 103:S5-S9 (2010).*

198. (SA) Set out the decision sequence a beekeeper should follow on finding an abnormal brood pattern, and state the rule that applies throughout.

Model answer: First, examine the affected cells closely in good light: capping appearance for sunkenness, perforation and greasiness; the position and appearance of dead larvae; odor; a matchstick test on discolored capped larvae; and the adherence and shape of any scale. Second, consider and systematically exclude the alternatives: American and European foulbrood, sacbrood, chalkbrood, stonebrood, chilled brood, a plant-toxin disorder, a failing queen, laying workers, inbreeding and heavy Varroa infestation, taking a mite count as part of this. Third, weigh colony history, season and management. Fourth, if American foulbrood cannot be excluded, obtain laboratory confirmation through the state apiary inspector. The rule that applies throughout is that no frame, bee, tool or piece of equipment moves from the suspect colony to any other until the diagnosis is settled.

Rationale: The containment rule is the substantive answer, because the interval between suspicion and diagnosis is when most apiary-wide outbreaks are created.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000;*
Genersch, J. Invertebr. Pathol. 103:S10-S19 (2010).

Section 11: Viruses, Nosema & Adult Bee Disorders (Q199–213)

Part A — Questions

199. (MC) Deformed wing virus is important to beekeepers principally because:

- **A)** It responds readily to an antibiotic fed in syrup, so a colony showing visible signs can be treated directly and will normally recover within a single brood cycle
- **B)** It infects only queens, so a colony showing deformed wings in emerging workers has a failing queen and should be requeened rather than treated for any parasite
- **C)** Varroa acts as a vector, injecting virus directly and bypassing the gut, so visible deformed wings usually indicate a serious mite problem rather than a separate disease
- **D)** It is spread mainly on contaminated hive tools and equipment, so disinfecting tools between colonies is the principal means of limiting its spread within an apiary

200. (SA) Explain the difference between a covert and an overt viral infection in a colony, and describe Varroa's role in the transition.

201. (SA) Describe the appearance of sacbrood-affected larvae, explain why the sac forms, and state how it is distinguished from American foulbrood.

202. (MC) Chronic bee paralysis virus typically presents as:

- **A)** Larvae failing to pupate after capping and forming a fluid-filled sac when lifted, with the dried remains curling upward at the head end into a brittle gondola shape
- **B)** Ropy larval remains under sunken cappings with a glue-pot odor, together with hard scales adhering to the lower cell wall that cannot be removed intact with a probe
- **C)** Chalky white and grey mummified larvae accumulating at the hive entrance and on the bottom board, most conspicuous in spring in colonies kept in damp shaded sites
- **D)** Two syndromes in adults: trembling, bloated, flightless bees with dead bees piled outside, and separately hairless, dark, shiny bees that guards harass and reject

203. (MC) Nosema in honey bees is caused by:

- **A)** A microsporidian, Vairimorpha (formerly Nosema) apis or V. ceranae, infecting the midgut lining of adult bees, transmitted by spores in feces and on comb, and shortening lifespan
- **B)** A virus vectored by Varroa and amplified by mite feeding, which is why colonies with heavy mite infestations also show the highest spore counts on laboratory examination
- **C)** A mite that colonizes the tracheae of adult bees, entering through the thoracic spiracles and obstructing gas exchange, which is why diagnosis requires dissection
- **D)** A bacterium responsive to oxytetracycline, which colonizes the midgut of adult bees and is controlled by the same antibiotic regime historically used against foulbrood

204. (SA) Describe how a Nosema assessment is performed, including which bees to sample and how the result is expressed, and state two limitations of the method.

205. (TF) Brown fecal spotting on the hive front and top bars is diagnostic of Nosema infection, so a colony showing it can be treated for Nosema without further examination.

True / False

206. (MC) Comb sanitation contributes to Nosema management because:

- **A)** Spores persist on comb and are re-ingested, so replacing comb or disinfecting it reduces the reservoir; colonies restocked onto contaminated comb become reinfected
- **B)** Comb has no role in the transmission of any honey bee disease, since all significant pathogens are transmitted by direct contact between adult bees within the colony
- **C)** Nosema spores cannot survive outside the bee for more than a few hours, so comb from a heavily infected colony is safe to reuse once it has stood empty overnight
- **D)** Nosema is transmitted only by Varroa mites moving between adult bees, so comb plays no role in transmission and comb management has no bearing on infection levels

207. (MC) Which statement about treating Nosema is most accurate?

- **A)** Oxytetracycline is the treatment of choice and is effective against both Nosema species, which is why the same product is used for foulbrood and for Nosema control
- **B)** There is no relationship between colony condition and Nosema levels, so management factors such as nutrition, comb age and colony strength are irrelevant to control
- **C)** Freezing the adult bees for 24 hours eliminates the infection, after which the colony can be restocked onto the same comb without any risk of reinfection occurring
- **D)** Fumagillin, sold over the counter in the US as Fumidil-B and Fumagilin-B (an unapproved animal drug that FDA has not found safe and effective), suppresses the parasite in the host but does not kill spores in comb and degrades in stored syrup

208. (SA) A beekeeper finds many dead and dying adult bees in front of several hives on a summer morning, some trembling and disoriented. List the possible causes and describe the first steps you would take.

209. (MC) So-called parasitic mite syndrome is best understood as:

- **A)** A descriptive term for the mixed brood and adult pathology produced by heavy Varroa infestation and its viruses, which resolves into mite-vectored viral disease
- **B)** A newly described bacterial disease requiring antibiotic treatment under veterinary direction, distinguished from foulbrood by the absence of a ropy strand on testing
- **C)** A synonym for tracheal mite infestation, which produces the same combination of crawling adults and irregular brood and is diagnosed by dissection of the thorax
- **D)** A condition unrelated to mites, arising from accumulated pesticide residues in old brood comb and resolving once the affected comb has been culled and replaced

210. (TF) Black queen cell virus kills queen pupae and prepupae in their cells, turning the cell wall dark, and has a documented association with Nosema infection, making it a recognized hazard in queen rearing.

True / False

211. (MC) A colony that died over winter is found with abundant capped honey two frames from a small cluster of dead bees with their heads in empty cells. This indicates:

- **A)** American foulbrood, since a colony weakened by brood disease through the autumn enters winter with too few bees and dies with its stores largely unconsumed
- **B)** Acute pesticide poisoning, indicated by the compact cluster and by the fact that the colony died with its stores intact rather than consuming them before it finally perished
- **C)** Isolation starvation, in which the cluster consumed the stores around it and could not reach the remaining honey in cold weather, prompting the question of why it was small
- **D)** Absconding, since the small number of dead bees indicates that most of the adult population departed and only a remnant remained behind to die on the comb

212. (MC) Colony collapse disorder as defined in the research literature of roughly 2007 to 2010 was characterized by:

- **A)** Any colony that fails to survive the winter, regardless of the signs present, which is why annual winter loss figures and disorder incidence are reported together
- **B)** Colonies dying with heavy Varroa infestation, visible deformed wings and mite fecal deposits in vacated brood cells, which is the classic post-mortem picture
- **C)** Colonies absconding and leaving no brood behind, typically in response to a pest or a disturbance, which is why the phenomenon was most reported in warm climates
- **D)** Rapid loss of the adult population with few dead bees present, a laying queen and brood remaining, and stores not immediately robbed by neighbors or attacked by pests

213. (SA) Since no registered treatment exists for honey bee viruses, state the practical measures that constitute viral disease management and explain why each helps.

Part B — Answer Key: Section 11

199. (MC) Deformed wing virus is important to beekeepers principally because:

Answer: C) Varroa acts as a vector, injecting virus directly and bypassing the gut, so visible deformed wings usually indicate a serious mite problem rather than a separate disease

Rationale: There is no registered treatment for a honey bee virus, so virus management is mite management. Bees with shrivelled wings and shortened abdomens crawling at the entrance should send the beekeeper directly to a mite count and, almost always, to a treatment decision. The virus can persist covertly without visible harm, so its visible expression marks a colony that is already in trouble.

References: *de Miranda & Genersch, J. Invertebr. Pathol. 103:S48-S61 (2010); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

200. (SA) Explain the difference between a covert and an overt viral infection in a colony, and describe Varroa's role in the transition.

Model answer: Most honey bee viruses persist in most colonies as covert, low-level infections that produce no visible signs and no measurable colony effect, maintained by oral transmission and by transmission from queen to offspring. An overt infection is a high-level infection producing clinical signs and colony damage. Varroa drives the transition in two ways: it acts as a vector delivering virus directly into the bee's body cavity, bypassing the gut barrier and raising virus levels by orders of magnitude; and

its feeding, on fat body tissue in adult bees and largely on hemolymph in developing pupae, drains the bee's reserves and suppresses immune function, so the bee controls the infection less well.

Rationale: The practical consequence is that a positive virus test is not by itself informative, since almost every colony would return one, and that the manageable lever is the mite rather than the virus. Keeping mite levels low keeps infections covert.

References: *de Miranda & Genersch, J. Invertebr. Pathol. 103:S48-S61 (2010); Ramsey et al., PNAS 116:1792-1801 (2019); Han et al., Nat. Commun. 15:725 (2024).*

201. (SA) Describe the appearance of sacbrood-affected larvae, explain why the sac forms, and state how it is distinguished from American foulbrood.

Model answer: An affected larva fails to pupate after its cell is capped, lies extended on its back with the head raised toward the cell opening, and changes from pearly white through pale yellow to brown. When lifted from the cell it forms a fluid-filled sac. The sac forms because the larva fails to shed its final larval skin at pupation, so ecdysial fluid accumulates between the unshed cuticle and the body and the intact skin acts as a bag. Dried remains form a brittle, gondola-shaped scale with the head end curled upward, which lifts out of the cell easily. It is distinguished from American foulbrood by the ease of removal of the scale, the absence of ropiness, the characteristic raised head and sac appearance, and the absence of the glue-pot odor.

Rationale: Sacbrood is caused by a virus, has no specific treatment and is usually self-limiting; the response is to maintain colony strength and nutrition and to requeen if the problem persists.

References: *Bailey & Ball, Honey Bee Pathology, 2nd ed., Academic Press, 1991; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

202. (MC) Chronic bee paralysis virus typically presents as:

Answer: D) Two syndromes in adults: trembling, bloated, flightless bees with dead bees piled outside, and separately hairless, dark, shiny bees that guards harass and reject

Rationale: Both presentations arise from the same virus and are worth recognizing because they are readily mistaken for pesticide poisoning or for another condition. Outbreaks are associated with crowding and confinement. There is no treatment; reducing crowding is the specific response, and requeening is traditionally suggested but has no robust evidence of benefit, and the differential from a pesticide kill matters because the two call for entirely different follow-up.

References: *Bailey & Ball, Honey Bee Pathology, 2nd ed., Academic Press, 1991; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

203. (MC) Nosema in honey bees is caused by:

Answer: A) A microsporidian, *Vairimorpha* (formerly *Nosema*) *apis* or *V. ceranae*, infecting the midgut lining of adult bees, transmitted by spores in feces and on comb, and shortening lifespan

Rationale: Because the parasite is a microsporidian rather than a bacterium, antibacterial antibiotics have no effect. Two species affect *Apis mellifera*, and *V. ceranae* has become widespread in the United

States. Critically, *V. ceranae* frequently causes no visible dysentery, so a colony can carry a heavy infection with no outward sign, which means diagnosis requires microscopy of a bee sample rather than observation of soiled equipment. On the name: in 2020 both species were moved from *Nosema* to the genus *Vairimorpha* on molecular evidence, a change some bee pathologists dispute, so both names appear in current literature and *Nosema* remains the everyday name of the disease.

References: *Fries, J. Invertebr. Pathol. 103:S73-S79 (2010); Higes, Martin-Hernandez & Meana, Apidologie 41:375-392 (2010); Tokarev et al., J. Invertebr. Pathol. 169:107279 (2020).*

204. (SA) Describe how a *Nosema* assessment is performed, including which bees to sample and how the result is expressed, and state two limitations of the method.

Model answer: Collect about 30 to 60 older bees, preferably returning foragers or bees at the hive entrance rather than young house bees, since infection is concentrated in older bees. Crush the sample in a measured volume of water, conventionally one millilitre per bee, and examine the suspension under a compound microscope at about 400 times magnification, where *Nosema* spores appear as uniform, rice-grain-shaped refractile bodies. Quantify by loading a hemocytometer and counting, expressing the result as spores per bee, with about one million per bee commonly used as a level of concern, although this is an arbitrary, unvalidated threshold and counts correlate imperfectly with colony harm. Limitations: light microscopy gives a spore count but does not distinguish the two species, which requires molecular testing; and a composite count is a colony average that conceals the distribution among individuals and does not establish that *Nosema* is the cause of any observed problem.

Rationale: A third limitation worth noting is that spore counts vary seasonally and with the bees sampled, so consistency of sampling matters if counts are to be compared over time.

References: *Cantwell, Am. Bee J. 110:222-223 (1970); Fries et al., J. Apic. Res. 52:1-28 (2013).*

205. (TF) Brown fecal spotting on the hive front and top bars is diagnostic of *Nosema* infection, so a colony showing it can be treated for *Nosema* without further examination.

Answer: False

Rationale: Spotting is a sign, not a diagnosis. It can result from *Nosema* but also from unsuitable or fermented stores, excess moisture, or prolonged confinement without cleansing flights. Confirming *Nosema* requires microscopy of a bee sample. The reverse error matters as much: *V. ceranae* frequently causes no dysentery at all, so a colony can carry a heavy infection while the hive front stays clean.

References: *Fries, J. Invertebr. Pathol. 103:S73-S79 (2010); Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

206. (MC) Comb sanitation contributes to *Nosema* management because:

Answer: A) Spores persist on comb and are re-ingested, so replacing comb or disinfecting it reduces the reservoir; colonies restocked onto contaminated comb become reinfected

Rationale: This is the same principle underlying comb rotation generally. For most beekeepers the practical version is simply culling and replacing the oldest comb on a regular schedule, since irradiation

services are not universally available and acetic acid fumigation requires careful handling and corrodes metal fittings. Maintaining strong, well-fed colonies and requeening failing queens are the other principal controls.

References: *Fries, J. Invertebr. Pathol. 103:S73-S79 (2010); Bailey & Ball, Honey Bee Pathology, 2nd ed., Academic Press, 1991.*

207. (MC) Which statement about treating Nosema is most accurate?

Answer: D) Fumagillin, sold over the counter in the US as Fumidil-B and Fumagilin-B (an unapproved animal drug that FDA has not found safe and effective), suppresses the parasite in the host but does not kill spores in comb and degrades in stored syrup

Rationale: Because the comb spore reservoir is untouched by any in-hive treatment, reinfection follows unless comb is addressed. Fumagillin is also less dependable against *V. ceranae*, which can rebound as the drug degrades, and it is not available in every country, so management rests heavily on reducing the reservoir, maintaining strong well-fed colonies, requeening, and avoiding the stresses that predispose colonies to infection.

References: *Fries, J. Invertebr. Pathol. 103:S73-S79 (2010); Huang, Solter, Yau & Imai, PLoS Pathog. 9:e1003185 (2013).*

208. (SA) A beekeeper finds many dead and dying adult bees in front of several hives on a summer morning, some trembling and disoriented. List the possible causes and describe the first steps you would take.

Model answer: Possible causes: acute pesticide poisoning from a nearby application; chronic bee paralysis virus; a bacterial hemolymph infection such as spiroplasmosis, which produces a similar seasonal adult crawling mortality; heavy Nosema in combination with other stressors; robbing-related fighting mortality; and, less commonly, a toxic plant. First steps: examine the dying bees for characteristic signs such as extended proboscises, tremors and disorientation; determine how many colonies in the yard are affected and whether other apiaries nearby show the same thing; find out what has been applied in the surrounding area and when; collect a substantial sample of the freshly dead bees, several hundred per hive, and freeze them immediately; photograph the scene and record details; and contact the state apiary inspector and, if a pesticide incident is suspected, the state lead pesticide agency.

Rationale: Timing is decisive because many insecticides degrade quickly in dead bees, so a sample collected several days later may show nothing even where exposure occurred.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; US EPA and state lead agency pesticide incident procedures.*

209. (MC) So-called parasitic mite syndrome is best understood as:

Answer: A) A descriptive term for the mixed brood and adult pathology produced by heavy Varroa infestation and its viruses, which resolves into mite-vectoring viral disease

Rationale: Heavily infested colonies present with scattered brood, discolored and sunken cells, larvae dying in varied positions and adult symptoms, which matches no single classical disease description. It is not a distinct etiological entity. The practical value of recognizing the pattern is that the correct response is a mite count and treatment, together with exclusion of foulbrood, rather than a search for a novel pathogen.

References: *Shimanuki, Calderone & Knox, Am. Bee J. 134:827-828 (1994); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

210. (TF) Black queen cell virus kills queen pupae and prepupae in their cells, turning the cell wall dark, and has a documented association with Nosema infection, making it a recognized hazard in queen rearing.

Answer: True

Rationale: For a queen producer the implication is direct: unexplained losses of sealed queen cells, particularly in spring, warrant assessment of the cell-building and nurse-bee source colonies for Nosema as well as review of grafting hygiene and cell handling. The virus is a common cause of cell failure that is easily misattributed to poor grafting technique.

References: *Bailey & Woods, J. Gen. Virol. 37:175-182 (1977); de Miranda, Cordoni & Budge, J. Invertebr. Pathol. 103:S30-S47 (2010).*

211. (MC) A colony that died over winter is found with abundant capped honey two frames from a small cluster of dead bees with their heads in empty cells. This indicates:

Answer: C) Isolation starvation, in which the cluster consumed the stores around it and could not reach the remaining honey in cold weather, prompting the question of why it was small

Rationale: The head-in-cell posture with honey elsewhere in the box is the classic picture, and stopping at that diagnosis leads a beekeeper to respond by feeding more, which will not prevent recurrence. The further question usually leads back to Varroa and virus damage to the autumn bee cohort, evidenced by deformed wings among the dead and by white mite fecal deposits on the upper inner walls of vacated brood cells.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

212. (MC) Colony collapse disorder as defined in the research literature of roughly 2007 to 2010 was characterized by:

Answer: D) Rapid loss of the adult population with few dead bees present, a laying queen and brood remaining, and stores not immediately robbed by neighbors or attacked by pests

Rationale: The delayed robbing of abandoned stores was among the more distinctive elements of the case definition. No single cause was established, and the consensus treats it as multifactorial. Reported incidence declined afterward, and most current colony loss does not meet the definition, so the term should be used precisely rather than as a synonym for colony loss generally.

References: *vanEngelsdorp et al., PLoS ONE 4:e6481 (2009); vanEngelsdorp & Meixner, J. Invertebr. Pathol. 103:S80-S95 (2010).*

213. (SA) Since no registered treatment exists for honey bee viruses, state the practical measures that constitute viral disease management and explain why each helps.

Model answer: Control Varroa, because the mite is the vector that converts covert infections into overt disease and because its feeding suppresses immune function; this is by far the most important measure. Maintain good nutrition, particularly adequate and diverse pollen, since nutritional status supports immune competence and the production of physiologically sound bees. Requeen failing colonies, which introduces different genetics, restores brood production and produces a brood break. Reduce colony stress from crowding, confinement, repeated disturbance and poorly timed manipulation, since crowding in particular is associated with chronic bee paralysis outbreaks. Cull heavily affected comb and avoid moving brood from affected colonies into healthy ones.

Rationale: The practical summary a beekeeper should be able to give is that virus management is mite management plus good husbandry, and that any product claiming to treat bee viruses directly should be regarded skeptically.

References: *de Miranda & Genersch, J. Invertebr. Pathol. 103:S48-S61 (2010); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

Section 12: Varroa & Tracheal Mites (Q214–238)

Part A — Questions

214. (MC) The mite parasitizing *Apis mellifera* worldwide is correctly named:

- **A)** *Tropilaelaps mercedesae*, which is now the dominant brood-parasitic mite of European-derived honey bee colonies throughout the Americas and much of Europe
- **B)** *Varroa jacobsoni*, which shifted directly from *Apis mellifera* to *Apis cerana* in the early twentieth century and has since returned to its original host across the world
- **C)** *Varroa destructor*, distinguished in 2000 from *V. jacobsoni*, which remains largely confined to *Apis cerana*; only a few haplotypes proved able to reproduce on *A. mellifera*
- **D)** *Acarapis woodi*, which is the species responsible for the great majority of colony losses attributed to parasitic mites in managed colonies across North America

215. (SA) Describe the Varroa reproductive cycle within a brood cell, and explain why drone brood yields more mite offspring than worker brood.

216. (MC) Work published in 2019 revised the long-standing account of what Varroa feeds on. Ramsey and colleagues showed that mites on adult bees feed principally on:

- **A)** Hemolymph, as described in the older literature, the volume removed being sufficient to weaken the bee directly through a straightforward loss of circulating fluid
- **B)** Beeswax and stored pollen within the cell, which is why heavily infested colonies show measurable losses of stored beebread as well as damage to the developing brood
- **C)** Nectar carried in the crop of adult bees, which is why phoretic mites concentrate on returning foragers rather than on the nurse bees working within the brood nest
- **D)** The fat body, a tissue central to immune function, detoxification, vitellogenin production and overwintering, which explains the harm caused by small nutritional losses

217. (SA) Explain how Varroa and deformed wing virus interact, and state what this means for interpreting a mite count.

218. (MC) The reference method for quantifying Varroa infestation is:

- **A)** A 24-hour count of natural mite fall onto a sticky board beneath a screened bottom, which is the most direct measure of the colony's total mite population
- **B)** An estimate from the proportion of emerging bees showing deformed wings, which correlates closely enough with infestation to serve as a practical field measure
- **C)** An alcohol wash of about 300 bees taken from a brood frame so nurse bees are sampled, the queen first confirmed absent, expressed as mites per hundred bees
- **D)** A count of mites visible on the bodies of adult bees during a routine frame-by-frame inspection, expressed as the number seen per frame of bees examined

219. (SA) An alcohol wash of 300 bees taken in late summer yields 12 mites. Calculate the infestation rate, state whether action is indicated, and explain the reasoning behind the threshold.

220. (TF) Varroa populations remain roughly constant through the brood-rearing season, so a single count taken in spring reliably predicts the level a colony will carry in late summer.

True / False

221. (MC) Formic acid is distinguished among Varroa treatments because:

- **A)** It has no effect on mites within capped brood or on adult bees, and works instead by sterilizing the foundress mites so that their offspring fail to reach maturity
- **B)** It may be applied at any ambient temperature without restriction, which is its principal practical advantage over the other organic acids used against the mite
- **C)** It acts as a vapor penetrating the cappings of sealed brood, killing mites in the reproductive phase as well as on adults, though it is strongly temperature dependent
- **D)** It is fed to the colony in syrup and acts systemically through the bee's hemolymph, so that mites feeding on treated bees receive a lethal dose wherever they are

222. (MC) Oxalic acid applied by dribble or vaporization is most effective when:

- **A)** The colony has little or no sealed brood, because oxalic acid does not penetrate cappings and reaches only the mites on adult bees
- **B)** A strong nectar flow is underway, since the bees distribute the acid rapidly through the colony by trophallaxis while they are actively processing nectar
- **C)** Honey supers are in place, because the additional volume allows the vapor to circulate through the hive and reach mites in every part of the colony
- **D)** The colony is at the peak of brood rearing, since the acid concentrates in the brood food and reaches the mites reproducing within the sealed cells

223. (SA) Explain what a brood break is, how a beekeeper can create one, how long it must last, and why it assists mite management.

224. (MC) Drone brood trapping controls mites by:

- **A)** Killing mites on adult bees, since drones carry a disproportionate share of the phoretic population and removing the drone comb removes those mites with them
- **B)** Exploiting the mites' preference for drone cells, so a frame of drone comb acts as a sink which is removed and the brood destroyed before the drones emerge
- **C)** Preventing the colony from producing drones at all, which removes the longer capped period that allows the mite to complete more generations within a single cell
- **D)** Repelling mites chemically from the brood nest by means of compounds present in drone larvae, which drives foundresses to seek worker cells where they reproduce poorly

225. (SA) After treating for Varroa, describe how a beekeeper determines whether the treatment worked, and explain what distinguishes treatment failure from reinvasion.

226. (TF) Mites move into treated colonies from collapsing or untreated colonies nearby through robbing and drifting, so mite management is properly considered at the apiary and area level rather than colony by colony.

True / False

227. (MC) Meaningful rotation among Varroa treatments requires:

- **A)** Alternating between two products of the same chemical class, since even a small difference in formulation is enough to prevent resistance developing to either one of them

- **B)** Alternating among products with genuinely different modes of action, since products within a class share a resistance mechanism and cross-resistance makes such rotation useless
- **C)** Changing the brand name of the product used each season, so that the mite population is never exposed to the same commercial preparation in consecutive years
- **D)** Using the same product but applying it at a different time of year, since seasonal variation in mite physiology prevents resistance from becoming established

228. (SA) A beekeeper reports that a treatment did not work. List, in order of likelihood, the explanations to exclude before concluding that resistance is present.

229. (MC) Resistance to a miticide develops because:

- **A)** Repeated exposure to one mode of action selects the small proportion of mites carrying a heritable survival trait, so those individuals come to dominate the population
- **B)** The bees develop a tolerance to the product and cease distributing it through the colony, so the treatment no longer reaches the mites in effective concentrations
- **C)** Mites learn to avoid treated surfaces after a sublethal exposure, and the learned avoidance is passed to their offspring through contact within the sealed brood cell
- **D)** The product degrades in storage and loses potency, so that apparent resistance reflects the age of the material rather than any change in the mite population itself

230. (TF) Because Varroa is an arachnid and the honey bee an insect, registered in-hive acaricides are entirely selective and carry no toxicity to bees at any dose.

True / False

231. (MC) Which post-mortem findings indicate that Varroa and associated viruses caused a colony's death?

- **A)** Chalky white and grey mummies on the bottom board and at the entrance, together with a scattered brood pattern in the comb the colony occupied before it died
- **B)** Deformed wings and shortened abdomens on dead bees, mites visible in cells, white mite fecal deposits on upper cell walls, and substantial stores left unconsumed
- **C)** Ropy larval remains under sunken, perforated cappings with a glue-pot odor, together with hard dark scales adhering to the lower walls of the affected cells
- **D)** A tight cluster of dead bees with heads pushed into empty cells and no stores remaining anywhere in the hive, indicating the colony exhausted its reserves in winter

232. (SA) Outline an integrated Varroa management plan across a full year for a sideline operation in the southeastern US.

233. (MC) Thymol-based products for Varroa control are characterized by:

- **A)** Systemic action after being fed to the colony in syrup, so that the compound reaches mites feeding on adult bees and on brood throughout the entire hive at once
- **B)** Activity as a vapor and by contact, with efficacy falling at low temperatures and brood removal, a halt in laying and possible queen loss rising at high ones, so label ranges bind
- **C)** Independence from ambient temperature, which is the principal reason these products are favored for late-season use when nights are cold and days remain warm

- **D)** No documented effect on Varroa at any concentration, the observed mite drop following treatment being attributable to the disturbance of applying the product

234. (TF) Screened bottom boards, small-cell foundation and powdered sugar dusting have each been evaluated as Varroa controls and found to produce at most modest reductions, so none should be relied upon as a stand-alone control.

True / False

235. (MC) A colony collapsing from Varroa in autumn poses a risk to neighboring colonies because:

- **A)** Its dead bees release mite eggs into the air, which are carried on the wind to neighboring hives, which is why dead-outs should be removed and sealed promptly
- **B)** The abandoned equipment attracts mites from the surrounding soil, where they overwinter, so the hive position itself becomes a source of reinfestation the next season
- **C)** It poses no risk once the bees are dead, since mites cannot survive more than a few hours without a living host and die within the abandoned equipment
- **D)** As it collapses its stores are robbed by neighbors, and the robbers carry mites home, so a collapsing colony is a mite source for every colony within flight range

236. (MC) Acarapis woodi, the tracheal mite, differs from Varroa in that:

- **A)** It is plainly visible on the exterior of adult bees and on the surface of sealed brood, so a beekeeper can assess infestation levels during a routine frame inspection
- **B)** It lives internally in the prothoracic tracheae, entering through the first thoracic spiracle of very young adults, so diagnosis requires dissection or laboratory work
- **C)** It is an insect rather than a mite, having six legs rather than eight, and is more closely related to the bee louse than to any of the parasitic mites of honey bees
- **D)** It reproduces inside sealed brood cells in the same manner as Varroa, so brood interruption is equally effective against it and the same monitoring methods apply

237. (SA) Describe the historical control measures used against tracheal mites and state the general principle they illustrate.

238. (SA) Explain to a new beekeeper, in plain terms, why Varroa matters far more than the small number of visible mites would suggest.

Part B — Answer Key: Section 12

214. (MC) The mite parasitizing *Apis mellifera* worldwide is correctly named:

Answer: C) Varroa destructor, distinguished in 2000 from *V. jacobsoni*, which remains largely confined to *Apis cerana*; only a few haplotypes proved able to reproduce on *A. mellifera*

Rationale: The reclassification matters more than it might appear. The narrow genetic base of the invading mite population helps explain the near-uniformity of its behavior worldwide, and it means further host shifts by other haplotypes remain a genuine biosecurity concern. It also clarifies that the original host is *Apis cerana*, in which the mite is a comparatively minor pest because that host has co-evolved defenses.

References: Anderson & Trueman, *Exp. Appl. Acarol.* 24:165-189 (2000); Rosenkranz, Aumeier & Ziegelmann, *J. Invertebr. Pathol.* 103:S96-S119 (2010).

215. (SA) Describe the Varroa reproductive cycle within a brood cell, and explain why drone brood yields more mite offspring than worker brood.

Model answer: A foundress mite enters a cell shortly before it is capped, conceals herself in the larval food, then feeds on the developing pupa and begins laying. She produces a male offspring first and then a series of female offspring at intervals of roughly thirty hours. The offspring mature within the sealed cell and the single male mates with his sisters there; mature mated daughters leave with the emerging bee, while the male and any immature daughters die. Drone brood yields more offspring because its capped period is roughly two to three days longer than that of worker brood, allowing more daughters to complete development and mate before emergence.

Rationale: Two management tools follow directly: drone brood trapping, which exploits the mites' preference for drone cells, and any manipulation that interrupts capped brood, which halts reproduction entirely. The sibling mating also explains why removal of an infested pupa by a hygienic colony sterilizes that whole mite family.

References: Rosenkranz, Aumeier & Ziegelmann, *J. Invertebr. Pathol.* 103:S96-S119 (2010); Martin, *Exp. Appl. Acarol.* 18:87-100 (1994).

216. (MC) Work published in 2019 revised the long-standing account of what Varroa feeds on. Ramsey and colleagues showed that mites on adult bees feed principally on:

Answer: D) The fat body, a tissue central to immune function, detoxification, vitellogenin production and overwintering, which explains the harm caused by small nutritional losses

Rationale: The finding supplies a mechanism for effects that hemolymph loss alone explained poorly: impaired immunity, reduced vitellogenin, poor overwintering and heightened sensitivity to other stressors. It also shows that mite feeding on adult bees, once dismissed as merely phoretic transport, is itself damaging. A 2024 study by Han and colleagues refined the picture: mites on adult bees feed on the fat body, but mites reproducing on pupae consume mainly hemolymph, so the diet depends on the host's life stage. Either way the drain falls on the reserves that make a long-lived winter bee, which is why bees reared during the late-summer mite peak make such poor winter bees.

References: Ramsey *et al.*, *PNAS* 116:1792-1801 (2019); Honey Bee Health Coalition, *Tools for Varroa Management*, 9th ed.; Han *et al.*, *Nat. Commun.* 15:725 (2024).

217. (SA) Explain how Varroa and deformed wing virus interact, and state what this means for interpreting a mite count.

Model answer: The mite causes direct harm by feeding, on fat body tissue in adult bees and largely on hemolymph in developing pupae, but its greater effect is as a vector: it injects virus directly into the bee's body cavity, bypassing the gut barrier and producing virus levels far above those achieved by oral transmission, while simultaneously suppressing immune function so the bee controls the infection less well. The combination therefore produces damage disproportionately greater than either factor alone.

For interpretation, this means a mite count should be read as an index of viral disease risk rather than merely as a parasite burden, which is why intervention thresholds are set at only 1 mite per 100 bees in spring (Dormant and Population Increase phases) and 2 per 100 from Peak Population onward.

Rationale: It also explains why colonies with similar mite counts can differ in outcome depending on their viral load, and why treating late does not always rescue a colony whose winter bees were already reared under high virus levels.

References: *de Miranda & Genersch, J. Invertebr. Pathol. 103:S48-S61 (2010); Nazzi et al., PLoS Pathog. 8:e1002735 (2012); Han et al., Nat. Commun. 15:725 (2024).*

218. (MC) The reference method for quantifying Varroa infestation is:

Answer: C) An alcohol wash of about 300 bees taken from a brood frame so nurse bees are sampled, the queen first confirmed absent, expressed as mites per hundred bees

Rationale: Three elements matter: the 300-bee sample size, which allows conversion to a percentage; the source, since mites concentrate on nurse bees and a sample of foragers or super bees underestimates infestation; and consistency, since the value is used to detect change over time. A sugar roll is non-lethal but recovers a smaller and more variable fraction, particularly in humid conditions; a sticky board measures a different quantity, natural daily fall, that depends on colony size and brood status.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Dietemann et al., J. Apic. Res. 52:1-54 (2013).*

219. (SA) An alcohol wash of 300 bees taken in late summer yields 12 mites. Calculate the infestation rate, state whether action is indicated, and explain the reasoning behind the threshold.

Model answer: Twelve mites per 300 bees is 4 mites per 100 bees, that is, a 4 percent infestation rate. This is above the late-summer action threshold of about 2 percent that the Honey Bee Health Coalition sets for colonies at peak population and in decline (its threshold during spring build-up is lower, about 1 percent), so prompt treatment is indicated. The reasoning is that the bees being reared at this point in the season become the long-lived population that must carry the colony through winter; mites feeding on them during pupation and the viruses transmitted at that time shorten their lives and compromise their physiology, so the damage is done before it becomes visible. The threshold is therefore set low enough that intervention still protects that cohort.

Rationale: Older sources often cite 2 to 3 percent; the current edition of the Coalition's guide sets 2 percent, so a count that once looked borderline now calls for action. The follow-up step is a second count promptly at the end of the treatment period to verify efficacy, without which the beekeeper has not completed the management cycle and cannot distinguish success from failure.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Dainat, Evans, Chen, Gauthier & Neumann, PLoS ONE 7:e32151 (2012).*

220. (TF) Varroa populations remain roughly constant through the brood-rearing season, so a single count taken in spring reliably predicts the level a colony will carry in late summer.

Answer: False

Rationale: Mite populations grow approximately multiplicatively with each brood cycle, so a low spring count is a starting point on a rising curve rather than a safe condition. In the southeastern US the long brood-rearing season allows more mite generations per year than in the North, making regular monitoring more important rather than less. Minimum practice is spring, mid-season and late summer, with the late-summer count decisive.

References: *Martin, Ecol. Model. 109:267-281 (1998); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

221. (MC) Formic acid is distinguished among Varroa treatments because:

Answer: C) It acts as a vapor penetrating the cappings of sealed brood, killing mites in the reproductive phase as well as on adults, though it is strongly temperature dependent

Rationale: Cap penetration is its unique advantage and makes it valuable in a brood-right colony, which matters greatly in a region where colonies are rarely broodless. The corresponding cost is a narrow margin between efficacy and harm, and label temperature limits are frequently exceeded by summer highs in the southeastern US, so timing the application to a suitable temperature window is essential rather than optional.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Rosenkranz, Aumeier & Ziegelmann, J. Invertebr. Pathol. 103:S96-S119 (2010).*

222. (MC) Oxalic acid applied by dribble or vaporization is most effective when:

Answer: A) The colony has little or no sealed brood, because oxalic acid does not penetrate cappings and reaches only the mites on adult bees

Rationale: Efficacy against phoretic mites is high, often above 90 percent, and low against mites in sealed brood, so a single application in a brood-right colony may kill only a modest fraction of the total population. In the southeastern US, where a reliable broodless window is short or absent, the options are to verify broodlessness, to create a break deliberately, or to use an extended-release oxalic acid strip (VarroSan, label duration 42 to 56 days), which keeps contact with successive cohorts of emerging mites and does not depend on broodlessness. Vaporization requires appropriate respiratory protection for the operator.

References: *Rademacher & Harz, Apidologie 37:98-120 (2006); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

223. (SA) Explain what a brood break is, how a beekeeper can create one, how long it must last, and why it assists mite management.

Model answer: A brood break is a period during which a colony has no sealed brood. It assists mite management because Varroa can reproduce only inside sealed brood, so a break halts reproduction and forces the entire mite population onto the adult bees, where contact treatments such as oxalic acid are highly effective. A beekeeper can create one by caging the queen, by making a split so that one portion

is queenless while rearing a new queen, by requeening after a queenless interval, or by removing all sealed brood. A complete break requires about three weeks (21 days), and up to 24 days where drone brood is present, so that all existing sealed brood emerges and none is newly capped.

Rationale: The cost is lost brood production and therefore population, so timing must account for the honey flow and for the rearing of the autumn bee cohort. In this region a post-flow break often fits the calendar well and can be combined with requeening.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Giacomelli et al., Apidologie 47:606-616 (2016).*

224. (MC) Drone brood trapping controls mites by:

Answer: B) Exploiting the mites' preference for drone cells, so a frame of drone comb acts as a sink which is removed and the brood destroyed before the drones emerge

Rationale: The absolute requirement is discipline: the frame must be removed and the brood destroyed, usually by freezing, before emergence, on a strict schedule. A drone frame left too long is a mite amplifier rather than a trap, and this is the most common way the technique fails. It is labor-intensive, suits smaller operations, removes drones from a colony intended as a drone source, and should be combined with monitoring rather than relied upon alone.

References: *Calderone, J. Econ. Entomol. 98:645-650 (2005); Rosenkranz, Aumeier & Ziegelmann, J. Invertebr. Pathol. 103:S96-S119 (2010).*

225. (SA) After treating for Varroa, describe how a beekeeper determines whether the treatment worked, and explain what distinguishes treatment failure from reinvasion.

Model answer: Take a quantitative mite count immediately before treatment and a second count promptly at the end of the treatment period, then compare them. Only a paired measurement demonstrates efficacy. The timing of the post-treatment count is what distinguishes the two explanations for a disappointing result: a count taken promptly at the end of treatment reflects what the treatment achieved, before mites can immigrate. A high count at that point indicates treatment failure, from application error, wrong temperature, brood status or resistance. A low count at that point followed by a rise over subsequent weeks indicates reinvasion from collapsing or untreated colonies within flight range.

Rationale: The distinction determines the response: failure calls for reviewing application and considering a different mode of action, whereas reinvasion calls for apiary-level and area-wide measures and for repeat monitoring.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Frey & Rosenkranz, J. Econ. Entomol. 107:508-515 (2014).*

226. (TF) Mites move into treated colonies from collapsing or untreated colonies nearby through robbing and drifting, so mite management is properly considered at the apiary and area level rather than colony by colony.

Answer: True

Rationale: Reinvasion can be substantial where colony density is high or where untreated collapsing colonies are within flight range, and it can undo an effective treatment within weeks. The implications are practical: reduce drift through apiary layout, avoid excessive hive density, deal promptly with collapsing colonies rather than letting them be robbed out, and where possible coordinate with neighboring beekeepers.

References: *Frey & Rosenkranz, J. Econ. Entomol. 107:508-515 (2014); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

227. (MC) Meaningful rotation among Varroa treatments requires:

Answer: B) Alternating among products with genuinely different modes of action, since products within a class share a resistance mechanism and cross-resistance makes such rotation useless

Rationale: Alternating two pyrethroids, for example, is not rotation, since both act on the same target and are subject to the same resistance mechanism. A defensible rotation moves among distinct modes of action, such as an organic acid, a thymol-based product, a synthetic acaricide of a different class and biotechnical methods such as brood interruption, with efficacy verified after each treatment by paired counts.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Gonzalez-Cabrera et al., PLoS ONE 8:e82941 (2013).*

228. (SA) A beekeeper reports that a treatment did not work. List, in order of likelihood, the explanations to exclude before concluding that resistance is present.

Model answer: First, whether a valid pre-treatment count was taken with correct methodology, since a wrong baseline invalidates the comparison. Second, application error: wrong dose for colony size, incorrect placement relative to the cluster, wrong duration, strips removed early or left beyond efficacy, or product past its shelf life or heat-damaged in storage. Third, environmental conditions, particularly temperature relative to the label window for volatile products. Fourth, brood status, since a treatment that does not penetrate cappings leaves most of the mite population untouched in a brood-right colony. Fifth, reinvasion, assessed by when the post-treatment count was taken and by the apiary's surroundings. Only after excluding these does resistance become the leading explanation, and it should be confirmed by testing a product with a different mode of action.

Rationale: The ordering reflects base rates: application and timing errors are far more common than resistance, and a premature attribution to resistance causes a beekeeper to abandon a product that would still serve. Amitraz resistance is now widespread: all 39 mites screened in the 2026 Lamas et al. study, drawn from 18 colonies in five amitraz-reliant operations, carried the Y215H mutation. That makes resistance a real possibility with amitraz, but the order above still applies, and resistance should be confirmed by a better result with a product of a different mode of action.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Rosenkranz, Aumeier & Ziegelmann, J. Invertebr. Pathol. 103:S96-S119 (2010); Lamas et al., PLoS Pathog. 22:e1013939 (2026).*

229. (MC) Resistance to a miticide develops because:

Answer: A) Repeated exposure to one mode of action selects the small proportion of mites carrying a heritable survival trait, so those individuals come to dominate the population

Rationale: Understanding resistance as selection rather than as learning or product degradation makes the management response evident: reduce selection pressure by using non-chemical tools, rotate among genuinely different modes of action, treat only when thresholds are exceeded rather than by calendar, and never use a reduced dose that kills only the most susceptible mites while allowing the rest to breed.

References: *Gonzalez-Cabrera et al., PLoS ONE 8:e82941 (2013); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

230. (TF) Because Varroa is an arachnid and the honey bee an insect, registered in-hive acaricides are entirely selective and carry no toxicity to bees at any dose.

Answer: False

Rationale: Both are arthropods, and every in-hive acaricide has some toxicity to bees. Treatments work on a margin of selectivity arising from differences in size, physiology, exposure route and behavior, not on absolute safety. This is why label doses matter, why improvising a stronger dose is dangerous as well as unlawful, and why sublethal effects on queens, drones and worker longevity are documented for products used at label rates.

References: *Johnson, Ellis, Mullin & Frazier, Apidologie 41:312-331 (2010); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

231. (MC) Which post-mortem findings indicate that Varroa and associated viruses caused a colony's death?

Answer: B) Deformed wings and shortened abdomens on dead bees, mites visible in cells, white mite fecal deposits on upper cell walls, and substantial stores left unconsumed

Rationale: The white guanine deposits in vacated brood cells are especially useful because they persist after the mites themselves are gone, providing evidence of heavy mite reproduction during the autumn brood cycle. Abundant remaining stores indicate the colony did not run out of food but ran out of bees. The choice describing a cluster with heads in cells and no stores remaining is true starvation, and the remaining choices describe chalkbrood and American foulbrood.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

232. (SA) Outline an integrated Varroa management plan across a full year for a sideline operation in the southeastern US.

Model answer: Late winter to early spring: take a baseline mite count as brood rearing begins, and treat if thresholds are exceeded using a product suited to the temperature while supers are off. Spring: make splits for increase and swarm control, taking advantage of the brood breaks they create; continue

monitoring; do not apply anything not labeled for use with supers on during the flow. Immediately after the main flow: remove and extract supers, monitor and treat as needed, and reduce entrances before the dearth. Late summer: the decisive monitoring point, since the winter bee cohort is being reared; treat promptly if thresholds are exceeded, choosing a product whose label temperature range fits the conditions. Autumn: verify efficacy with a follow-up count, requeen failing colonies, and build stores. Winter: if a genuinely broodless window occurs, an oxalic acid application is highly effective, but broodlessness must be verified rather than assumed. Throughout: keep records, use stock with resistance traits where available, cull old comb, manage drift through apiary layout, and address collapsing colonies promptly.

Rationale: The examinable habits are monitoring before and after every intervention, choosing products by temperature and super status, and treating late summer as the decisive point of the year.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Cooperative Extension apiculture publications, southeastern US.*

233. (MC) Thymol-based products for Varroa control are characterized by:

Answer: B) Activity as a vapor and by contact, with efficacy falling at low temperatures and brood removal, a halt in laying and possible queen loss rising at high ones, so label ranges bind

Rationale: Temperature dependence is the recurring theme across volatile treatments and a central constraint on summer treatment in the southeastern US. Thymol also commonly causes a temporary reduction in laying and some brood removal, which alarms beekeepers who have not read the label, and honey tainting is why labels restrict use when supers are present.

References: *Imdorf, Bogdanov, Ochoa & Calderone, Apidologie 30:209-228 (1999); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

234. (TF) Screened bottom boards, small-cell foundation and powdered sugar dusting have each been evaluated as Varroa controls and found to produce at most modest reductions, so none should be relied upon as a stand-alone control.

Answer: True

Rationale: Each has been tested. Screened bottoms give a small reduction and are useful mainly for monitoring and ventilation; controlled trials of small-cell foundation have not found a significant reduction in mite population growth; and powdered sugar dusting removes some phoretic mites but does not reach mites in sealed brood and has not been shown to control populations. Presenting any of them as a control is among the more consequential errors in beekeeping advice.

References: *Ellis, Delaplane & Hood, Am. Bee J. 141:813-816 (2001); Berry, Owens & Delaplane, Apidologie 41:40-44 (2010); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

235. (MC) A colony collapsing from Varroa in autumn poses a risk to neighboring colonies because:

Answer: D) As it collapses its stores are robbed by neighbors, and the robbers carry mites home, so a collapsing colony is a mite source for every colony within flight range

Rationale: This is the mechanism behind what beekeepers describe as a mite bomb, and it is why leaving a collapsing colony to die untended imposes real costs on neighbors. The responsible action is to monitor, identify colonies in collapse, and remove, treat or combine them before they are robbed out. It is also the strongest argument for area-wide coordination among beekeepers.

References: *Frey & Rosenkranz, J. Econ. Entomol. 107:508-515 (2014); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

236. (MC) *Acarapis woodi*, the tracheal mite, differs from *Varroa* in that:

Answer: B) It lives internally in the prothoracic tracheae, entering through the first thoracic spiracle of very young adults, so diagnosis requires dissection or laboratory work

Rationale: Because tracheal mites are internal and microscopic, a beekeeper cannot diagnose them by looking at bees, and finding *Acarapis* mites on the exterior proves nothing, since two non-pathogenic external *Acarapis* species also occur. Signs such as crawling bees with disjointed wings are suggestive but not specific. The problem has become far less prominent than in the 1980s and 1990s, largely because widely available stock now carries substantial resistance and because some *Varroa* treatments also suppress it.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Sammartaro, Gerson & Needham, Annu. Rev. Entomol. 45:519-548 (2000).*

237. (SA) Describe the historical control measures used against tracheal mites and state the general principle they illustrate.

Model answer: Menthol crystals placed in the hive, which sublime at warm temperatures to produce a vapor lethal to the mites, and which therefore require ambient temperatures in roughly the 60s to 80s degrees Fahrenheit to work, with placement at the top or bottom of the hive depending on whether temperatures are high or low; and vegetable shortening and sugar grease patties, which are thought to interfere with the mites' ability to locate and transfer to young host bees. The general principle is that a volatile treatment's efficacy depends on achieving and maintaining a therapeutic vapor concentration inside the hive, so temperature, ventilation, entrance size and placement of the material are part of the dose rather than incidental details.

Rationale: That principle transfers directly to formic acid and thymol used against *Varroa*, which is why their labels specify temperature ranges and placement and why those specifications are not optional.

References: *Sammartaro, Gerson & Needham, Annu. Rev. Entomol. 45:519-548 (2000); Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

238. (SA) Explain to a new beekeeper, in plain terms, why *Varroa* matters far more than the small number of visible mites would suggest.

Model answer: The mites feed on developing and adult bees, drawing on the fat body and the bee's blood, or hemolymph, which hold the reserves for immunity, food processing and the long life of winter bees, so parasitized bees are physiologically weaker even when they look normal. More importantly, the mite works like a hypodermic needle for viruses, injecting deformed wing virus and others directly into

the bee's body and bypassing the defenses that keep such infections harmless in a mite-free colony. A colony can therefore be destroyed by a mite population that seems small, because the real damage is viral disease amplified by the mite. That is why beekeepers monitor and act at thresholds of a few mites per hundred bees rather than waiting for visible damage, and why most of the mites are invisible anyway, sealed inside brood cells where they are reproducing.

Rationale: Being able to deliver this explanation clearly and without condescension is a core competency, because the most common failure in small-scale beekeeping is a beekeeper who believes their colonies look fine and therefore never monitors.

References: *Ramsey et al., PNAS 116:1792-1801 (2019); de Miranda & Genersch, J. Invertebr. Pathol. 103:S48-S61 (2010); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Han et al., Nat. Commun. 15:725 (2024).*

Section 13: Small Hive Beetle, Wax Moth, Predators & Other Pests (Q239–257)

Part A — Questions

239. (SA) Describe the life cycle of *Aethina tumida*, identifying which stage occurs outside the hive and why that stage matters for control.

240. (MC) The single most important factor in preventing small hive beetle damage is:

- **A)** Feeding protein patties continuously, since well-nourished colonies are better able to confine and harass the adult beetles sheltering in the hive's crevices
- **B)** Painting the hive a dark color, since beetles orient to pale surfaces and a dark hive receives markedly fewer arriving adults over the course of a season
- **C)** Removing the bottom board to increase ventilation, since beetle larvae cannot complete development in a colony with a high rate of air exchange through the nest
- **D)** Maintaining a colony strong enough to patrol and defend all of its comb, and not giving a colony more space than its population can cover

241. (SA) Describe three types of in-hive beetle trap and state the behavioral principle they all exploit.

242. (MC) Honey supers removed from colonies during warm weather in the southeastern US should be:

- **A)** Sprayed with water and covered to keep them cool, since beetle larvae cannot develop in comb whose surface remains damp throughout the period before extraction
- **B)** Stacked in an open shed for a week or two so that the honey continues to ripen and lose moisture before extraction, which improves its keeping quality in the jar
- **C)** Left in the apiary for the bees to clean before storage, which removes the residual honey that would otherwise sustain wax moth and beetle larvae during storage
- **D)** Extracted within a day or two and held in a beetle-tight, sealed space, because comb no longer defended by bees is rapidly destroyed by beetle larvae

243. (TF) Honey slimed by small hive beetle larvae is fermented but remains safe for human consumption once it has been strained and gently heated, so the crop can be salvaged rather than discarded.

True / False

244. (MC) A soil drench for small hive beetle control should be:

- **A)** A product specifically registered and labeled for that use, applied per label to the soil around the hives to target wandering larvae, never inside the hive
- **B)** Any insecticide the beekeeper has available, applied generously to the soil beneath and around the hives at intervals through the season to suppress the pupal stage
- **C)** A product applied inside the hive on the bottom board, where the wandering larvae must pass on their way out, which intercepts them before they reach the soil
- **D)** A product targeting adult beetles within the colony, applied as a fine spray over the frames so that the sheltering adults are contacted where the bees cannot reach

245. (SA) Explain why nucleus colonies, splits and mating nuclei are especially vulnerable to small hive beetle in the southeastern US, and list four precautions.

246. (MC) The relationship between apiary shade and small hive beetle pressure is best stated as:

- **A)** Heavily shaded moist sites are generally associated with greater beetle pressure, so morning sun on well-drained ground is preferable, balanced against summer heat
- **B)** Beetles cannot complete development in sandy soils, so apiaries on sand experience no beetle pressure and the shade question does not arise on such sites at all
- **C)** Shade has no measurable effect on beetle populations, since the pupal stage occurs at a depth in the soil where surface conditions do not influence survival
- **D)** Full sun throughout the day is always correct regardless of temperature, since beetle larvae cannot survive soil temperatures reached in unshaded ground in summer

247. (MC) The greater wax moth damages colonies and stored comb by:

- **A)** Larvae tunneling through comb to feed on pollen, cocoons, brood remains and debris, leaving silken galleries and frass, with damage worst on old dark brood comb
- **B)** Adult moths feeding on adult bees at the hive entrance at night, which is why the damage is most severe in colonies too weak to maintain a guard force after dark
- **C)** Adult moths parasitizing the queen by ovipositing in her abdomen, which is why heavily infested colonies show supersedure as well as damage to the comb itself
- **D)** Larvae consuming stored honey rather than comb, which is why the damage is confined to supers and why brood comb is generally left intact by an infestation

248. (SA) Describe how drawn comb should be protected during storage in the southeastern US, naming acceptable methods and one that is not acceptable, and explain the regional complication.

249. (TF) Wax moth or small hive beetle damage found in an occupied colony should prompt the beekeeper to determine why the colony became too weak to defend itself, rather than treating the pest as the primary problem.

True / False

250. (MC) Imported fire ants affect apiaries in the southeastern US principally by:

- **A)** Transmitting American foulbrood between colonies as they move from hive to hive, which is why apiaries with heavy ant pressure show elevated disease incidence
- **B)** Preying on queens during their mating flights, since the ants forage on the vegetation beneath drone congregation areas and intercept queens returning to the hive
- **C)** Competing directly with honey bees for nectar at flowers, which reduces the surplus available to colonies placed in areas where the ants are numerous
- **D)** Overwhelming weak colonies, nucs and newly hived swarms, robbing brood and stores, harassing bees, and making the apiary hazardous for the beekeeper to work in

251. (MC) Skunk predation on a colony is indicated by:

- **A)** Silken galleries running through the comb with accumulated frass, most severe in old dark brood comb and in colonies that have become too weak to patrol it

- **B)** Slimed frames with fermenting honey and an orange froth, together with the rapid loss of adult bees and the eventual absconding of the remaining population
- **C)** Nighttime scratching at the entrance, trampled grass in front of the hive, scratch marks on the hive front, and a colony unusually defensive during daylight
- **D)** Chewed comb and shredded nesting material inside the hive during winter, together with a strong odor and comb destroyed around the edges of the frames

252. (SA) Describe the correct approach to protecting an apiary from black bears in the mountainous parts of the southeastern US, and explain the behavioral reason for the timing.

253. (MC) Yellowjackets and hornets pressing on hive entrances in late summer are best managed by:

- **A)** Reducing entrances so colonies can defend them, maintaining strong colonies, removing nearby nests where safe and lawful, and using baited traps away from the hives
- **B)** Spraying insecticide at the hive entrance where the wasps hover, which kills them on contact without harming the bees inside the colony behind the entrance reducer
- **C)** Taking no action at all, since wasps at a hive entrance are scavenging dead bees rather than attacking the colony and cause no measurable harm to it
- **D)** Opening the hives during an attack so that the full colony can pursue the intruders, which drives the wasps from the apiary and discourages their return

254. (TF) *Braula coeca*, the bee louse, is a mite distinguished from *Varroa* by its smaller size and its eight legs, and it feeds by piercing the cuticle of adult bees.

True / False

255. (MC) Freezing frames or supers at about 0 degrees F for 24 to 48 hours is used to:

- **A)** Sterilize comb against American foulbrood spores, which is why frozen frames from a dead-out can safely be given to a healthy colony the following season
- **B)** Improve the flavor and clarity of the honey by precipitating the finer wax particles and pollen grains, which then settle out during subsequent warming
- **C)** Reduce the moisture content of honey remaining in the comb, since ice crystals form preferentially from the water and can be separated from the sugars
- **D)** Kill all life stages of wax moth and small hive beetle in comb before storage, without harming the comb or the honey and without leaving any chemical residue

256. (SA) List the routine sanitation practices that reduce pest pressure in an apiary and honey house in the southeastern US.

257. (SA) A colony is found with slimed frames, beetle larvae throughout the comb and few bees remaining. Describe what you do with the colony, the equipment and the rest of the apiary.

Part B — Answer Key: Section 13

239. (SA) Describe the life cycle of *Aethina tumida*, identifying which stage occurs outside the hive and why that stage matters for control.

Model answer: Adult beetles enter colonies and are herded into cracks and corners by the bees, where they may be fed by trophallaxis or feed on pollen, honey and brood. Females lay eggs in crevices and in

brood comb. Larvae tunnel through the combs feeding on pollen, honey and brood, defecating in the honey and introducing a yeast that ferments it, producing the characteristic slimed, frothy, foul-smelling mass. Mature wandering larvae leave the hive and burrow into the soil close to it, generally within a few feet and at shallow depth, where they pupate before emerging as adults and seeking a colony. The soil pupation stage is the one occurring outside the hive, and it matters because it is the only life stage accessible to an out-of-hive control such as a labeled soil drench, and because soil type, moisture and shade influence pupation success.

Rationale: It also explains why an apiary can suffer sustained beetle pressure even after in-hive numbers are reduced: the surrounding soil holds a developing population.

References: *Neumann & Elzen, Apidologie 35:229-247 (2004); Ellis & Hepburn, Insectes Soc. 53:8-19 (2006).*

240. (MC) The single most important factor in preventing small hive beetle damage is:

Answer: D) Maintaining a colony strong enough to patrol and defend all of its comb, and not giving a colony more space than its population can cover

Rationale: Bees control beetles by confining and harassing them, so a colony that cannot patrol its comb cannot do this. Every practical recommendation follows: do not over-supply weak colonies, reduce entrances, size protein patties for rapid consumption, combine failing colonies rather than letting them dwindle, and remove supers promptly after a flow. Traps and chemical controls supplement colony strength rather than substituting for it.

References: *Neumann & Elzen, Apidologie 35:229-247 (2004); Cooperative Extension small hive beetle publications, southeastern US.*

241. (SA) Describe three types of in-hive beetle trap and state the behavioral principle they all exploit.

Model answer: Oil-filled tray traps placed beneath a screened bottom board, into which beetles fall and drown; slotted plastic in-hive traps placed between top bars or hung on frame ends and charged with vegetable oil or an oil and diatomaceous earth mixture, which beetles enter to escape harassment and cannot leave; and corrugated cardboard traps on the bottom board holding a coumaphos strip (the only in-hive chemical labeled for small hive beetle), where beetles shelter and contact the strip but bees cannot, reserved for high-pressure situations. Entrance-mounted and bottom-board oil traps operate similarly. The behavioral principle they all exploit is the beetles' tendency to seek refuge in narrow spaces where bees cannot reach them, so the trap presents an attractive refuge that is lethal.

Rationale: Traps must be maintained, since oil evaporates or fills with debris and a neglected trap is useless. They reduce beetle numbers but will not save a colony that lacks the population to defend itself.

References: *Cooperative Extension small hive beetle publications, southeastern US; Neumann & Elzen, Apidologie 35:229-247 (2004).*

242. (MC) Honey supers removed from colonies during warm weather in the southeastern US should be:

Answer: D) Extracted within a day or two and held in a beetle-tight, sealed space, because comb no longer defended by bees is rapidly destroyed by beetle larvae

Rationale: Bee defense is what limits beetle development, so any hive product removed from bee protection becomes vulnerable. This is one of the sharpest practical differences between beekeeping in this region and in cooler states, where supers can stand for a week without consequence. Prompt extraction, a sealed honey house, and immediate handling of cappings and wet comb are the standard practices.

References: *Cooperative Extension small hive beetle publications, southeastern US; Neumann & Elzen, Apidologie 35:229-247 (2004).*

243. (TF) Honey slimed by small hive beetle larvae is fermented but remains safe for human consumption once it has been strained and gently heated, so the crop can be salvaged rather than discarded.

Answer: False

Rationale: Slimed honey is unfit for human consumption and must be discarded; neither straining nor heating makes it saleable. The larvae defecate in the honey and introduce a yeast that ferments it, producing the characteristic foul odor, and that odor attracts further beetles, which is why slimed material should be removed from the apiary promptly rather than left standing near other colonies.

References: *Neumann & Elzen, Apidologie 35:229-247 (2004); Cooperative Extension small hive beetle publications, southeastern US.*

244. (MC) A soil drench for small hive beetle control should be:

Answer: A) A product specifically registered and labeled for that use, applied per label to the soil around the hives to target wandering larvae, never inside the hive

Rationale: The drench targets the one life stage outside the colony and is among the few chemical tools available. Because it is an insecticide applied close to colonies, label compliance and careful placement are essential, and it should form one component of a program built on colony strength, trapping and sanitation rather than serving as the primary control.

References: *Cooperative Extension small hive beetle publications, southeastern US; product labels.*

245. (SA) Explain why nucleus colonies, splits and mating nuclei are especially vulnerable to small hive beetle in the southeastern US, and list four precautions.

Model answer: Small units have few adult bees relative to their comb area, so they cannot patrol and confine beetles effectively, and a beetle population a full colony would contain can overwhelm a nuc within a week, producing slimed comb and absconding. Precautions: size the unit tightly so the bees cover all the comb, using follower boards or smaller boxes rather than a partly filled full box; reduce entrances; install and maintain beetle traps; avoid protein patties or use only small pieces consumed within days; place nucs in morning sun rather than deep shade; and inspect frequently, since a nuc can

be lost between weekly visits. Combine or build up any nuc that is losing ground rather than hoping it recovers.

Rationale: This vulnerability shapes how splits, queen rearing and mating are managed throughout the region and is one of the clearest practical divergences from northern practice.

References: *Cooperative Extension small hive beetle publications, southeastern US; Neumann & Elzen, Apidologie 35:229-247 (2004).*

246. (MC) The relationship between apiary shade and small hive beetle pressure is best stated as:

Answer: A) Heavily shaded moist sites are generally associated with greater beetle pressure, so morning sun on well-drained ground is preferable, balanced against summer heat

Rationale: The trade-off is genuine: summers in the region demand some afternoon shade for colony heat management, while dense full-day shade over damp ground favors beetles. The usual compromise is morning sun with dappled or afternoon shade on well-drained soil, which also improves beekeeper access and reduces the moisture problems that favor chalkbrood.

References: *Cooperative Extension small hive beetle publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

247. (MC) The greater wax moth damages colonies and stored comb by:

Answer: A) Larvae tunneling through comb to feed on pollen, cocoons, brood remains and debris, leaving silken galleries and frass, with damage worst on old dark brood comb

Rationale: The larvae depend on protein from pollen and cocoon residue rather than on pure wax, which is why old dark comb is destroyed rapidly while clean new comb is comparatively resistant. In a living colony wax moth is fundamentally a symptom rather than a cause: a strong colony keeps it in check, so wax moth damage in an occupied hive signals that something else has weakened the colony.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Morse & Flottum (eds.), Honey Bee Pests, Predators, and Diseases, 3rd ed., A.I. Root, 1997.*

248. (SA) Describe how drawn comb should be protected during storage in the southeastern US, naming acceptable methods and one that is not acceptable, and explain the regional complication.

Model answer: Acceptable methods: freeze comb at about 0 degrees F for 24 to 48 hours to kill all life stages of wax moth and small hive beetle, then store it moth-tight and beetle-tight; store comb in light and moving air, for example in spaced stacks under a roof, since wax moth strongly avoids light and airflow; treat stored comb with a registered *Bacillus thuringiensis* subsp. *aizawai* preparation; and seal frozen comb in plastic (warmed inside the sealed bag to prevent condensation) so it stays pest-tight. Light and airflow works best on honey comb and is not reliable alone in the Southeast. Not acceptable: paradichlorobenzene or naphthalene, which leave residues in wax and honey and should not be used on comb that will hold honey or brood; paradichlorobenzene products are registered for stored comb, but naphthalene is not. The regional complication is that mild winters mean wax moth remains active for

much of the year, so simply stacking comb in an unheated building over winter, which suffices farther north, does not work here.

Rationale: Comb should also be extracted, cleaned by the bees where possible, and stored dry, since residual honey and pollen sustain both pests. Registration of a paradichlorobenzene product for stored comb does not make it a sound choice: the residue persists in wax and can taint honey later stored in that comb, so freezing, light and moving air, and cold storage are the methods to rely on.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Cooperative Extension apiculture publications, southeastern US; product labels.*

249. (TF) Wax moth or small hive beetle damage found in an occupied colony should prompt the beekeeper to determine why the colony became too weak to defend itself, rather than treating the pest as the primary problem.

Answer: True

Rationale: Both pests are largely opportunists on colonies already weakened by a failing queen, Varroa and virus damage, disease, starvation, or the beekeeper having given more space than the colony could cover. Attacking the pest without identifying the underlying weakness leaves the colony to fail anyway. This diagnostic habit, asking what allowed the problem, distinguishes a competent beekeeper from one who treats symptoms.

References: *Cooperative Extension small hive beetle publications, southeastern US; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

250. (MC) Imported fire ants affect apiaries in the southeastern US principally by:

Answer: D) Overwhelming weak colonies, nucs and newly hived swarms, robbing brood and stores, harassing bees, and making the apiary hazardous for the beekeeper to work in

Rationale: Fire ants are as much an occupational hazard as a colony pest: a beekeeper standing in a mound while lifting a heavy super faces a genuine risk. Controls include hive stands with legs in oil or grease barriers, clearing vegetation that bridges to the hive, maintaining strong colonies, and baiting mounds at a distance from the hives with an approved product applied per label so that hive products are not contaminated.

References: *Morse & Flottum (eds.), Honey Bee Pests, Predators, and Diseases, 3rd ed., A.I. Root, 1997; Cooperative Extension apiculture publications, southeastern US.*

251. (MC) Skunk predation on a colony is indicated by:

Answer: C) Nighttime scratching at the entrance, trampled grass in front of the hive, scratch marks on the hive front, and a colony unusually defensive during daylight

Rationale: Skunks scratch at the entrance and eat the bees that emerge, night after night, which both depletes the colony and leaves it chronically agitated, so the daytime defensiveness is a useful secondary clue. Controls include raising hive stands to 18 to 24 inches so the animal must stand upright to reach the entrance, strips of carpet tacks or roofing nails placed face-up in front of the entrance, and,

where legal, cage trapping. Opossums produce similar scratching and respond to the same controls; raccoons more often tip or disturb light hives.

References: Morse & Flottum (eds.), *Honey Bee Pests, Predators, and Diseases*, 3rd ed., A.I. Root, 1997; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

252. (SA) Describe the correct approach to protecting an apiary from black bears in the mountainous parts of the southeastern US, and explain the behavioral reason for the timing.

Model answer: Install a properly constructed electric fence before any damage occurs: an energizer of adequate output, good grounding, appropriate wire spacing, vegetation cleared from the wires, and baiting of the wires so the animal contacts them with its nose and learns the lesson. Maintain the fence and test it regularly. Site apiaries away from known bear travel corridors where possible. The behavioral reason for the timing is that a bear which has fed successfully at an apiary is far harder to deter than one that has not, because it has learned that the site is a food source and will persist through considerable discomfort to return.

Rationale: Bears are protected game animals, so any other response is governed by state wildlife law, and some states require a functioning fence to have been in place before any damage compensation is available.

References: State wildlife agency bear damage guidance; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

253. (MC) Yellowjackets and hornets pressing on hive entrances in late summer are best managed by:

Answer: A) Reducing entrances so colonies can defend them, maintaining strong colonies, removing nearby nests where safe and lawful, and using baited traps away from the hives

Rationale: Wasp pressure peaks in late summer and autumn, coinciding with the regional dearth when colonies are already stressed and robbing pressure is high, so the same entrance management that addresses robbing also addresses wasps. Spraying insecticide at a hive entrance kills bees and contaminates the colony and its products.

References: Morse & Flottum (eds.), *Honey Bee Pests, Predators, and Diseases*, 3rd ed., A.I. Root, 1997; *Cooperative Extension apiculture publications, southeastern US*.

254. (TF) *Braula coeca*, the bee louse, is a mite distinguished from *Varroa* by its smaller size and its eight legs, and it feeds by piercing the cuticle of adult bees.

Answer: False

Rationale: *Braula* is not a mite but a wingless fly, and the standard discrimination is the leg count: six legs for an insect, eight for a mite. It does not pierce the cuticle; adults ride on adult bees, particularly queens, and steal food at the mouthparts with little direct harm. The economically relevant damage is done by the larvae, which tunnel beneath honey comb cappings and mar comb honey.

References: Shimanuki & Knox, *Diagnosis of Honey Bee Diseases*, USDA Agriculture Handbook 690, 2000; Morse & Flottum (eds.), *Honey Bee Pests, Predators, and Diseases*, 3rd ed., A.I. Root, 1997.

255. (MC) Freezing frames or supers at about 0 degrees F for 24 to 48 hours is used to:

Answer: D) Kill all life stages of wax moth and small hive beetle in comb before storage, without harming the comb or the honey and without leaving any chemical residue

Rationale: Freezing is the most reliable non-chemical treatment available to a small beekeeper. Its important limitation is that it has no effect on *Paenibacillus* larvae spores, so it is not a foulbrood control. Comb should be sealed in plastic before freezing, must reach 0 degrees F throughout and not just at the surface, should be allowed to return to room temperature inside the sealed bag so that moisture condenses on the bag rather than in the cells, and should be stored pest-tight afterward, or it will simply be reinfested.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Cooperative Extension apiculture publications, southeastern US.*

256. (SA) List the routine sanitation practices that reduce pest pressure in an apiary and honey house in the southeastern US.

Model answer: In the apiary: keep colonies strong and correctly sized for their population; reduce entrances on weak colonies and during the dearth; maintain and service beetle traps; remove burr comb, scrapings, dead-out equipment and slimed material from the yard rather than leaving it; deal promptly with failing or collapsing colonies; keep vegetation cleared and hives on stands; and avoid spilling syrup or leaving exposed comb. In the honey house: extract within a day or two of removing supers; keep the building sealed against beetle entry (door sweeps, window screens, doors closed during processing); process cappings and wet comb, or return them to the bees, the same day rather than leaving them overnight; return wet supers to colonies promptly or store them dry and protected; and clean up spills and debris the same day.

Rationale: Sanitation is unglamorous, but it is the practice that most reliably distinguishes apiaries that manage small hive beetle from those that are managed by it.

References: *Cooperative Extension small hive beetle publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

257. (SA) A colony is found with slimed frames, beetle larvae throughout the comb and few bees remaining. Describe what you do with the colony, the equipment and the rest of the apiary.

Model answer: Treat the colony as lost. Remove the hive from the apiary promptly so it does not seed beetles into neighboring colonies and so the odor does not attract more. If a queen and a worthwhile cluster of bees remain, they can be shaken onto clean equipment and combined with a strong colony, though this is often not worth doing. Destroy the slimed comb by scraping it into a bag and disposing of it away from the apiary, and never feed it back or melt it into wax; clean and reuse frames only where damage is limited to a small area caught early. Wash, scrape and thoroughly dry the boxes, bottom board and covers, preferably in sunlight, before reuse. Consider whether the soil at that hive position warrants a labeled drench where pressure is high. Then inspect the remaining colonies in the yard, because a colony is normally overwhelmed only after something else, such as queen failure, mite damage or excessive space, weakened it.

Rationale: That last step is what separates a competent response from a merely tidy one: slime-out is an end point rather than a beginning, and the original cause is probably still present in the apiary.

References: *Cooperative Extension small hive beetle publications, southeastern US; Neumann & Elzen, Apidologie 35:229-247 (2004).*

Section 14: Integrated Pest Management & Treatment Pharmacology (Q258–274)

Part A — Questions

258. (MC) Integrated pest management in beekeeping is best described as:

- **A)** Using monitoring to determine pest levels, relying first on genetic, cultural and mechanical controls, treating only when thresholds are exceeded, and verifying the outcome
- **B)** Applying the most potent product available as soon as any pest is detected, on the principle that early and decisive intervention prevents populations from establishing
- **C)** Treating every colony on a fixed calendar schedule regardless of measured pest levels, so that no colony is ever left untreated during the periods of greatest risk
- **D)** Refusing all chemical treatment under every circumstance and relying entirely on stock selection, so that susceptible colonies are allowed to fail and are not replaced

259. (SA) Explain the difference between an economic injury level and an action threshold, and apply the distinction to late-summer Varroa management.

260. (MC) In the United States, a pesticide label on an in-hive miticide is:

- **A)** A set of manufacturer recommendations that an experienced beekeeper may vary at their discretion, provided the deviation is made in good faith and causes no visible harm
- **B)** Binding only on commercial beekeepers holding a pesticide applicator's license, since hobbyist and sideline operations fall outside the scope of the relevant statute
- **C)** Advisory for products sold to hobbyists in small package sizes, with enforceable status attaching only to products sold in commercial quantities to registered operations
- **D)** A legally enforceable document, so applying the product at a different dose, at a different time, or with supers present contrary to the label violates federal law

261. (SA) Explain the mode of action of formic acid against Varroa and state the property that distinguishes it from most other treatments, together with the associated risks.

262. (MC) Oxalic acid's action against Varroa is best described as:

- **A)** Inhibition of chitin synthesis in the developing mite, so that the foundress reproduces normally but her offspring fail to complete their moults inside the cell
- **B)** Contact activity against mites on adult bees, distributed among the bees by their movement and contact, with no penetration of cappings and little effect in sealed brood
- **C)** A repellent action that drives mites off the adult bees and out of the colony entirely, which is why mite fall continues for several weeks after the treatment ends
- **D)** Systemic activity following uptake by the bee, so that the compound circulates in the hemolymph and reaches mites feeding on adults and on sealed brood alike

263. (MC) Amitraz differs from pyrethroid miticides such as tau-fluvalinate in that:

- **A)** It is a fungicide rather than an acaricide, and controls mites indirectly by suppressing the fungal pathogens on which the developing mites depend within the cell

- **B)** It cannot lawfully be used in honey bee colonies in the United States, and is registered only for use on livestock, which is why pyrethroids remain the standard
- **C)** It acts on octopamine receptors rather than on sodium channels, so the two represent genuinely different modes of action for the purposes of resistance management
- **D)** It acts on the same target site as the pyrethroids, so the two are interchangeable and alternating between them constitutes a sound resistance-management rotation

264. (TF) Personal protective equipment listed on a pesticide label is a manufacturer's recommendation rather than part of the enforceable label, so an experienced applicator may substitute their own judgment.

True / False

265. (SA) State what a treatment record should contain and give three distinct uses to which such records are put.

266. (MC) Which of the following is a cultural or mechanical control rather than a chemical one?

- **A)** Vaporizing oxalic acid into the colony with appropriate respiratory protection, repeated at intervals timed to catch successive cohorts of emerging mites
- **B)** Applying a thymol-based product within the label temperature range, accepting the temporary reduction in laying and the brood removal that commonly follow
- **C)** Applying an amitraz strip according to the label at the rate specified for the colony size, and removing the strips at the end of the prescribed treatment period
- **D)** Making a split to create a brood break, trapping mites in drone comb, culling old comb, reducing entrances and arranging hives to limit drift between colonies

267. (MC) Sublethal effects of in-hive acaricides that have been documented include:

- **A)** Effects on worker bees alone, with the reproductive castes protected by the physiological differences between them and the workers that handle the treated surfaces
- **B)** Reduced queen weight, acceptance and survival, impaired drone sperm viability, altered worker learning and longevity, and interactions with other agrochemicals
- **C)** Effects that appear only at approximately ten times the label dose, which is why accidental overdosing is the only realistic route to harm from a registered product
- **D)** No effects of any kind at label doses, which is the basis on which the products are registered and the reason label rates carry a substantial margin of safety

268. (SA) Set out the components of an integrated Varroa management program in the order they should be applied, and state the governing principle.

269. (TF) Increasing the dose above the label rate to overcome suspected resistance is both unlawful and counterproductive, since it increases harm to bees, raises residues in wax and honey, and accelerates the selection of resistant mites.

True / False

270. (MC) A colony monitored at mid-season shows a mite level well below the action threshold. The appropriate response is to:

- **A)** Treat anyway as a precaution, since treatment carries no cost to the colony and a low count in one sample may not represent the true infestation across the whole hive
- **B)** Requeen the colony with resistant stock, since a low count indicates that the existing queen's genetics are worth propagating throughout the rest of the operation
- **C)** Withhold treatment, record the result and schedule the next monitoring point, recognizing that populations grow through the season and the late-summer count is decisive
- **D)** Stop monitoring for the remainder of the year, since a colony below threshold at mid-season will not reach a damaging level before the end of the brood-rearing period

271. (SA) Describe how IPM principles apply to small hive beetle management in the southeastern US.

272. (MC) Hop beta acids, sold as HopGuard 3, are best characterized as:

- **A)** A contact treatment (potassium salt of hop beta acids), acting on mites on adult bees rather than in sealed brood, and labeled for use with honey supers on
- **B)** A systemic treatment fed in syrup, which reaches mites in sealed brood through the brood food and must therefore be kept off colonies carrying honey supers
- **C)** A synthetic pyrethroid derived from hop resins, sharing its mode of action with tau-fluvalinate and therefore of no value in a rotation that already uses one
- **D)** A fumigant released as a vapor that penetrates cappings like formic acid, so that a single application is fully effective in a colony with a full brood nest

273. (SA) Set out the argument for and against a treatment-free approach to Varroa, and state what responsible treatment-free practice requires.

274. (SA) A club member says they do not monitor for mites because their colonies look healthy. Compose the explanation you would give.

Part B — Answer Key: Section 14

258. (MC) Integrated pest management in beekeeping is best described as:

Answer: A) Using monitoring to determine pest levels, relying first on genetic, cultural and mechanical controls, treating only when thresholds are exceeded, and verifying the outcome

Rationale: IPM is neither calendar treatment nor refusal to treat. Its defining features are that decisions follow measurement and that non-chemical tools carry as much of the load as possible, so that chemicals remain effective when genuinely needed. In Varroa management the practical version is monitor, use resistant stock and brood breaks, treat at thresholds, and verify with a follow-up count.

References: Delaplane, Berry, Skinner, Parkman & Hood, *J. Apic. Res.* 44:157-162 (2005); Honey Bee Health Coalition, *Tools for Varroa Management*, 9th ed.

259. (SA) Explain the difference between an economic injury level and an action threshold, and apply the distinction to late-summer Varroa management.

Model answer: The economic injury level is the pest density at which the cost of the damage equals the cost of control. The action threshold, sometimes called the economic threshold, is set below it, at the density at which intervention must occur to prevent the population from reaching the injury level. The

gap between them must be wide enough to allow the intervention time to work. Applied to Varroa in late summer, the gap must be large because mite populations grow multiplicatively and because damage to the winter bee cohort occurs during pupation, before it becomes visible. This is why the action threshold is set at only 1 mite per 100 bees in spring (Dormant and Population Increase phases) and 2 per 100 from Peak Population onward rather than at the level where colony damage is apparent.

Rationale: A candidate who can state this framework can also explain why waiting to see deformed wings or a dwindling population is not conservative management but a sign that the injury level has already been passed.

References: *Stern, Smith, van den Bosch & Hagen, Hilgardia 29:81-101 (1959); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

260. (MC) In the United States, a pesticide label on an in-hive miticide is:

Answer: D) A legally enforceable document, so applying the product at a different dose, at a different time, or with supers present contrary to the label violates federal law

Rationale: Under federal pesticide law, use inconsistent with the labeling is unlawful. The restrictions are substantive rather than bureaucratic: dose limits define the margin between mite efficacy and bee harm, super restrictions define the conditions under which residues stay within tolerance, and temperature limits define when a volatile product is effective without killing brood and queens. Labels change, so the current label of the specific product should be read before each use.

References: *7 U.S.C. 136 et seq.; US EPA pesticide labeling requirements.*

261. (SA) Explain the mode of action of formic acid against Varroa and state the property that distinguishes it from most other treatments, together with the associated risks.

Model answer: Formic acid acts as a volatile compound whose vapor permeates the hive atmosphere and interferes with mite respiration at the cellular level, killing mites at concentrations that bees mostly tolerate. Its distinguishing property is that the vapor penetrates the cappings of sealed brood, so it kills mites in the reproductive phase inside brood cells as well as those on adult bees, which few other commonly used treatments do effectively. The associated risks are brood mortality, queen loss, bee mortality and absconding when applied outside the label temperature range, together with a narrow margin between efficacy and harm that makes strict adherence to dose and temperature limits essential.

Rationale: That combination makes it particularly relevant in the southeastern US, where colonies are rarely broodless, but also particularly constrained, since summer temperatures frequently exceed label maxima.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Rosenkranz, Aumeier & Ziegelmann, J. Invertebr. Pathol. 103:S96-S119 (2010).*

262. (MC) Oxalic acid's action against Varroa is best described as:

Answer: B) Contact activity against mites on adult bees, distributed among the bees by their movement and contact, with no penetration of cappings and little effect in sealed brood

Rationale: Because it does not reach mites under cappings, timing to a broodless or nearly broodless period is decisive, which is precisely the difficulty in this region. The one exception in design is the extended-release strip (VarroSan, registered December 2023, 42 to 56 days), which keeps oxalic acid active across successive brood cycles; Api-Bioxal, Api-Bioxal RTU and EZ-OX are single-application products. Repeated dribble applications damage bees and shorten their lives, so repeat regimens generally use vaporization where permitted, and vaporization requires an appropriately rated respirator for the operator, not a dust mask.

References: Rademacher & Harz, *Apidologie* 37:98-120 (2006); Honey Bee Health Coalition, *Tools for Varroa Management*, 9th ed.

263. (MC) Amitraz differs from pyrethroid miticides such as tau-fluvalinate in that:

Answer: C) It acts on octopamine receptors rather than on sodium channels, so the two represent genuinely different modes of action for the purposes of resistance management

Rationale: Knowing modes of action is what makes genuine rotation possible: alternating two pyrethroids is not rotation because they share a target and a resistance mechanism. Amitraz also degrades more rapidly and is less persistent in wax than the older synthetic products, which is one reason for its wide adoption. Resistance to it is now widespread, however: in a small, non-random sample from collapsing, amitraz-dependent operations in the 2024–25 US losses (39 mites from 18 colonies in five operations), every mite screened carried the Y215H mutation in the octopamine receptor that reduces sensitivity to amitraz, compared with about two thirds in an earlier regional survey; this is not a national prevalence estimate, so a count at the end of every amitraz treatment is essential.

References: Honey Bee Health Coalition, *Tools for Varroa Management*, 9th ed.; Rinkevich, *PLoS ONE* 15:e0227264 (2020); Lamas et al., *PLOS Pathog.* 22:e1013939 (2026).

264. (TF) Personal protective equipment listed on a pesticide label is a manufacturer's recommendation rather than part of the enforceable label, so an experienced applicator may substitute their own judgment.

Answer: False

Rationale: The PPE section is part of the legally binding label, and using the product without the specified equipment is use inconsistent with the labeling. The requirement is also substantive rather than formal: concentrated formic acid causes severe skin and eye burns and damages the respiratory tract, and oxalic acid vapor requires an appropriately rated respirator rather than a dust mask. Working outdoors is not a substitute.

References: *Product labels and safety data sheets for formic and oxalic acid formulations*; Honey Bee Health Coalition, *Tools for Varroa Management*, 9th ed.

265. (SA) State what a treatment record should contain and give three distinct uses to which such records are put.

Model answer: Product name and lot number, dose, application and removal dates, which colonies were treated, ambient temperature during the treatment period, and paired pre- and post-treatment mite counts. Uses: resistance management and diagnosis, since a series of paired counts across seasons reveals declining efficacy of a product in that operation, which is the only practical way to detect emerging resistance before it causes losses; regulatory and food safety compliance, since records demonstrate label-compliant use and support residue traceability for buyers and regulators; and operational troubleshooting, since when colonies fail the record allows the beekeeper to distinguish treatment failure from wrong timing, reinvasion or an unrelated cause, and informs future product choice and timing.

Rationale: Lot number and temperature deserve specific mention because product performance can vary by lot and because temperature determines both efficacy and bee safety for volatile treatments, and neither can be reconstructed later from memory.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

266. (MC) Which of the following is a cultural or mechanical control rather than a chemical one?

Answer: D) Making a split to create a brood break, trapping mites in drone comb, culling old comb, reducing entrances and arranging hives to limit drift between colonies

Rationale: Non-chemical tools reduce how often chemicals are needed, slow the development of resistance, cost little and leave no residue. Their limitation is that they are labor-intensive and generally insufficient alone to control a serious infestation, which is why an integrated program uses them alongside rather than instead of treatments, and why a beekeeper who relies solely on them must monitor even more rigorously.

References: *Delaplane, Berry, Skinner, Parkman & Hood, J. Apic. Res. 44:157-162 (2005); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

267. (MC) Sublethal effects of in-hive acaricides that have been documented include:

Answer: B) Reduced queen weight, acceptance and survival, impaired drone sperm viability, altered worker learning and longevity, and interactions with other agrochemicals

Rationale: The reproductive-caste effects matter most to queen producers, since residues in comb used in cell builders and mating nuclei can degrade the product without an obvious cause. The interaction effects matter to anyone whose colonies are also exposed to agricultural fungicides, since some of those inhibit the enzymes bees use to detoxify acaricides and insecticides, producing greater toxicity than either compound alone would cause.

References: *Johnson, Ellis, Mullin & Frazier, Apidologie 41:312-331 (2010); Johnson, Dahlgren, Siegfried & Ellis, PLoS ONE 8:e54092 (2013).*

268. (SA) Set out the components of an integrated Varroa management program in the order they should be applied, and state the governing principle.

Model answer: Begin with monitoring: quantitative counts at defined points in the season with results recorded. Then action thresholds: predetermined, phase-keyed levels (1 mite per 100 bees in spring, 2 per 100 from Peak Population onward) that trigger a response. Then choose the tactic, non-chemical tools first: genetic control (stock carrying documented resistance traits, propagated from survivors), cultural control (apiary layout and density that limit drift and reinvasion, sound nutrition and colony health). Then biotechnical and cultural methods: drone brood trapping, induced brood breaks through splits, queen caging or requeening, and comb management. Then chemical intervention when thresholds are exceeded, with the product chosen by season, temperature, brood status, presence of supers and the operation's resistance history, applied strictly per label. Finally verification by post-treatment counts, feeding back into the record and the next decision. The governing principle is that measurement precedes and follows every intervention, and that chemicals are one tool within a program rather than the program itself.

Rationale: An examiner will look for monitoring both before and after intervention, for apiary-level thinking about reinvasion, and for treatment selection driven by measured conditions rather than by habit or convenience.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Delaplane, Berry, Skinner, Parkman & Hood, J. Apic. Res. 44:157-162 (2005).*

269. (TF) Increasing the dose above the label rate to overcome suspected resistance is both unlawful and counterproductive, since it increases harm to bees, raises residues in wax and honey, and accelerates the selection of resistant mites.

Answer: True

Rationale: The margin between mite efficacy and bee harm is narrow for most in-hive acaricides, so overdosing produces queen loss, brood damage and worker mortality. The correct response to suspected resistance is to verify it by testing a product with a different mode of action, then to rotate away from the failing product, while reviewing whether the apparent failure was in fact an application, timing or reinvasion problem.

References: *7 U.S.C. 136 et seq.; Johnson, Ellis, Mullin & Frazier, Apidologie 41:312-331 (2010).*

270. (MC) A colony monitored at mid-season shows a mite level well below the action threshold. The appropriate response is to:

Answer: C) Withhold treatment, record the result and schedule the next monitoring point, recognizing that populations grow through the season and the late-summer count is decisive

Rationale: Restraint is as much a part of IPM as intervention. Unnecessary treatment costs money, exposes bees to an acaricide, adds residue to the wax and accelerates resistance. But a low mid-season count does not license neglect: the essential follow-up is the late-summer count, and skipping it is the single most common route to winter loss.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Delaplane, Berry, Skinner, Parkman & Hood, J. Apic. Res. 44:157-162 (2005).*

271. (SA) Describe how IPM principles apply to small hive beetle management in the southeastern US.

Model answer: Monitor by counting beetles observed during inspections and captured in traps, and by watching for larvae and slimed comb. Apply cultural controls first: keep colonies strong and correctly sized so bees patrol all comb, reduce entrances on weak colonies, avoid oversized protein patties, site apiaries in morning sun on well-drained ground, and maintain honey house sanitation with prompt extraction. Apply mechanical controls: in-hive and bottom-board oil traps, maintained and refreshed. Use genetic and colony-strength tools, including stock and management that produce populous, well-defended colonies. Reserve chemical control, principally a labeled soil drench targeting the pupal stage, for high-pressure situations, applying strictly per label. Verify by continued monitoring, and combine or remove colonies losing the battle before they become a source for the rest of the yard.

Rationale: The organizing logic is the same as for Varroa: measurement first, non-chemical tools carrying most of the load, chemicals reserved and label-compliant, results verified.

References: *Cooperative Extension small hive beetle publications, southeastern US; Neumann & Elzen, Apidologie 35:229-247 (2004).*

272. (MC) Hop beta acids, sold as HopGuard 3, are best characterized as:

Answer: A) A contact treatment (potassium salt of hop beta acids), acting on mites on adult bees rather than in sealed brood, and labeled for use with honey supers on

Rationale: The practical points follow from contact action. Because it acts by contact, it reaches only mites on adult bees, so mites inside sealed brood are not reached. Its label permits use with honey supers on and in hot weather (to 100 degrees F), which gives the southeastern beekeeper an option in summer when formic acid is excluded by temperature and supers are still on. Hop beta acids are a distinct class, so they add a genuinely different mode of action to a rotation. As with every treatment, efficacy is verified by a count at the end of the treatment period.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; product labels.*

273. (SA) Set out the argument for and against a treatment-free approach to Varroa, and state what responsible treatment-free practice requires.

Model answer: For: treating every colony prevents natural selection for resistance; chemical residues accumulate in wax; and some populations (the Arnot Forest colonies, isolated island populations) have been documented persisting with Varroa under conditions of low colony density and frequent swarming. Against: in a densely stocked managed landscape, colonies that collapse from mites are robbed by neighbors, so an untreated failing colony becomes a mite and virus source for every beekeeper within flight range; and most beekeepers attempting the approach in managed settings do not achieve the natural selection they intend, because they replace losses with purchased commercial queens from unrelated stock rather than propagating from survivors. Responsible practice requires rigorous monitoring, willingness to identify and remove collapsing colonies before they are robbed out

rather than letting them die in place, honest accounting of losses, propagation from genuine survivors, and transparency with neighboring beekeepers.

Rationale: The examinable point is that the philosophical position and its execution are separable, and that the obligation not to impose mite pressure on neighbors applies regardless of philosophy.

References: Seeley, *Apidologie* 38:19-29 (2007); Frey & Rosenkranz, *J. Econ. Entomol.* 107:508-515 (2014); Honey Bee Health Coalition, *Tools for Varroa Management*, 9th ed.

274. (SA) A club member says they do not monitor for mites because their colonies look healthy. Compose the explanation you would give.

Model answer: Colonies look healthy right up until they do not. Most of the mite population is invisible, sealed inside brood cells where it is reproducing, and mite numbers grow multiplicatively through the season, so a colony can carry a damaging load with no outward sign. By the time deformed wings, crawling bees or a shrinking population are visible, the mite population is near its seasonal peak and the bees that should have carried the colony through winter were already damaged during their development, months before the loss becomes apparent. Monitoring costs a few minutes and a half-cup of bees and converts a guess into a number that can be compared against a threshold and tracked across the season. Looking at a colony tells you how it appears today; a mite count tells you whether it will be alive at the end of winter.

Rationale: Delivering this argument clearly and without condescension is itself an examinable skill, since much of an experienced beekeeper's value to a local association lies in changing this specific habit in others.

References: Honey Bee Health Coalition, *Tools for Varroa Management*, 9th ed.; Cooperative Extension apiculture publications, southeastern US.

Section 15: Pesticides & Environmental Hazards (Q275–287)

Part A — Questions

275. (MC) Honey bees are exposed to pesticides through which combination of routes?

- **A)** Direct contact with spray droplets alone, which is why closing colonies during an application is sufficient to protect them from any exposure that might otherwise occur
- **B)** Contaminated honey purchased from other beekeepers and fed back to colonies, which is the principal route by which agricultural residues enter managed hives
- **C)** Soil contact beneath the hive stand, since residues accumulate in the ground under an apiary and are taken up by bees walking on the bottom board and the landing area
- **D)** Contact with spray or drift, residues on foliage and flowers, contaminated nectar and pollen brought home, contaminated water including guttation, and planting dust

276. (SA) Distinguish acute from sublethal pesticide effects and give two examples of each, then explain why the distinction complicates diagnosis.

277. (MC) Neonicotinoid insecticides are of particular concern for pollinators because:

- **A)** They are toxic only to social wasps and not to bees, so their presence in a landscape is a concern for the beekeeper only where wasp control affects hive defense
- **B)** They are systemic, so they are taken up by the plant and can appear in nectar, pollen and guttation fluid, and can be released as abraded seed-coating dust at planting
- **C)** They cannot be detected by any available analytical method, so residues in pollen and wax cannot be quantified and exposure cannot be established after an incident
- **D)** They break down within minutes of application and therefore require repeated treatment, which multiplies the number of exposure events a colony experiences in a season

278. (TF) Certain fungicides, though of low direct toxicity to bees, can substantially increase the toxicity of some insecticides and in-hive miticides through effects on the enzyme systems bees use to detoxify those compounds.

True / False

279. (SA) Describe the correct procedure on discovering a suspected pesticide kill, and explain why timing is critical.

280. (MC) Symptoms suggesting acute poisoning by an acetylcholinesterase-inhibiting insecticide include:

- **A)** Large numbers of dead and dying bees at the entrance, many with extended proboscises, together with tremors, disorientation and paralysis preceding death
- **B)** Ropy larval remains under sunken and perforated cappings with a glue-pot odor, together with dark scales adhering firmly to the lower walls of the affected cells
- **C)** Chalky white and grey mummified larvae accumulating at the hive entrance and on the bottom board, most conspicuous in colonies kept in damp and heavily shaded sites

- **D)** Bees emerging with shrivelled wings and shortened abdomens, crawling at the entrance and unable to fly, together with a spotty and irregular sealed brood pattern

281. (MC) The most appropriate advice to a grower planning an insecticide application near an apiary is to:

- **A)** Take no precautions provided the product is registered for that crop, since registration establishes that the compound is safe for use wherever the crop is grown
- **B)** Apply at a higher rate than the label specifies so that fewer applications are needed, reducing the total number of occasions on which bees are exposed to the product
- **C)** Apply at midday when bees are most active, so that the material is carried away from the crop by foraging bees and dissipates before the following morning
- **D)** Follow label pollinator statements, apply at night, choose lower-toxicity products, avoid drift onto margins and water, disclose tank mixes, and notify the beekeeper

282. (SA) Explain why residues detected in wax, pollen or honey must be interpreted with reference to both concentration and toxicity, and name the concept used to combine them.

283. (TF) Miticides applied by the beekeeper are themselves pesticides, and their residues are commonly found in beeswax, which recycles into commercial foundation and is one reason for comb rotation and for strict adherence to label doses.

True / False

284. (MC) If colonies must be protected during a nearby daytime application, the safest approach is to:

- **A)** Spray the hive entrances continuously with water during the application, which both cools the colony and washes away any material settling on the landing board
- **B)** Cover the hives with plastic sheeting, which excludes drift while allowing the colony to remain in place and to resume foraging as soon as the covering is removed
- **C)** Move them out of the area if practical; otherwise confine for the shortest possible period with full ventilation and water, preferring cool conditions
- **D)** Seal the hives completely until the following day, so that no bee can leave the colony and the entire population is protected from any contact with the application

285. (MC) Mosquito control programs are a recurring concern in parts of the southeastern US. The most effective protective step a beekeeper can take is to:

- **A)** Move colonies indoors permanently for the duration of the mosquito season, which is the only reliable means of avoiding exposure in districts with active programs
- **B)** Assume that no risk exists, since mosquito adulticides are applied at rates far below those affecting bees and are formulated specifically to spare non-target insects
- **C)** Apply a protective coating to the hive exteriors before the spraying season begins, which prevents the deposition of adulticide on the surfaces bees walk across
- **D)** Register apiary locations with the relevant county or district program and any state or voluntary registry, learn the schedule and method, and maintain contact

286. (SA) Explain how apiary registration systems help protect colonies, and state two limitations.

287. (SA) A beekeeper suspects chronic pesticide exposure is causing gradual decline across an apiary near intensive agriculture. Explain why this is difficult to establish and what alternatives must be evaluated.

Part B — Answer Key: Section 15

275. (MC) Honey bees are exposed to pesticides through which combination of routes?

Answer: D) Contact with spray or drift, residues on foliage and flowers, contaminated nectar and pollen brought home, contaminated water including guttation, and planting dust

Rationale: The multiplicity of routes is why a beekeeper cannot protect colonies simply by closing them during an application. Contaminated pollen carried into the hive continues to expose nurse bees and brood for weeks after the application, and colonies foraging two or three miles away can be exposed to an application the beekeeper never saw and was never told about.

References: *Johansen & Mayer, Pollinator Protection: A Bee and Pesticide Handbook, Wicwas, 1990; US EPA pollinator risk assessment guidance.*

276. (SA) Distinguish acute from sublethal pesticide effects and give two examples of each, then explain why the distinction complicates diagnosis.

Model answer: Acute effects are rapid mortality following exposure: examples include piles of dead bees at the entrance following an application, and the sudden loss of a colony's foraging force leaving a hive populated only by young bees. Sublethal effects occur below lethal doses and impair function rather than killing outright: examples include impaired navigation and homing so that foragers fail to return, impaired learning and memory, reduced brood rearing, queen supersedure and reduced queen quality, and increased susceptibility to disease. The distinction complicates diagnosis because a colony can be seriously harmed with no dead bees to show for it, and because the resulting signs, poor build-up, spotty brood and queen problems, are non-specific and overlap with nutritional, mite and disease causes.

Rationale: The practical consequence is that chronic pesticide exposure is far harder to establish than an acute kill, and that a beekeeper should investigate the alternatives rather than defaulting to a pesticide explanation.

References: *Desneux, Decourtye & Delpuech, Annu. Rev. Entomol. 52:81-106 (2007); Henry et al., Science 336:348-350 (2012).*

277. (MC) Neonicotinoid insecticides are of particular concern for pollinators because:

Answer: B) They are systemic, so they are taken up by the plant and can appear in nectar, pollen and guttation fluid, and can be released as abraded seed-coating dust at planting

Rationale: Systemic activity changes the exposure pattern relative to a contact insecticide, because the residue is inside the plant tissue the bee consumes rather than on the surface, so timing an application away from bee flight does not eliminate exposure. Acute toxicity to honey bees is high for imidacloprid, clothianidin, thiamethoxam and dinotefuran but far lower for acetamiprid and thiacloprid, and both

acute and sublethal effects are documented, although the magnitude of field-realistic effects remains a subject of active study and debate.

References: *Blacquiere, Smagghe, van Gestel & Mommaerts, Ecotoxicology 21:973-992 (2012); Krupke, Hunt, Eitzer, Andino & Given, PLoS ONE 7:e29268 (2012).*

278. (TF) Certain fungicides, though of low direct toxicity to bees, can substantially increase the toxicity of some insecticides and in-hive miticides through effects on the enzyme systems bees use to detoxify those compounds.

Answer: True

Rationale: This is why a beekeeper discussing a spray program with a grower should ask about everything being applied, including fungicides and adjuvants, rather than only the insecticide, and why bloom-time fungicide applications on crops such as blueberries and cucurbits are a legitimate topic of conversation. It also bears on the beekeeper's own practice, since colonies exposed to agricultural fungicides may be more sensitive to in-hive treatments.

References: *Johnson, Dahlgren, Siegfried & Ellis, PLoS ONE 8:e54092 (2013); Johnson, Ellis, Mullin & Frazier, Apidologie 41:312-331 (2010).*

279. (SA) Describe the correct procedure on discovering a suspected pesticide kill, and explain why timing is critical.

Model answer: Act quickly. Photograph the scene, including any accumulation of dead bees, and record the date, time, weather and observations. Collect a substantial sample of freshly dead bees, ideally several hundred per hive from multiple affected colonies, taken from the ground in front of the hives and from the bottom boards, place them in clean containers as the receiving laboratory directs, and freeze them immediately. Collect samples of pollen or beebread and of suspect plant material where relevant. Determine what was applied nearby and when if that information is available. Notify the state apiary inspector and the state lead pesticide agency, usually the department of agriculture, and follow their chain-of-custody instructions rather than sending samples independently. Timing is critical because many insecticides degrade rapidly in dead bees and in the environment, so a sample taken days later may show no detectable residue even where exposure clearly occurred.

Rationale: The two most common failures are delay and non-reporting, the second of which forecloses any formal determination or remedy.

References: *US EPA and state lead agency pesticide incident investigation procedures; Johansen & Mayer, Pollinator Protection: A Bee and Pesticide Handbook, Wicwas, 1990.*

280. (MC) Symptoms suggesting acute poisoning by an acetylcholinesterase-inhibiting insecticide include:

Answer: A) Large numbers of dead and dying bees at the entrance, many with extended proboscises, together with tremors, disorientation and paralysis preceding death

Rationale: The tongue-out posture with tremors and rapid mass mortality is the classic picture of organophosphate or carbamate poisoning. It is suggestive rather than conclusive, since chronic bee paralysis virus and certain bacterial infections of the hemolymph produce superficially similar adult mortality, so the field impression should prompt sample collection and formal investigation rather than a firm conclusion.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Johansen & Mayer, Pollinator Protection: A Bee and Pesticide Handbook, Wicwas, 1990.*

281. (MC) The most appropriate advice to a grower planning an insecticide application near an apiary is to:

Answer: D) Follow label pollinator statements, apply at night, choose lower-toxicity products, avoid drift onto margins and water, disclose tank mixes, and notify the beekeeper

Rationale: Timing, product and formulation selection, drift management and communication together form the standard risk mitigation package, and the mandatory pollinator-protection statements in a label's Directions for Use are legally binding (the Bee Advisory Box itself is advisory). Advance notice matters because moving colonies is far safer than confining them in the heat of the southeastern US, where a closed hive can overheat fatally within hours.

References: *US EPA pollinator protection labeling and the Bee Advisory Box; Delaplane & Mayer, Crop Pollination by Bees, CABI, 2000.*

282. (SA) Explain why residues detected in wax, pollen or honey must be interpreted with reference to both concentration and toxicity, and name the concept used to combine them.

Model answer: A detection reports only that a compound is present above the analytical limit; it says nothing about hazard, because compounds differ in toxicity by orders of magnitude and modern analytical methods detect vanishingly small quantities. Interpretation requires comparing the measured concentration against a toxicological reference point for that compound, such as an LD50 or a chronic no-effect concentration, to express the finding as a proportion of a harmful dose. The concept that combines the two is the hazard quotient, calculated as residue concentration divided by the relevant toxicity endpoint, and summed across compounds where appropriate to estimate total hazard for a sample.

Rationale: The lesson for a beekeeper is to resist both errors: dismissing detections as meaningless, and treating any detection as proof of harm. Large residue surveys have shown that the most frequently detected compounds are not always those contributing most to hazard.

References: *Mullin et al., PLoS ONE 5:e9754 (2010); Stoner & Eitzer, PLoS ONE 8:e77550 (2013).*

283. (TF) Miticides applied by the beekeeper are themselves pesticides, and their residues are commonly found in beeswax, which recycles into commercial foundation and is one reason for comb rotation and for strict adherence to label doses.

Answer: True

Rationale: Surveys of United States wax have found miticide residues among the most frequently detected and most concentrated contaminants. Because commercial foundation is manufactured from pooled recycled wax, residues circulate through the supply chain beyond the operation that applied them. Sublethal effects on queens and drones at comb-relevant concentrations have been reported, which is particularly relevant to queen producers, and the practical responses are comb culling and, where it matters most, use of cappings-derived or residue-tested foundation.

References: Mullin *et al.*, *PLoS ONE* 5:e9754 (2010); Collins, Pettis, Wilbanks & Feldlaufer, *J. Apic. Res.* 43:128-134 (2004).

284. (MC) If colonies must be protected during a nearby daytime application, the safest approach is to:

Answer: C) Move them out of the area if practical; otherwise confine for the shortest possible period with full ventilation and water, preferring cool conditions

Rationale: Confinement is a last resort with real hazards, and plastic sheeting in summer sun is lethal. Overheating kills colonies faster than most pesticide exposures. Moving colonies, or negotiating with the applicator for a night application, is almost always preferable, which is why advance notification is the term that matters most in any agreement with a grower.

References: Johansen & Mayer, *Pollinator Protection: A Bee and Pesticide Handbook*, Wicwas, 1990; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

285. (MC) Mosquito control programs are a recurring concern in parts of the southeastern US. The most effective protective step a beekeeper can take is to:

Answer: D) Register apiary locations with the relevant county or district program and any state or voluntary registry, learn the schedule and method, and maintain contact

Rationale: Most mosquito adulticiding is conducted at night specifically because target insects are active then and non-target pollinators are not, which greatly reduces risk. Problems arise with daytime applications, with aerial applications after storms and flooding, and where a program does not know an apiary is present. Registration plus a working relationship is the practical protection.

References: *US EPA Managed Pollinator Protection Plan guidance; Cooperative Extension mosquito control and pollinator publications, southeastern US.*

286. (SA) Explain how apiary registration systems help protect colonies, and state two limitations.

Model answer: Registration places apiary locations in a database that growers, applicators and public spray programs consult before an application, so they know bees are present and can adjust timing, product choice or buffer distances, or notify the beekeeper directly. Systems include state apiary registration where it is required, county or district mosquito control notification lists, and voluntary online mapping registries used by applicators to identify sensitive sites. Limitations: participation by both beekeepers and applicators is voluntary in many jurisdictions, so coverage is incomplete and an unregistered neighbor's apiary may be missed; and registration does not change label requirements or compel any particular practice, so it works only through communication and goodwill. A registration is also useless if the contact information is stale or if the beekeeper does not respond when notified.

Rationale: Registration therefore complements rather than replaces direct communication with immediate neighbors and growers.

References: *US EPA Managed Pollinator Protection Plan guidance; state department of agriculture apiary registration programs.*

287. (SA) A beekeeper suspects chronic pesticide exposure is causing gradual decline across an apiary near intensive agriculture. Explain why this is difficult to establish and what alternatives must be evaluated.

Model answer: Chronic exposure produces no discrete event to date or sample, residues degrade, and the resulting effects, poor build-up, spotty brood, elevated supersedure and reduced longevity, are non-specific. Establishing causation would require residue analysis of beebread and wax interpreted quantitatively against toxicity benchmarks rather than as simple presence or absence, together with systematic exclusion of alternatives and ideally a comparison against colonies moved to a contrasting location. The alternatives that must be evaluated seriously are Varroa and virus load, Vairimorpha (Nosema), queen quality and queen events, nutritional stress from a landscape offering narrow and seasonally exhausted forage, and management factors including treatment timing and comb age.

Rationale: The honest position is that a beekeeper can document exposure and can rule alternatives in or out, but should not assert causation from a pattern alone. Overstating such a case weakens the credibility of beekeepers in pesticide discussions generally.

References: *Mullin et al., PLoS ONE 5:e9754 (2010); Traynor et al., Sci. Rep. 6:33207 (2016); Desneux, Decourtye & Delpuech, Annu. Rev. Entomol. 52:81-106 (2007).*

Section 16: Honey Chemistry, Production & Food Safety (Q288–308)

Part A — Questions

288. (MC) The principal sugars in honey are:

- **A)** Sucrose and maltose together making up about 80 percent, with glucose and fructose present only in traces produced during the final stages of ripening in the comb
- **B)** Fructose and glucose making up roughly 70 percent, fructose generally exceeding glucose, with small amounts of sucrose and other sugars and about 17 to 20 percent water
- **C)** Starch and cellulose derived from the pollen incorporated during nectar processing, which accounts for the viscosity of honey and for its tendency to granulate
- **D)** Lactose and galactose, derived from the glandular secretions bees add during ripening, together with the water content that determines the honey's keeping quality

289. (SA) State the maximum moisture content for extracted honey under United States grade standards, the level below which fermentation is generally prevented, and explain why the two figures differ.

290. (MC) A honey refractometer must be read at, or corrected to, its calibration temperature because:

- **A)** Temperature affects only the color of the sample as seen through the prism, so a warm sample reads darker and can be mistaken for a honey of a different grade
- **B)** Honey changes composition with temperature as sucrose continues to invert, so a warm sample genuinely contains different sugars from the same sample when cool
- **C)** The refractive index of honey varies with temperature, so a reading taken warmer or cooler than calibration will misstate moisture unless corrected or equilibrated
- **D)** The instrument's glass and metal components expand at different rates, so readings taken outside the calibration range damage the prism and void the calibration

291. (SA) Explain what hydroxymethylfurfural indicates in honey, name one other heat-sensitive quality indicator, and describe how both should influence honey house practice.

292. (MC) Honey resists microbial spoilage principally because of:

- **A)** Antibiotic compounds secreted by the bees into the nectar during ripening, which persist in the finished honey and account for its keeping quality in storage
- **B)** Sterilization by the heat of the brood nest during ripening, which raises the honey above the temperature at which yeasts and bacteria survive in the finished product
- **C)** Low water activity from high sugar concentration, a pH generally around 3.2 to 4.5, and hydrogen peroxide from bee-derived glucose oxidase acting on glucose when diluted
- **D)** A high concentration of ethanol produced by yeasts during ripening in the comb, which is why honey of higher moisture content is in fact more resistant to spoilage

293. (MC) The advisory that honey should not be fed to infants under twelve months of age exists because:

- **A)** Infants are commonly allergic to the pollen naturally present in honey, and early exposure sensitizes them to the pollens of the region for the rest of their lives
- **B)** Honey may contain *Clostridium botulinum* spores, which can germinate in the immature infant gut and produce toxin, while being harmless to older children and adults
- **C)** Honey contains hydroxymethylfurfural at concentrations that are harmless to adults but that exceed the tolerance established for infants under twelve months of age
- **D)** Honey contains too much concentrated sugar for an infant's digestive system, which cannot process the fructose load and responds with diarrhoea and dehydration

294. (SA) Describe how creamed honey is produced and explain why the finished product may still be labeled simply as honey.

295. (TF) Ordinary straining and ultrafiltration are equivalent processes differing only in scale, and both retain the pollen that allows the geographic origin of a honey to be determined.

True / False

296. (MC) Honey color is graded commercially on a scale running:

- **A)** From grade A through grade F, assigned on the combined basis of color, clarity, flavor and moisture, with the letter grade appearing on the retail label of the product
- **B)** By measuring electrical conductivity, which rises with the mineral content responsible for darker color and so provides an instrumental substitute for visual grading
- **C)** From Water White through Extra White, White, Extra Light Amber, Light Amber, Amber to Dark Amber, measured with a Pfund grader or an equivalent optical comparator
- **D)** By counting pollen grains per gram, since darker honeys carry more pollen and the count therefore provides an objective and reproducible measure of the color grade

297. (SA) Explain how honey granulation is controlled by composition and storage, and state the practical implications for a producer.

298. (MC) Adulteration of honey with cane or corn syrup can be detected by stable carbon isotope ratio analysis because:

- **A)** The method detects added water rather than added sugar, since commercial syrups carry more moisture than honey and raise the finished product's water content
- **B)** The method counts pollen grains and compares the count with the sugar content, since an adulterated honey contains less pollen per unit of sugar than a pure one
- **C)** Those syrups contain no carbon of biological origin, having been produced by chemical synthesis, so their presence is detectable as a dilution of the natural isotopic signal
- **D)** Sugarcane and corn use the C4 pathway and are isotopically distinguishable from the C3 plants producing most nectar, and the honey's own protein serves as internal standard

299. (MC) United States labels for honey sold at retail must generally include:

- **A)** The name of the beekeeper and the location of the apiary, so that the product can be traced to its source in the event of a complaint or a recall being necessary
- **B)** The floral source of the nectar and the season of harvest, which together constitute the statement of identity required for any honey offered for retail sale

- **C)** Statement of identity, net quantity, name and place of business of the manufacturer or packer, country of origin for imports, and nutrition labeling unless exempt
- **D)** The word honey alone, since the product is a single-ingredient food and no further declaration is required of a producer selling directly to consumers

300. (TF) A product consisting of honey to which any sweetener has been added is not honey under FDA labeling guidance and must be labeled as a blend with an accurate ingredient statement.

True / False

301. (SA) A batch of extracted honey tests at 19.5 percent moisture. State the risk and describe two acceptable remedies and two unacceptable ones.

302. (MC) Which method of clearing bees from honey supers is gentlest on both colony and crop?

- **A)** A chemical fume board used at maximum strength in the heat of the day, which clears supers in minutes and is therefore the least disruptive method for the colony
- **B)** Shaking every frame in front of the hive entrance, which returns the bees directly to their own colony and avoids the drifting that other methods can cause
- **C)** Directing compressed air down through the brood nest and out the entrance, which drives the bees from the supers without the delay a clearer board requires
- **D)** A bee escape board placed beneath the supers a day or two before removal, allowing bees to move down and not return, working best when nights are cool enough

303. (SA) Identify the hazards a honey house food safety plan should control, and explain why lot coding matters.

304. (MC) Comb honey production differs from extracted honey production principally in that it requires:

- **A)** Honey of higher moisture content than extracted honey, since the wax capping protects the contents and the additional moisture improves the eating quality
- **B)** New white comb drawn from clean foundation during a strong flow, removed promptly once capped so the wax is not travel-stained, with attention to wax residue status
- **C)** A larger extractor than is needed for extracted honey, since the sections must be spun gently to remove any uncapped nectar before they are packaged for sale
- **D)** Old dark brood comb for structural strength, since new comb is too fragile to survive handling and packaging and will collapse in the section during transport

305. (TF) Honey is hygroscopic only above about 25 percent moisture, so finished honey below the grade maximum can safely be held in open or loosely covered containers even in humid conditions.

True / False

306. (MC) A claim on a honey label that the product treats or prevents a medical condition is:

- **A)** Regulated; an unauthorized disease claim can render the product an unapproved drug and the label misbranded, so claims must be limited to those permitted
- **B)** Permitted for any product sold directly by the producer to the consumer, since the regulations governing health claims apply only to interstate commerce

- **C)** Permitted provided the word natural appears alongside the claim, which signals to the consumer that the statement is descriptive rather than therapeutic
- **D)** Required by law for honey offered at retail, since the consumer must be informed of the recognized properties of the product before making a purchase

307. (SA) Explain what wet supers are, how they should be handled after extraction, and why open placement in the apiary is discouraged in the southeastern US.

308. (MC) The United States Standards for Grades of Extracted Honey are:

- **A)** Mandatory requirements that all honey offered for sale must meet, enforced by the state departments of agriculture through routine inspection of retail premises
- **B)** Voluntary standards used in trade and quality description, based on moisture, flavor and aroma, absence of defects and clarity, alongside mandatory food safety law
- **C)** International treaty obligations binding on all exporting countries, which is why imported honey carries the same grade designations as domestically produced honey
- **D)** Standards regulating pesticide residues in honey, establishing the maximum concentrations of miticides and agricultural chemicals permitted in the finished product

Part B — Answer Key: Section 16

288. (MC) The principal sugars in honey are:

Answer: B) Fructose and glucose making up roughly 70 percent, fructose generally exceeding glucose, with small amounts of sucrose and other sugars and about 17 to 20 percent water

Rationale: The fructose-to-glucose ratio is the practically important figure, because glucose is the sugar that crystallizes: honeys with a higher glucose fraction granulate quickly and those with a higher fructose fraction remain liquid. Sucrose content is normally low because bee invertase hydrolyzes it during ripening, which is why an elevated sucrose level can indicate immature honey or adulteration.

References: *White, in Crane (ed.), Honey: A Comprehensive Survey, Heinemann, 1975; Bogdanov, Honey Composition, Bee Product Science.*

289. (SA) State the maximum moisture content for extracted honey under United States grade standards, the level below which fermentation is generally prevented, and explain why the two figures differ.

Model answer: United States grade standards set a maximum of 18.6 percent moisture for Grade A honey (the more permissive Grade C allows up to 20 percent); the Codex Alimentarius general standard separately sets 20 percent. Fermentation by osmophilic yeasts is generally prevented below about 17 to 17.5 percent, with risk rising steeply above roughly 18 to 19 percent, which is why the Grade A ceiling of 18.6 percent tracks the fermentation threshold far more closely than the looser 20 percent figures do. The figures differ because the grade maximum is a commercial and regulatory limit reflecting what is acceptable in trade, whereas the fermentation threshold is a microbiological one determined by water activity and by the yeast population present. Honey can therefore comply with a looser grade standard, such as Grade C or the general Codex limit, and still ferment, particularly if it carries a high yeast load or if partial granulation raises the moisture of the remaining liquid phase.

Rationale: That last mechanism explains the common experience of a jar that tested acceptable at bottling and ferments later after beginning to granulate.

References: *USDA AMS United States Standards for Grades of Extracted Honey (1985); Codex Alimentarius Standard for Honey CXS 12-1981; White, in Crane (ed.), Honey: A Comprehensive Survey, Heinemann, 1975.*

290. (MC) A honey refractometer must be read at, or corrected to, its calibration temperature because:

Answer: C) The refractive index of honey varies with temperature, so a reading taken warmer or cooler than calibration will misstate moisture unless corrected or equilibrated

Rationale: This is a routine source of error, particularly in a hot honey house where samples are warm and the instrument is not. The practical procedure is to let sample and instrument reach a common, known temperature, to calibrate the instrument regularly against the supplied standard, and to test individual supers or tanks rather than a single composite, since one wet super can raise an entire tank above specification.

References: *Bogdanov, Harmonised Methods of the International Honey Commission, 2009; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

291. (SA) Explain what hydroxymethylfurfural indicates in honey, name one other heat-sensitive quality indicator, and describe how both should influence honey house practice.

Model answer: Hydroxymethylfurfural is essentially absent from fresh honey and accumulates with heating and with prolonged or warm storage, and is also elevated by adulteration with certain invert syrups, so an elevated value indicates heat abuse, age or adulteration. Diastase activity, an enzyme added by the bee, is the other standard indicator: it declines with heat and with storage, so a low diastase number points the same way. Because both respond to time and temperature together, honey house practice should limit warming to the lowest temperature and shortest duration necessary, commonly no higher than about 100 to 110 degrees F for bottling, avoid repeated heating cycles, and store finished honey cool and sealed with stock rotated on a first-in first-out basis.

Rationale: The two are used together in standards because diastase can be naturally low in some honeys of particular floral origin even when fresh, so a paired assessment is more reliable than either alone.

References: *Codex Alimentarius Standard for Honey CXS 12-1981; White, J. Assoc. Off. Anal. Chem. 62:509-514 (1979).*

292. (MC) Honey resists microbial spoilage principally because of:

Answer: C) Low water activity from high sugar concentration, a pH generally around 3.2 to 4.5, and hydrogen peroxide from bee-derived glucose oxidase acting on glucose when diluted

Rationale: Of the three, low water activity and low pH protect sealed honey in storage; glucose oxidase is inhibited in undiluted honey and produces peroxide only when honey is diluted (as in wound care), so peroxide does not account for the keeping quality of the jar. Honey is not sterile, however. Osmophilic

yeasts tolerant of high sugar concentrations survive and will ferment honey if the moisture is high enough, and bacterial spores including those of *Clostridium botulinum* survive dormant even though they cannot grow. These two exceptions correspond exactly to the two practical food safety issues in honey: fermentation, controlled by moisture, and the infant feeding advisory.

References: *Molan, Bee World 73:5-28 (1992); White, in Crane (ed.), Honey: A Comprehensive Survey, Heinemann, 1975.*

293. (MC) The advisory that honey should not be fed to infants under twelve months of age exists because:

Answer: B) Honey may contain *Clostridium botulinum* spores, which can germinate in the immature infant gut and produce toxin, while being harmless to older children and adults

Rationale: The mechanism is colonization rather than preformed toxin, which distinguishes infant botulism from foodborne botulism. Because the spores are environmental and cannot be excluded by any practical processing, and because heating sufficient to destroy them would ruin the product, the advisory is standard. A producer selling honey should be able to explain it accurately rather than dismissing it, and should check whether the statement is required on labels in their state.

References: *Arnon et al., J. Pediatr. 94:331-336 (1979); US FDA and CDC guidance on infant botulism.*

294. (SA) Describe how creamed honey is produced and explain why the finished product may still be labeled simply as honey.

Model answer: Liquid honey is seeded with roughly 5 to 10 percent of finely ground granulated honey, mixed thoroughly without incorporating air, and held at a temperature near 57 degrees F for one to two weeks. The abundant fine seed crystals combined with the temperature at which crystal growth proceeds fastest cause the honey to granulate rapidly with a very fine crystal size, giving a smooth, spreadable texture rather than the coarse crystals of natural granulation. It may still be labeled simply as honey because nothing has been added: the seed is itself honey, and the process changes only the physical form.

Rationale: The technique is particularly useful for honeys that granulate rapidly anyway, converting what customers perceive as a defect into a premium product, and it is a practical option for a producer whose local crop is glucose-rich.

References: *Dyce, US Patent 1,987,893 (1935); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

295. (TF) Ordinary straining and ultrafiltration are equivalent processes differing only in scale, and both retain the pollen that allows the geographic origin of a honey to be determined.

Answer: False

Rationale: They are treated quite differently. Ordinary straining and settling remove wax and debris while retaining the pollen naturally present, and are normal practice. Ultrafiltration under pressure removes the pollen, which destroys the principal means of establishing geographic origin, and is why

ultrafiltered honey features in customs and Justice Department enforcement against transshipped honey of disguised origin. The USDA grade standards likewise distinguish strained from filtered honey. The FDA's 2018 labeling guidance does not address filtration or ultrafiltration; the concern arises in customs and country-of-origin enforcement.

References: *USDA AMS United States Standards for Grades of Extracted Honey (1985); Codex Alimentarius Standard for Honey CXS 12-1981.*

296. (MC) Honey color is graded commercially on a scale running:

Answer: C) From Water White through Extra White, White, Extra Light Amber, Light Amber, Amber to Dark Amber, measured with a Pfund grader or an equivalent optical comparator

Rationale: Color correlates loosely with flavor intensity and floral source and strongly affects price, with light honeys generally preferred for table use. It is not a measure of purity or freshness, and honey darkens with heating and with storage, so a dark honey may be a fine dark varietal or a mishandled light one. In the southeastern US, sourwood and tupelo are prized light honeys while tulip poplar is characteristically dark.

References: *USDA AMS United States Standards for Grades of Extracted Honey (1985); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

297. (SA) Explain how honey granulation is controlled by composition and storage, and state the practical implications for a producer.

Model answer: Granulation is driven chiefly by the ratio of glucose to water and of glucose to fructose, since glucose is the sugar that crystallizes, so glucose-rich honeys granulate quickly and fructose-rich honeys remain liquid. Nucleation sites such as pollen grains and fine wax fragments accelerate the onset, which is why very finely filtered honey stays liquid longer and why seeding is used deliberately in creamed honey production. Storage temperature governs the rate, which is fastest near 57 degrees F and slower both above and well below that; freezing effectively halts it. Practical implications: fast-granulating honeys should be extracted and bottled promptly and are good candidates for creamed honey; slow-granulating honeys command a premium as a liquid product; and finished honey should be kept either above about 77 degrees F (accepting some HMF accumulation) or frozen at 0 to 10 degrees F, since both the roughly 57 degrees F peak and refrigerator temperatures promote granulation, and always sealed against moisture uptake.

Rationale: Customers frequently believe granulation indicates spoilage or adulteration, so explaining it is part of selling honey.

References: *White, in Crane (ed.), Honey: A Comprehensive Survey, Heinemann, 1975; Bogdanov, Honey Composition, Bee Product Science.*

298. (MC) Adulteration of honey with cane or corn syrup can be detected by stable carbon isotope ratio analysis because:

Answer: D) Sugarcane and corn use the C4 pathway and are isotopically distinguishable from the C3 plants producing most nectar, and the honey's own protein serves as internal standard

Rationale: The internal protein standard is the ingenious element, since it controls for natural isotopic variation among honeys by comparing the sample against material originating in the same honey. The method's limitation is equally examinable: it does not detect adulteration with C3-derived syrups such as beet or rice syrup, which is why additional techniques including profiling methods and marker analyses are now used alongside it.

References: AOAC Official Method 998.12; White & Winters, J. Assoc. Off. Anal. Chem. 72:907-911 (1989).

299. (MC) United States labels for honey sold at retail must generally include:

Answer: C) Statement of identity, net quantity, name and place of business of the manufacturer or packer, country of origin for imports, and nutrition labeling unless exempt

Rationale: Small producers frequently overlook net weight statements, required placement and type size, and the requirement to give a business address. Some small businesses are exempt from nutrition labeling, but exemptions have conditions. State cottage food rules and weights-and-measures requirements add further elements, so both federal and state rules should be checked before labels are printed.

References: US FDA Guidance for Industry: Proper Labeling of Honey and Honey Products (2018); 21 CFR part 101.

300. (TF) A product consisting of honey to which any sweetener has been added is not honey under FDA labeling guidance and must be labeled as a blend with an accurate ingredient statement.

Answer: True

Rationale: Honey is the natural product produced by bees from nectar; adding anything makes it something else. This applies as much to a small producer topping up a batch as to large-scale adulteration, and the same logic prohibits selling honey that contains sugar syrup stored by colonies fed while supers were in place. Misbranding is a legal matter independent of any grade standard.

References: US FDA Guidance for Industry: Proper Labeling of Honey and Honey Products (2018); 21 U.S.C. 343.

301. (SA) A batch of extracted honey tests at 19.5 percent moisture. State the risk and describe two acceptable remedies and two unacceptable ones.

Model answer: The batch fails the Grade A maximum (18.6 percent) but is within the more permissive Grade C and general Codex maxima (20 percent); either way, it is above the level at which fermentation is reliably prevented, so if bottled and stored it may ferment, producing foam, a sour or alcoholic odor and an unsalable product. Acceptable remedies: reduce the moisture by exposing the honey to warm dry moving air, for example in a warm room with a dehumidifier and fans, or by drying supers before extraction, at a temperature low enough to avoid heat damage; or blend with a drier batch to bring the combined moisture below target, retesting before bottling. Unacceptable: adding anything to the honey, and bottling and selling it as is in the hope that it will not ferment.

Rationale: The better answer starts earlier: harvest only well-capped frames, set aside uncapped combs for the bees to finish, and test individual supers or tanks rather than a composite, since one wet super can raise an entire tank above specification.

References: *Bogdanov, Harmonised Methods of the International Honey Commission, 2009; White, in Crane (ed.), Honey: A Comprehensive Survey, Heinemann, 1975.*

302. (MC) Which method of clearing bees from honey supers is gentlest on both colony and crop?

Answer: D) A bee escape board placed beneath the supers a day or two before removal, allowing bees to move down and not return, working best when nights are cool enough

Rationale: Escape boards are slow but gentle and use no chemicals. Fume boards are faster and suit larger operations but must be used per label and can taint honey if overused in high heat, a real risk in regional summers. Bee blowers are effective and chemical-free but noisy and disruptive. The choice depends on scale, weather and the number of supers, and in this region the additional constraint is that supers once cleared must be extracted promptly.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Sammataro & Avitabile, The Beekeeper's Handbook, 5th ed., Cornell Univ. Press, 2021.*

303. (SA) Identify the hazards a honey house food safety plan should control, and explain why lot coding matters.

Model answer: Physical hazards such as glass, metal fragments and foreign material; chemical hazards such as cleaning agents, lubricants and pesticide residues; microbiological and quality hazards, principally moisture control to prevent fermentation; and process control of temperature and holding time to limit heat damage. Sanitation, pest exclusion and personnel hygiene support all of these. Lot coding matters because it makes a proportionate response possible if a defect is found: a single tank or day's production can be identified, held or recalled, whereas without coding a problem in one batch puts an entire season's output in question and offers no way to trace which customers received it.

Rationale: In the southeastern US the food safety plan must also address beetle and pest exclusion in the building, since infested comb and cappings are both a quality and a sanitation problem.

References: *US FDA Preventive Controls for Human Food rule (21 CFR 117); Codex General Principles of Food Hygiene.*

304. (MC) Comb honey production differs from extracted honey production principally in that it requires:

Answer: B) New white comb drawn from clean foundation during a strong flow, removed promptly once capped so the wax is not travel-stained, with attention to wax residue status

Rationale: Because the wax is part of the product, foundation carrying miticide residues is unacceptable and old comb cannot be used. Appearance is a large part of the value, so uneven capping, incomplete filling and travel staining all downgrade the product. Comb honey suits a strong colony forced into restricted space during a reliable heavy flow, which in the region generally means the main spring flow.

References: Killion, C.E., *Honey in the Comb*, 1951 (rev. ed. with E. Killion, Dadant, 1981); Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

305. (TF) Honey is hygroscopic only above about 25 percent moisture, so finished honey below the grade maximum can safely be held in open or loosely covered containers even in humid conditions.

Answer: False

Rationale: Honey absorbs moisture from humid air at its normal moisture content, not only at some elevated threshold. Open tanks, loosely covered buckets and partly filled containers all allow uptake sufficient to push honey past the fermentation threshold, which is a particular hazard in the humid southeastern US. Sealed containers in cool storage address both the moisture problem and the separate degradation of enzymes and color.

References: White, in Crane (ed.), *Honey: A Comprehensive Survey*, Heinemann, 1975; Bogdanov, *Honey Composition*, *Bee Product Science*.

306. (MC) A claim on a honey label that the product treats or prevents a medical condition is:

Answer: A) Regulated; an unauthorized disease claim can render the product an unapproved drug and the label misbranded, so claims must be limited to those permitted

Rationale: Disease claims convert a food into a drug in regulatory terms, and enforcement actions against honey and hive product sellers for such claims are well documented. Implied claims through imagery, testimonials or website copy count as well as explicit statements on the jar. The safe course is to describe the product accurately and let quality and provenance do the selling.

References: 21 U.S.C. 321(g) and 343(r); US FDA warning letters concerning honey and bee product health claims.

307. (SA) Explain what wet supers are, how they should be handled after extraction, and why open placement in the apiary is discouraged in the southeastern US.

Model answer: Wet supers are supers of extracted comb still carrying a film of residual honey. They should be returned to colonies to be cleaned, either to the colonies they came from or placed above an inner cover on strong colonies, ideally late in the day, and then removed once dry and stored protected against wax moth and small hive beetle. Open placement in the apiary, where supers are simply set out for the bees to clean, is discouraged because during the regional dearth it reliably triggers apiary-wide robbing, and because it mixes bees from many colonies over shared comb, which spreads disease.

Rationale: Storing supers still wet is also a mistake, since residual honey and pollen sustain both wax moth and beetle larvae; comb should be stored dry and pest-tight, or frozen first.

References: Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.

308. (MC) The United States Standards for Grades of Extracted Honey are:

Answer: B) Voluntary standards used in trade and quality description, based on moisture, flavor and aroma, absence of defects and clarity, alongside mandatory food safety law

Rationale: The distinction is frequently misunderstood. A producer is not required to grade honey, but is required to label it truthfully and to produce it under sanitary conditions, and those obligations are not voluntary. Grade standards provide a common commercial vocabulary, which is useful in wholesale trade and in honey shows, where moisture, flavor, cleanliness and container presentation are scored.

References: *USDA AMS United States Standards for Grades of Extracted Honey (1985); US FDA labeling requirements.*

Section 17: Hive Products – Wax, Propolis, Pollen, Royal Jelly & Venom (Q309–320)

Part A – Questions

309. (MC) Beeswax is chemically characterized as:

- **A)** A protein-based secretion produced by the mandibular glands, which is why wax production and brood food production are performed by bees of the same age group
- **B)** A polysaccharide polymer secreted in solution and hardening on contact with air, which accounts for the pliability of new comb and its brittleness once it has aged
- **C)** A simple triglyceride mixture closely similar to rendered vegetable fat, which is why it can be substituted for by paraffin in foundation without detectable difference
- **D)** A complex mixture dominated by esters of long-chain fatty acids and alcohols, with hydrocarbons, free acids and alcohols, melting over roughly 144 to 149 degrees F

310. (SA) Describe two methods of rendering beeswax and list the errors that most commonly spoil the finished product.

311. (MC) Adulteration of beeswax with paraffin or stearin is detected principally by:

- **A)** Weighing a standard-sized block, since paraffin and stearin are appreciably less dense than beeswax and a diluted block therefore weighs measurably less
- **B)** Physicochemical indices including melting point, acid value, ester value and saponification value, supported by chromatographic analysis of the hydrocarbon profile
- **C)** Testing a molten sample with a refractometer, since the refractive index of beeswax is sharply distinct from that of the petroleum-derived adulterants used
- **D)** Color and odor assessed by an experienced grader, since adulterated wax is consistently paler and lacks the characteristic aroma of pure rendered cappings wax

312. (TF) Beeswax is lipophilic and accumulates miticide and pesticide residues, and because commercial foundation is manufactured from pooled recycled wax, residues can circulate from one beekeeper's operation into foundation used by others.

True / False

313. (SA) Estimate the honey cost of producing beeswax, explain why published figures vary widely, and state the management conclusion.

314. (MC) Propolis is best described as:

- **A)** A pheromone produced by the queen and deposited on the comb as she walks, which inhibits queen cell construction and is used by workers to seal small openings
- **B)** Plant resin from buds and wounds mixed with wax and glandular secretions, used to seal cracks, varnish surfaces, entomb intruders and provide antimicrobial protection
- **C)** A protein food produced by nurse bees and stored in the cells surrounding the brood nest, from which it is drawn during periods when incoming pollen is scarce
- **D)** A wax secreted from the abdominal glands and mixed with pollen, used to seal the cappings of honey cells and to strengthen the attachment of the comb to the frame above it

315. (SA) Explain how a propolis trap works and why the resulting product is superior to scraped propolis.

316. (MC) Pollen collected in a pollen trap must be handled promptly because:

- **A)** It becomes toxic to humans within about an hour of collection as the enzymes added by the bees begin to break down the pollen wall and release stored compounds
- **B)** It draws foraging bees back into the trap, where they become confused and die, so the trap must be emptied frequently to prevent losses to the colony's workforce
- **C)** It loses its color within minutes of collection through oxidation, and the faded product is unmarketable even though its nutritional value remains entirely unaffected
- **D)** It carries substantial moisture and a microbial load and will mold or ferment within hours in warm weather, so traps must be emptied daily and the pollen dried or frozen

317. (TF) Royal jelly is produced by the wax glands of nurse bees, is harvested commercially from worker cells rather than queen cells, and is stable at room temperature for extended periods.

True / False

318. (MC) Bee venom for commercial use is normally collected by:

- **A)** Presenting an electrically charged frame with a glass surface, which stimulates bees to sting the glass without losing their stings, the dried venom then scraped off
- **B)** Killing bees and dissecting out the venom sacs individually, which is why commercial venom is expensive and why collection is limited to colonies being culled anyway
- **C)** Extracting it from honey during processing, since traces of venom are deposited in the comb during colony defense and concentrate in the honey stored nearby
- **D)** Squeezing individual bees over a collecting dish so that venom is expressed from the sting without the bee being killed, after which the bee is returned to the colony

319. (SA) A beekeeper intends to sell beeswax cosmetics and candles. Set out the considerations to address before selling.

320. (MC) Which statement about hive products and colony treatment history is most accurate?

- **A)** Rendering and drying remove any residues present, which is why rendered wax and dried pollen are exempt from the residue considerations that apply to raw honey
- **B)** Treatment history affects honey but not the other hive products, since honey is the only product the colony processes internally and the only route for residues
- **C)** Wax, propolis and pollen concentrate lipophilic compounds far more than honey, so a producer should know the treatment history of every colony contributing to them
- **D)** No hive product can carry pesticide residues, because the bees metabolize any compound they encounter before it can be incorporated into a stored product

Part B — Answer Key: Section 17

309. (MC) Beeswax is chemically characterized as:

Answer: D) A complex mixture dominated by esters of long-chain fatty acids and alcohols, with hydrocarbons, free acids and alcohols, melting over roughly 144 to 149 degrees F

Rationale: The ester-dominated composition gives beeswax its characteristic acid, ester and saponification values, the ratios of which are used to detect adulteration with paraffin or stearin. The narrow melting range has two practical consequences: wax must never be melted over direct heat because it is flammable, and comb can collapse catastrophically in a closed vehicle during a summer move in the southeastern US.

References: *Tulloch, Bee World 61:47-62 (1980); Coggschall & Morse, Beeswax: Production, Harvesting, Processing and Products, Wicwas, 1984.*

310. (SA) Describe two methods of rendering beeswax and list the errors that most commonly spoil the finished product.

Model answer: Solar rendering uses a glazed insulated box that melts wax by direct sunlight into a collecting pan; it produces clean wax from cappings and light comb with no fuel cost and suits the regional climate, but leaves wax behind in the slumgum and depends on weather. Steam or hot-water rendering melts larger quantities, with the wax floating and solidifying as a cake above the water; it handles dark comb with better recovery. Common errors: overheating, which darkens and degrades the wax; using iron, copper or brass vessels, which discolor it, so stainless steel, aluminum or plastic should be used; inadequate filtering, which leaves slumgum and debris in the block; cooling too rapidly, which traps debris and water; and failing to scrape the dirty layer from the underside of the cooled cake.

Rationale: Cappings wax should be rendered separately from dark brood comb, since it is cleaner, lighter and carries substantially lower pesticide residues, and therefore commands the highest-value uses.

References: *Coggschall & Morse, Beeswax: Production, Harvesting, Processing and Products, Wicwas, 1984; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

311. (MC) Adulteration of beeswax with paraffin or stearin is detected principally by:

Answer: B) Physicochemical indices including melting point, acid value, ester value and saponification value, supported by chromatographic analysis of the hydrocarbon profile

Rationale: The classical indices work because the adulterants differ systematically from beeswax: paraffin contributes hydrocarbons with no ester or acid value, while stearin raises the acid value. The problem is practically important because adulterated foundation has been associated with comb failure and brood mortality, and because a beekeeper cannot detect it by inspection, which is a reason to buy foundation from reputable suppliers.

References: *Svečnjak et al., J. Apic. Res. 58:1-108 (2019); Bogdanov, Beeswax: Quality Issues Today, Bee Product Science.*

312. (TF) Beeswax is lipophilic and accumulates miticide and pesticide residues, and because commercial foundation is manufactured from pooled recycled wax, residues can circulate from one beekeeper's operation into foundation used by others.

Answer: True

Rationale: Surveys of United States wax have found miticide residues among the most frequent and most concentrated contaminants. Sublethal effects on queens and drones at comb-relevant concentrations have been reported, which matters particularly to queen producers, since contaminated comb in cell builders and mating nuclei can degrade the product without any obvious cause. The practical responses are regular comb culling, segregating cappings wax, and considering residue-tested or cappings-derived foundation where it matters most.

References: Mullin *et al.*, *PLoS ONE* 5:e9754 (2010); Wu, Anelli & Sheppard, *PLoS ONE* 6:e14720 (2011).

313. (SA) Estimate the honey cost of producing beeswax, explain why published figures vary widely, and state the management conclusion.

Model answer: Published estimates range from roughly six to eight pounds of honey per pound of wax at the low end to considerably higher figures, with older literature citing ratios as high as twenty to one. They vary because the figure depends on whether the metabolic cost of maintaining the wax-secreting bees at comb-building temperature is included, on colony temperature, age structure and nutritional state, and on the difficulty of measuring wax production directly in a working colony. The management conclusion is unaffected by the uncertainty: comb drawing is a real cost charged against the honey crop, so drawn comb is a capital asset that should be protected from wax moth, small hive beetle, mice and careless handling, and reused rather than discarded.

Rationale: A beekeeper entering spring with drawn comb has a substantial advantage over one starting on foundation, which is why comb protection during storage is worth genuine effort in a region where pests remain active most of the year.

References: Hepburn, *Honeybees and Wax*, Springer, 1986; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

314. (MC) Propolis is best described as:

Answer: B) Plant resin from buds and wounds mixed with wax and glandular secretions, used to seal cracks, varnish surfaces, entomb intruders and provide antimicrobial protection

Rationale: Because propolis derives from local plant resins, its chemistry varies by region and season, which matters to anyone marketing it, since no single specification describes propolis generally. Its documented contribution to colony health, including lower, more uniform baseline immune gene expression in colonies with a propolis envelope (Borba *et al.* 2015) and reduced bacterial loads with resin exposure (Simone *et al.* 2009), has shifted the modern view from nuisance to asset, and some beekeepers now encourage it with rough interior surfaces or collect it with traps.

References: Bankova, Castro & Marcucci, *Apidologie* 31:3-15 (2000); Simone, Evans & Spivak, *Evolution* 63:3016-3022 (2009); Borba *et al.*, *J. Exp. Biol.* 218:3689-3699 (2015).

315. (SA) Explain how a propolis trap works and why the resulting product is superior to scraped propolis.

Model answer: A propolis trap is a flexible plastic mesh or slotted screen placed above the brood nest under the cover, sometimes with a small gap admitting light. The bees respond to the openings as gaps

to be sealed and fill the mesh with propolis. The trap is then removed and chilled or frozen so that the propolis becomes brittle and can be flexed out cleanly in small pieces. The product is superior to scraped propolis because it is almost entirely pure propolis, with only the trace wax naturally present in it and none of the wood fragments, paint chips, caulk or general hive debris that scraping from frames, boxes and covers inevitably collects and which must otherwise be removed by laborious cleaning.

Rationale: Propolis intended for human use should come from colonies whose treatment history is known, since propolis is lipophilic and concentrates residues, and trap material should be food grade.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Bogdanov, Propolis, Bee Product Science.*

316. (MC) Pollen collected in a pollen trap must be handled promptly because:

Answer: D) It carries substantial moisture and a microbial load and will mold or ferment within hours in warm weather, so traps must be emptied daily and the pollen dried or frozen

Rationale: In the humid summers of the southeastern US this is a matter of hours rather than days. Standard handling is daily emptying, removal of debris and dead bees, and either freezing or drying at a temperature low enough to preserve nutritional quality, generally no higher than about 105 to 113 degrees F (40 to 45 degrees C) with dry moving air. Trapping also removes pollen the colony needs, so traps should be run intermittently and never on colonies already under nutritional stress.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Bogdanov, Pollen: Production, Nutrition and Health, Bee Product Science.*

317. (TF) Royal jelly is produced by the wax glands of nurse bees, is harvested commercially from worker cells rather than queen cells, and is stable at room temperature for extended periods.

Answer: False

Rationale: Three errors. It is produced by the hypopharyngeal and mandibular glands, not the wax glands, which secrete wax from the abdominal sternites. It is harvested from queen cells started with grafted larvae, the jelly being removed after roughly 72 hours before the larva consumes it. And it is highly perishable, requiring refrigeration or freezing and protection from light, since enzyme activity continues after harvest, furosine and 5-HMF rise, the color darkens and microbial growth begins at room temperature (10-HDA itself changes little).

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Bogdanov, Royal Jelly, Bee Product Science.*

318. (MC) Bee venom for commercial use is normally collected by:

Answer: A) Presenting an electrically charged frame with a glass surface, which stimulates bees to sting the glass without losing their stings, the dried venom then scraped off

Rationale: Because glass does not grip the barbs as skin does, the bee withdraws its sting and survives. The practice has real costs: colonies become markedly more defensive for a period afterward, and the dried venom powder is a serious respiratory and anaphylaxis hazard to the operator, requiring

appropriate protective equipment. It should not be conducted near the public or where colony temperament matters for other work.

References: *Benton, Morse & Stewart, Science 142:228-230 (1963); Bogdanov, Bee Venom, Bee Product Science.*

319. (SA) A beekeeper intends to sell beeswax cosmetics and candles. Set out the considerations to address before selling.

Model answer: Product classification and labeling: candles are consumer products with their own safety expectations and warnings, while a balm or salve is a cosmetic requiring ingredient labeling, net contents and producer identification, and would become a drug in regulatory terms if therapeutic claims were made. Since the Modernization of Cosmetics Regulation Act of 2022, anyone marketing a cosmetic must also be able to substantiate its safety, report serious adverse events to FDA, and give a US address, telephone number or electronic contact on the label for such reports; businesses with average annual cosmetic sales under about one million dollars are exempt from facility registration, product listing and the manufacturing-practice rules, but not from those duties. Product integrity: the wax should be clean, well filtered and of known residue status, since wax concentrates lipophilic pesticide residues, which argues for cappings wax rather than dark brood comb wax in anything applied to skin. Production practice: clean equipment, controlled melting temperatures, consistent formulation and batch records. Business matters: liability insurance, lot coding for traceability, and applicable state and local requirements for cosmetic manufacture or home-based food and cosmetic businesses.

Rationale: The residue point is the one beekeepers most often overlook, and it is the strongest practical argument for segregating cappings wax at the rendering stage.

References: *US FDA cosmetic labeling requirements (21 CFR parts 701 and 740); Modernization of Cosmetics Regulation Act of 2022 (US FDA); Mullin et al., PLoS ONE 5:e9754 (2010).*

320. (MC) Which statement about hive products and colony treatment history is most accurate?

Answer: C) Wax, propolis and pollen concentrate lipophilic compounds far more than honey, so a producer should know the treatment history of every colony contributing to them

Rationale: Honey is a water-soluble sugar matrix and carries comparatively few fat-soluble residues; wax and propolis are the opposite, and rendering and drying do not remove them. A beekeeper who intends to market wax for cosmetics, produce comb honey, or sell propolis for human use should plan the treatment program with that in mind and keep the records to support it.

References: *Mullin et al., PLoS ONE 5:e9754 (2010); Bogdanov, Bee Product Science.*

Section 18: Laws, Regulation, Inspection & Organizations (Q321–331)

Part A — Questions

321. (MC) Apiary inspection and bee disease regulation in the United States is primarily:

- **A)** A federal function administered by the Environmental Protection Agency, which sets uniform national requirements for registration, inspection and movement of colonies
- **B)** Entirely unregulated in the United States, so that beekeepers are free to move colonies and equipment across state lines without notification, permit or inspection
- **C)** A state function, with each state's designated agency, usually the department of agriculture, administering apiary law covering registration, inspection, disease reporting and movement certification
- **D)** A function of county law enforcement, which is why apiary complaints and disease reports are directed to the sheriff's office rather than to an agricultural agency

322. (SA) Describe what a beekeeper should do before moving colonies across a state line for pollination or a honey flow.

323. (MC) The Honey Bee Act of 1922 is significant because it:

- **A)** Established the federal grade standards for extracted honey, including the color designations and the moisture maximum that still govern honey sold in trade today
- **B)** Set the labeling requirements for miticides and other pesticides used in honey bee colonies, and established the enforcement framework administered by the states
- **C)** Created the state apiary inspection programs and provided the federal funding under which they operate, which is why inspection services exist in nearly every state
- **D)** Restricted the importation of adult honey bees into the United States, originally to prevent introduction of the tracheal mite, and remains the basis of that control

324. (TF) American foulbrood is a notifiable or reportable condition in many states, so a beekeeper who identifies it may be legally required to report it, and the state may have authority to order destruction of infected colonies and equipment.

True / False

325. (MC) Local ordinances affecting beekeeping commonly address:

- **A)** The price at which honey may be sold at farmers markets and roadside stands, in order to prevent undercutting between producers within the same jurisdiction
- **B)** Colony numbers permitted per lot size, setbacks from property lines and dwellings, flyway barrier requirements, water provision, and sometimes registration
- **C)** The brand and type of equipment that must be used, so that inspectors can open and examine any colony in the jurisdiction using a single standard set of tools
- **D)** Which subspecies of honey bee may lawfully be kept, with most jurisdictions restricting keeping to European-derived stock and prohibiting other subspecies outright

326. (SA) Describe the general legal framework governing liability if a neighbor is stung, and list the practical measures that reduce a beekeeper's exposure.

327. (MC) Selling honey across state lines or wholesale to retailers generally:

- **A)** Is prohibited outright for any producer operating fewer than fifty colonies, which is the threshold at which an operation is treated as commercial for these purposes
- **B)** Is treated identically to direct sales under a state cottage food exemption, since the exemption attaches to the producer's scale rather than to the sales channel used
- **C)** Requires no labeling at all, since wholesale purchasers are commercial buyers who are presumed to know the nature of the product they are acquiring for resale
- **D)** Brings a producer under requirements not applying to direct intrastate sales, since cottage food exemptions typically cover only direct sales within the state

328. (SA) Explain what a cottage food law is and what a small honey producer in the southeastern US should determine before selling.

329. (MC) A beekeeper who suspects that a pesticide misuse killed their colonies should contact:

- **A)** No agency, since there is no legal recourse available to a beekeeper whose colonies are damaged by a lawful application made on a neighboring property
- **B)** The local police department, since pesticide misuse causing loss of livestock is a criminal matter and the initial report must be made to law enforcement
- **C)** The Food and Drug Administration, which has jurisdiction over pesticide residues in food and therefore over incidents affecting food-producing livestock such as bees
- **D)** The state lead pesticide agency, usually the department of agriculture, together with the state apiary inspector, since enforcement is carried out by the states

330. (SA) Name several national or regional organizations relevant to United States beekeepers and state what each contributes.

331. (TF) Master beekeeper certification programs assess written knowledge alone, since practical skill varies too much with regional conditions to be examined consistently between candidates.

True / False

Part B — Answer Key: Section 18

321. (MC) Apiary inspection and bee disease regulation in the United States is primarily:

Answer: C) A state function, with each state's designated agency, usually the department of agriculture, administering apiary law covering registration, inspection, disease reporting and movement certification

Rationale: Because apiary regulation is a state matter, requirements differ substantially among the states of the southeastern US: some require registration of all colonies, others do not; inspection programs and notifiable disease lists vary. A beekeeper must therefore know their own state's law rather than relying on a general text, and a beekeeper moving colonies must satisfy the destination state's requirements rather than assuming reciprocity.

References: *State apiary acts; Apiary Inspectors of America.*

322. (SA) Describe what a beekeeper should do before moving colonies across a state line for pollination or a honey flow.

Model answer: Contact the destination state's apiary regulatory authority and establish its current entry requirements, which commonly include a certificate of inspection issued within a specified period by the origin state's apiary inspector and may include additional requirements relating to African-derived bees, small hive beetle or other pests. Arrange the inspection well in advance, since inspections must be scheduled and certificates carry a validity period. Confirm any permit, notification or registration the destination state requires, carry the documentation with the load, and check the requirements again for the return movement. Requirements change, so information from a previous season should not be relied upon.

Rationale: Failure to comply can result in quarantine, refusal of entry or destruction of colonies at the state line, which makes this one of the more consequential regulatory risks in migratory beekeeping.

References: *State apiary acts and entry requirements; Apiary Inspectors of America summaries.*

323. (MC) The Honey Bee Act of 1922 is significant because it:

Answer: D) Restricted the importation of adult honey bees into the United States, originally to prevent introduction of the tracheal mite, and remains the basis of that control

Rationale: The Act is administered with the federal animal and plant health inspection service and has been amended over time to permit limited importation from designated countries and regions. It did not ultimately prevent the arrival of tracheal mite or Varroa, but it illustrates the long-standing role of quarantine in protecting the national bee population and is the reason a beekeeper cannot freely import queens or packages from abroad.

References: *Honey Bee Act of 1922, 7 U.S.C. 281-286; USDA APHIS honey bee importation regulations.*

324. (TF) American foulbrood is a notifiable or reportable condition in many states, so a beekeeper who identifies it may be legally required to report it, and the state may have authority to order destruction of infected colonies and equipment.

Answer: True

Rationale: The rationale is that spores persist for decades and a single infected colony threatens every apiary within flight range, so the disease is treated as a community rather than a private problem. The practical implication is that suspected American foulbrood should be reported to the state apiary inspector rather than handled quietly, and that where the inspector's direction is legally binding it must be followed.

References: *State apiary acts; Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000.*

325. (MC) Local ordinances affecting beekeeping commonly address:

Answer: B) Colony numbers permitted per lot size, setbacks from property lines and dwellings, flyway barrier requirements, water provision, and sometimes registration

Rationale: Ordinances vary widely and change, so a beekeeper should check the current municipal or county code before establishing an apiary and again before expanding. Many states have right-to-farm

provisions that may limit local restriction of agricultural activity, but their application to beekeeping in residential zones varies, and homeowner association covenants operate separately from public law and may be more restrictive.

References: *Municipal and county codes; state right-to-farm statutes.*

326. (SA) Describe the general legal framework governing liability if a neighbor is stung, and list the practical measures that reduce a beekeeper's exposure.

Model answer: Liability generally arises under ordinary negligence principles, that is, whether the beekeeper exercised reasonable care in siting and managing the colonies, and under nuisance law where the operation substantially and unreasonably interferes with a neighbor's use and enjoyment of their property. Compliance with applicable ordinances is relevant but not necessarily sufficient. Practical measures: keep gentle stock and requeen defensive colonies promptly; provide a dependable on-site water source; use flyway barriers such as fencing or hedges to raise flight paths above head height; site hives away from property lines, walkways and neighbors' outdoor living areas; practice swarm control; screen the apiary from view; maintain communication and good relations with neighbors; carry liability insurance; and comply with local ordinances and any state registration requirement.

Rationale: A knowledgeable beekeeper should describe the framework and recommend that a specific dispute be taken to a qualified attorney rather than offering legal advice.

References: *State right-to-farm statutes and municipal ordinances; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

327. (MC) Selling honey across state lines or wholesale to retailers generally:

Answer: D) Brings a producer under requirements not applying to direct intrastate sales, since cottage food exemptions typically cover only direct sales within the state

Rationale: Wholesale, internet and interstate sales generally require operating from an inspected or licensed facility and complying fully with federal labeling and, depending on scale, food safety requirements. A producer planning to grow should establish these requirements before committing to a market channel, and should not assume that an exemption from licensing is also an exemption from labeling or food safety obligations.

References: *State cottage food statutes; US FDA Preventive Controls for Human Food rule (21 CFR 117); 21 CFR part 101.*

328. (SA) Explain what a cottage food law is and what a small honey producer in the southeastern US should determine before selling.

Model answer: A cottage food law is a state statute or rule permitting certain low-risk foods to be produced in a home kitchen and sold directly to consumers, subject to limits on sales channels, annual sales volume, labeling and sometimes registration or training. Honey is commonly treated as a permitted product, and several states additionally exempt small honey producers from some food processing licensing. Before selling, a producer should determine: whether their state's cottage food or honey-specific provision covers their operation and at what sales volume; whether registration, food

handler certification, a permit or facility inspection is required; what labeling elements the state requires beyond the federal ones, such as a cottage food disclosure or an infant advisory; which sales channels are permitted; and what the venue itself requires, such as insurance and a vendor agreement.

Rationale: Requirements differ substantially among the states of the region and change over time, so the current rules of the specific state and county must be checked rather than relying on what another beekeeper does.

References: *State cottage food statutes and department of agriculture guidance; US FDA labeling requirements.*

329. (MC) A beekeeper who suspects that a pesticide misuse killed their colonies should contact:

Answer: D) The state lead pesticide agency, usually the department of agriculture, together with the state apiary inspector, since enforcement is carried out by the states

Rationale: Prompt reporting matters because residues degrade and because a formal investigation with proper chain of custody is the only route to an enforcement determination. The beekeeper should preserve and freeze samples, document the scene, and follow the agency's instructions rather than sending samples independently to a private laboratory in the first instance.

References: *US EPA and state lead agency pesticide incident investigation procedures.*

330. (SA) Name several national or regional organizations relevant to United States beekeepers and state what each contributes.

Model answer: National trade organizations representing commercial and sideline beekeepers on policy, trade and research funding; regional apicultural societies that provide conferences, short courses and master beekeeper certification; the Apiary Inspectors of America, which coordinates state regulatory officials and is a partner in the national colony loss survey; the U.S. Beekeeping Survey, led by Auburn University with Oregon State University and the Apiary Inspectors of America, which now produces the annual national colony loss figures, a role formerly filled by the Bee Informed Partnership; the Honey Bee Health Coalition, which produces widely used practical guidance including the standard Varroa management tools; and state and local beekeeping associations, which supply region-specific knowledge, mentoring and connection to the state inspection service. University Cooperative Extension apiculture programs supply region-specific publications and applied research.

Rationale: Knowing where authoritative, current information comes from is itself a competency, particularly in a field where a great deal of confident misinformation circulates online and in social media groups. It also means knowing when a source has moved: national loss figures once published by the Bee Informed Partnership now come from the U.S. Beekeeping Survey.

References: *Organization publications; Auburn University, U.S. Beekeeping Survey release (June 2026); Honey Bee Health Coalition.*

331. (TF) Master beekeeper certification programs assess written knowledge alone, since practical skill varies too much with regional conditions to be examined consistently between candidates.

Answer: False

Rationale: Established programs typically include written, laboratory, oral and field examination components (tiered state programs add public service). The practical and oral elements exist precisely because the role is largely to advise and teach: a candidate must handle colonies calmly, diagnose correctly in an unfamiliar hive, and explain their reasoning honestly, including where their certainty ends. Someone who can recite facts but cannot work a colony has not met the standard.

References: *Regional apicultural society master beekeeper program handbooks; university master beekeeper program requirements.*

Section 19: Safety, Stings & Public Relations (Q332–340)

Part A — Questions

332. (MC) A normal or large local reaction to a sting is distinguished from a systemic allergic reaction in that:

- **A)** Any swelling extending beyond the immediate sting site indicates anaphylaxis and requires the immediate administration of epinephrine and emergency medical care
- **B)** A local reaction, however large, is confined to and contiguous with the sting site, whereas a systemic reaction involves symptoms distant from it
- **C)** Any sting that produces pain lasting more than a few minutes constitutes an allergic reaction and indicates that the person should be referred to an allergist
- **D)** Local reactions are the more dangerous of the two, since the swelling can compromise circulation in a limb, whereas systemic reactions resolve without treatment

333. (SA) Describe the correct response if someone at your apiary shows signs of a systemic allergic reaction to a sting.

334. (MC) Regarding the removal of a sting, the evidence indicates that:

- **A)** The sting must always be scraped and never pinched, since pinching compresses the venom sac and injects the remaining contents into the wound in a single bolus
- **B)** Tweezers must be used and only after the area has been washed, so that surface contamination is not introduced into the puncture during the removal of the sting
- **C)** Speed of removal matters more than the method, since the detached venom sac continues to pump, so the sting should be removed at once by whatever means is fastest
- **D)** The sting should be left in place for several minutes so the venom sac empties naturally, since removing it prematurely tears the wound and increases the swelling

335. (TF) Mass stinging incidents involving large numbers of stings are dangerous even to people with no bee allergy, because the venom itself is toxic in quantity and can cause systemic effects requiring hospital care.

True / False

336. (SA) Identify the principal occupational safety hazards of beekeeping in the southeastern US beyond stings, and state a mitigation for each.

337. (MC) Regarding protective equipment, the most accurate statement is that:

- **A)** Gloves should be worn under all circumstances without exception, since the hands are the most frequently stung part of the body and the loss of dexterity is minor
- **B)** It reduces but does not eliminate stings, involves trade-offs against heat stress and dexterity, and does not substitute for gentle stock, weather and calm technique
- **C)** A full suit eliminates all risk of stinging, so that handling technique, colony temperament and weather conditions become irrelevant once the beekeeper is fully suited

- **D)** Experienced beekeepers have no need for a veil, since colonies respond to calm handling and the confidence of the operator far more than to any physical barrier

338. (SA) List the safety practices that should govern smoker use, with attention to conditions in the southeastern US.

339. (MC) When speaking publicly about honey bees, an informed beekeeper should:

- **A)** Avoid mentioning Varroa entirely, since the subject discourages prospective beekeepers and the mite is a management problem rather than a matter of public interest
- **B)** Say that honey bees are endangered and face imminent extinction, since a sense of urgency is what motivates public support for pollinator habitat and pesticide reform
- **C)** Advocate the immediate prohibition of all agricultural pesticides, since this is the single change that would most improve the prospects of managed and wild bees alike
- **D)** Give accurate information, distinguishing managed colony losses that beekeepers absorb and replace from conservation concerns affecting native pollinators

340. (SA) Describe how a beekeeper should handle a neighbor's complaint that bees are congregating at their swimming pool.

Part B — Answer Key: Section 19

332. (MC) A normal or large local reaction to a sting is distinguished from a systemic allergic reaction in that:

Answer: B) A local reaction, however large, is confined to and contiguous with the sting site, whereas a systemic reaction involves symptoms distant from it

Rationale: Getting this wrong in either direction is harmful: treating a large local reaction as anaphylaxis causes unnecessary alarm and may lead someone to abandon beekeeping unnecessarily, while dismissing early systemic symptoms is dangerous. The decisive question is whether symptoms have appeared away from the sting site. Any systemic reaction warrants emergency care and referral to an allergist for assessment and possible venom immunotherapy, which is highly effective.

References: *Golden et al., Ann. Allergy Asthma Immunol. 118:28-54 (2017); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

333. (SA) Describe the correct response if someone at your apiary shows signs of a systemic allergic reaction to a sting.

Model answer: Administer epinephrine immediately by intramuscular injection into the outer thigh using an auto-injector if one is available and prescribed; call emergency medical services at once; keep the person lying down with legs elevated unless breathing difficulty makes sitting necessary, and do not allow them to stand or walk; be prepared to give a second dose if there is no improvement within roughly five to fifteen minutes and a second injector is available; remove the sting promptly by any means; and ensure transport to hospital for observation even if symptoms improve, because reactions can recur hours later. Antihistamines are an adjunct and are not a substitute for epinephrine.

Rationale: A beekeeper hosting visitors, teaching or mentoring should ask in advance about sting allergies, confirm that a phone has signal at the apiary, know the location and route for emergency services, and never work alone with a known allergic person present without a plan.

References: *Golden et al., Ann. Allergy Asthma Immunol. 118:28-54 (2017); Muraro et al., Allergy 69:1026-1045 (2014).*

334. (MC) Regarding the removal of a sting, the evidence indicates that:

Answer: C) Speed of removal matters more than the method, since the detached venom sac continues to pump, so the sting should be removed at once by whatever means is fastest

Rationale: A small experiment (three volunteers) measuring wheal size after stings removed at different intervals and by different methods found that elapsed time governed the dose delivered while method did not significantly affect it. The study is small, but the practical conclusion is sound: the traditional instruction never to pinch is not supported and can cause harmful hesitation. Scraping with a hive tool or fingernail remains convenient; the point is simply not to delay.

References: *Visscher, Vetter & Camazine, Lancet 348:301-302 (1996).*

335. (TF) Mass stinging incidents involving large numbers of stings are dangerous even to people with no bee allergy, because the venom itself is toxic in quantity and can cause systemic effects requiring hospital care.

Answer: True

Rationale: This is a toxic rather than an allergic phenomenon, and a beekeeper who has become tolerant of ordinary stings has no protection against it. Effects can include muscle and red blood cell breakdown, kidney injury and cardiovascular effects, and the clinical course can develop over hours to days, so an adult receiving more than roughly 15 to 25 stings, and a child, older adult or person with heart or kidney disease after far fewer, should be medically evaluated and observed even if they initially feel well; about 500 stings is potentially life-threatening for an adult. The risk is greatest with highly defensive colonies and in confined spaces where escape is difficult.

References: *Vetter, Visscher & Camazine, West. J. Med. 170:223-227 (1999); Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004).*

336. (SA) Identify the principal occupational safety hazards of beekeeping in the southeastern US beyond stings, and state a mitigation for each.

Model answer: Musculoskeletal injury from repeated lifting of heavy supers and hive bodies, mitigated by using medium or eight-frame equipment, mechanical lifting aids and two-person handling. Heat stress, which is severe in the region because protective clothing prevents evaporative cooling, mitigated by ventilated suits, working early in the day, frequent shaded breaks, continuous hydration and never working alone in extreme heat. Chemical exposure when handling concentrated organic acids and acaricides, mitigated by the personal protective equipment specified on the label, including respiratory protection where required. Fire risk from smokers in dry pine landscapes, mitigated by careful fuel

choice, safe transport in a closed metal container and full extinguishment before leaving. Vehicle and lifting hazards during moves, mitigated by securing loads and planning access.

Rationale: Heat illness in particular is under-appreciated. Heavy sweating, nausea, headache and weakness signal heat exhaustion: stop work, get into shade, cool down and drink. Confusion or odd behavior in an overheated person signals heat stroke, a medical emergency requiring immediate cooling and a call for help, even if the person is still sweating.

References: *Occupational safety guidance for agriculture; product safety data sheets; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; US CDC/NIOSH heat stress guidance.*

337. (MC) Regarding protective equipment, the most accurate statement is that:

Answer: B) It reduces but does not eliminate stings, involves trade-offs against heat stress and dexterity, and does not substitute for gentle stock, weather and calm technique

Rationale: The item targets two opposite errors. Over-reliance on equipment encourages rough handling and creates heat illness risk; disdain for it, sometimes presented as a mark of experience, sets a poor example and creates avoidable risk, particularly with unfamiliar colonies, in public settings, or where African-derived bees may be present. Gloves reduce dexterity and can increase the number of bees crushed, which releases alarm pheromone, so their use is a judgment rather than an absolute. A veil, however, should be regarded as minimum equipment.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004).*

338. (SA) List the safety practices that should govern smoker use, with attention to conditions in the southeastern US.

Model answer: Use dry natural fuel free of treated, painted or synthetic material that could produce toxic smoke or taint hive products. Manage the smoker so it produces cool white smoke rather than flame or hot smoke, which drives bees off the combs and can provoke rather than calm. Never set a lit smoker on dry grass, pine straw or in a vehicle. Transport it in a closed metal container so that it is starved of air and extinguished. Ensure it is completely out before leaving the apiary or storing it, since a smoldering smoker in the pine landscapes of the region is a serious wildfire risk and open burning restrictions may apply in some seasons. Keep water or an extinguisher available, and be aware that a hot smoker burns the beekeeper as readily as anything else.

Rationale: Apiary and vehicle fires started by carelessly handled smokers are a recurring and entirely preventable problem.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; state forestry burn restriction guidance.*

339. (MC) When speaking publicly about honey bees, an informed beekeeper should:

Answer: D) Give accurate information, distinguishing managed colony losses that beekeepers absorb and replace from conservation concerns affecting native pollinators

Rationale: Accuracy builds credibility, and the true account is more interesting than the exaggerated one. Honey bees are managed livestock and are not at risk of extinction; the real story is that beekeepers sustain high annual losses, about 56 percent of managed colonies in 2024–25 and a preliminary 40 percent in 2025–26 by the national survey, and replace them at cost. Overstating the case invites correction and undermines the beekeeper's authority on the points that actually matter, including pesticide stewardship and habitat.

References: *Auburn University, U.S. Beekeeping Survey release (June 2026); vanEngelsdorp & Meixner, J. Invertebr. Pathol. 103:S80-S95 (2010).*

340. (SA) Describe how a beekeeper should handle a neighbor's complaint that bees are congregating at their swimming pool.

Model answer: Respond promptly, courteously and in person, and acknowledge the problem rather than disputing that the bees are yours. Explain that bees require water and that the practical remedy is to provide a better source: establish a dependable water source in your own yard with landing surfaces such as gravel, corks or a wet board, sited closer to the hives than the pool and in place continuously. Recognize that bees already fixed on the pool will take time to shift, so persistence is required, and suggest interim measures such as a pool cover or running the filter. Review your own siting, flyway barriers and colony numbers, offer honey and continued communication, and check the local ordinance. If the situation cannot be resolved, consider moving some colonies to an out-apiary.

Rationale: The examinable judgment is that neighbor relations are a management responsibility, that the technical fix is straightforward, and that a defensive or dismissive response is what converts a nuisance into an ordinance.

References: *Cooperative Extension apiculture publications, southeastern US; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

Section 20: Applied Scenarios & Case Studies (Q341–365)

Part A — Questions

341. (MC) Scenario: In early spring you open a strong two-story colony and find a laying queen, bees on nearly every frame, and eleven capped queen cells along the bottom bars. Before deciding what to do, the most important thing to establish is:

- **A)** Whether the bees are Italian or Carniolan derived, since the two stocks differ in swarming tendency and the appropriate intervention differs accordingly
- **B)** The color of the marking on the queen, since this establishes the year of her introduction and therefore whether her age alone accounts for the swarm preparation
- **C)** Whether the colony has already swarmed, by checking for eggs and whether the queen present is the original marked queen and whether any cells have been opened
- **D)** Whether the colony has sufficient honey stores to support both halves if a split is made, since a division without adequate stores in either portion will fail

342. (SA) Scenario: A colony in midsummer has a spotty brood pattern, several bees with deformed wings crawling at the entrance, and ample stores. Describe your diagnostic sequence and the likely conclusion.

343. (MC) Scenario continued: the mite count in the previous scenario is 12 mites per 300 bees, honey supers are on, and daytime highs are near 95 degrees F. The most defensible action is:

- **A)** Increase the label dose of a temperature-limited product to compensate for the reduced efficacy expected at the upper end of its permitted application range
- **B)** Apply a formic acid product at once, since it penetrates cappings and is the only treatment that reaches mites in sealed brood during a period of active rearing
- **C)** Wait until autumn when temperatures fall into the label range, since applying any volatile product at 95 degrees risks brood mortality and the loss of the queen
- **D)** Recognize the count as 4 percent, determine which products may lawfully be used with supers on and suit the temperature, and if none does, pull the supers and treat

344. (SA) Scenario: In spring you find, in one colony, a small area of brood with sunken, greasy, perforated cappings, and a probe drawn from one cell produces a brown ropy strand about an inch long. Set out exactly what you do, in order, and what you must not do.

345. (MC) Scenario: A queen introduced eleven days ago into a colony made queenless the same day is found dead in her cage, and the colony now has several capped queen cells on the comb face. What most likely happened?

- **A)** The cage was faulty and released her too quickly, before the colony had acquired her pheromonal signature, which is why she was balled and killed by the workers
- **B)** The queen was defective on arrival and should be replaced immediately using the same introduction method, since the failure lay with her rather than with the colony
- **C)** The colony has developed laying workers during the eleven days, which is why it rejected the introduced queen and began constructing cells over worker-laid eggs

- **D)** The colony was not truly queenless or retained young brood, so it reared its own cells and rejected her; the response is to remove every cell and any virgin, then reintroduce in a candy-plug cage

346. (SA) Scenario: A colony is found dead in late winter with a fist-sized cluster of dead bees, heads in cells, five frames of capped honey on the outer walls of the same box, several dead bees with deformed wings, and white specks on the upper inner walls of empty brood cells. Give the proximate and underlying causes and state the management change required.

347. (MC) Scenario: In the midsummer dearth you find bees flying erratically around several hives, fighting on landing boards, and wax flecks scattered in front of one colony. Your first action should be to:

- **A)** Open the affected colony to assess how much honey remains and whether the queen is still present, so that the decision whether to save the colony can be made
- **B)** Reduce that colony's entrance to a very small opening or fit a robbing screen at once, remove exposed comb and spilled feed, and close or move it if the attack persists
- **C)** Requeen the colony, since a colony that fails to defend itself against robbing has a failing queen and will not recover without a change of stock and temperament
- **D)** Add a super to give the colony more room, since a congested colony defends its entrance poorly and additional space allows the guards to concentrate at the opening

348. (SA) Scenario: In late July a colony in the coastal plain has a mite count of 3 percent, a full brood nest and no honey supers. Compare a single oxalic acid dribble with the extended-release oxalic acid strip (VarroXSan) for this colony, and state how you would confirm the result.

349. (MC) Scenario: A grower asks you to supply 60 colonies for a crop blooming in eight days. Your colonies currently average five frames of bees. The most professional response is to:

- **A)** Accept the contract, since sixty colonies exceeds the usual stocking rate for the acreage and the additional numbers compensate for the weakness of the individual units
- **B)** Decline or renegotiate, explaining that strength determines foraging force, and offering fewer colonies at an agreed standard, a later delivery, or an adjusted price
- **C)** Accept and add empty supers so that the colonies present a larger appearance at inspection, then remove them once the grower's assessment has been completed
- **D)** Accept and feed heavily on arrival so that the colonies build during the bloom period, reaching the contracted strength within the first week of the pollination

350. (SA) Scenario: A package installed three weeks ago has a released queen but no eggs, no larvae, no queen cells, and only two frames of drawn comb. Diagnose and state your next steps.

351. (MC) Scenario: You are called to a suburban yard where a basketball-sized cluster of bees hangs from a low branch. The most appropriate response is to:

- **A)** Recognize it as a swarm, typically docile; reassure the homeowner, capture it, then keep it separate while observing health and temperament, and consider requeening
- **B)** Advise the homeowner to have the cluster exterminated, since a swarm of unknown origin may carry disease or undesirable genetics into the local bee population
- **C)** Leave it in place, since a clustered swarm will move on within a day or two of its own accord and intervention risks provoking a defensive response in a public place

- **D)** Spray the cluster with soapy water before approaching, which subdues the bees sufficiently for the cluster to be shaken into a box without protective equipment

352. (SA) Scenario: An apiary of twelve colonies has produced a good crop, but three colonies have consistently shown mite counts roughly triple the others under identical management. Describe how you would investigate and respond.

353. (MC) Scenario: Two colonies in early autumn each cover four frames, both queenright, with adequate stores, low mite counts and no disease. The most sensible action is to:

- **A)** Requeen both immediately with young mated queens, since the small size of each colony indicates that the existing queens are failing and will not carry them through
- **B)** Add a second brood box to each so that the clusters have room to move upward into stores through the winter without becoming isolated from their remaining honey
- **C)** Leave both as they are, since both are queenright and disease free and a colony of four frames is adequate to overwinter successfully in the climate of the region
- **D)** Combine them over newspaper after removing one queen, or winter them as a paired double nucleus with separate entrances, since sharing heat improves survival

354. (SA) Scenario: While uncapping drone brood you see small, reddish-brown mites, clearly longer than they are wide and much narrower than Varroa, running quickly over the comb. The brood pattern is irregular and a few emerging bees have malformed wings. Explain what you may have found, why it matters, and what you do.

355. (MC) Scenario: Six of eighteen colonies in one apiary die between late autumn and midwinter. Post-mortem shows abundant stores, small clusters, no mites visible, no mite feces in brood cells, no deformed wings, and no foulbrood signs; August mite counts were below 1 percent in all six. The most appropriate response is to:

- **A)** Investigate the alternatives systematically: autumn queen events, Vairimorpha (Nosema), the autumn population's size and age, late-season nutrition, and any factor specific to the site
- **B)** Replace all equipment as a precaution against foulbrood, since a cluster of losses within one apiary most often indicates an undetected brood disease in that yard
- **C)** Conclude that Varroa was responsible despite the absence of any supporting evidence, since mites remain the commonest single cause of overwinter loss in managed colonies
- **D)** Assume the losses were random and change nothing, since a loss rate of one third is within the range reported nationally and does not indicate a management failure

356. (SA) Scenario: You extract 30 supers over two days. Ten days later, jars from one lot show foam at the top and a faint fermented smell, while other lots are unaffected. Diagnose, explain the selective effect, and state the immediate response and the process change.

357. (MC) Scenario: A beekeeper reports that an amitraz treatment applied per label reduced mite counts from 7 percent to only 6 percent, measured immediately at strip removal. The most likely explanation, and the way to test it, are:

- **A)** Resistance in the bees rather than the mites, since a colony that has been treated repeatedly ceases to distribute the active ingredient through the cluster

- **B)** Application error or resistance, since the prompt post-treatment count largely excludes reinvasion; test by treating a subset with a different mode of action
- **C)** Reinvasion from neighboring colonies, which can be tested by repeating the count in about six weeks to see whether the mite level has continued to climb
- **D)** A counting error in one or both samples, which requires no further action beyond repeating the wash on a larger sample from the same colonies the following week

358. (SA) Scenario: A beekeeper asks which Varroa treatments may lawfully be used while honey supers are on. Name those the Honey Bee Health Coalition's current guide lists as usable with supers on and those that are not, and explain how the distinction shapes the treatment calendar in the southeastern US.

359. (MC) Scenario: A colony has become progressively more defensive over six weeks. You confirm it is queenright with a laying queen, there is no evidence of predator harassment, and no dearth has begun. The queen you introduced was marked, but the queen you now find is unmarked. The best interpretation is:

- **A)** The colony has developed laying workers alongside the queen, and their presence accounts for both the temperament change and the absence of the original marking
- **B)** The colony has superseded or swarmed and requeened itself, so the current queen mated with unknown drones; requeening with known gentle stock is appropriate
- **C)** The colony is approaching starvation, which accounts for the defensiveness, and the queen has been superseded as a consequence of the nutritional stress involved
- **D)** The paint mark has simply worn off over the intervening weeks, so the queen is the original one and the temperament change must have an environmental explanation

360. (SA) Scenario: A neighboring beekeeper half a mile away does not monitor or treat for Varroa. Your colonies show sharp autumn mite increases despite good post-treatment counts. Explain how you would establish whether the two facts are connected and what you would do.

361. (MC) Scenario: A student in a class you are teaching states confidently that screened bottom boards control Varroa and that treatment is therefore unnecessary. The best response is to:

- **A)** Acknowledge the idea is widely repeated and reasonable, then explain what controlled trials found, offer the references, and describe what screened bottoms are useful for
- **B)** Tell the student plainly that the claim is wrong and move on, since class time is limited and the evidence on the question is not seriously in dispute
- **C)** Agree with the student in order to avoid embarrassing them in front of the class, then correct the point privately afterward once the teaching session has finished
- **D)** Avoid the subject entirely by redirecting the discussion, since disagreements about treatment philosophy are unproductive in a mixed teaching group

362. (SA) Scenario: You are asked to design a first-year plan for a new beekeeper starting with two colonies in the southeastern US. Outline the checkpoints across the year and the reason for each.

363. (MC) Scenario: A sideline beekeeper has treated every colony with amitraz strips each August for eight years and has never taken a post-treatment count. In light of the 2026 findings on the 2024–25 colony losses, the most defensible change is to:

- **A)** Verify each treatment with a count at strip removal, rotate to a different mode of action, and re-treat any colony whose count has not fallen
- **B)** Increase the number of strips per brood box, since resistant mites tolerate only the standard dose and a higher dose overcomes the resistance mutation
- **C)** Switch to tau-fluvalinate strips, since a pyrethroid acts on a different target and mites resistant to amitraz will not have been selected against it
- **D)** Continue as before, since the finding concerned large migratory pollination operations and has little bearing on a stationary sideline apiary

364. (TF) Scenario: Across the cases in this section, the correct answer usually depended less on recalling a single fact than on identifying which additional observation would distinguish among competing explanations before acting.

True / False

365. (SA) Final synthesis: Describe the habits of practice that most distinguish a capable beekeeper in the southeastern US from one who has read widely but managed little.

Part B — Answer Key: Section 20

341. (MC) Scenario: In early spring you open a strong two-story colony and find a laying queen, bees on nearly every frame, and eleven capped queen cells along the bottom bars. Before deciding what to do, the most important thing to establish is:

Answer: C) Whether the colony has already swarmed, by checking for eggs and whether the queen present is the original marked queen and whether any cells have been opened

Rationale: Numerous cells on the bottom bars of a congested queenright colony reads as swarm preparation, but a colony that has already swarmed will still contain a queen if a virgin has emerged, and the appropriate response differs completely: pre-swarm calls for an artificial swarm, split or Demaree, while post-swarm calls for reducing cells to one or introducing a mated queen. Establishing which situation you are in costs one careful look and determines everything that follows.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Winston, The Biology of the Honey Bee, Harvard Univ. Press, 1987.*

342. (SA) Scenario: A colony in midsummer has a spotty brood pattern, several bees with deformed wings crawling at the entrance, and ample stores. Describe your diagnostic sequence and the likely conclusion.

Model answer: Examine the brood closely first to exclude the serious alternatives: capping appearance for sunkenness, perforation and greasiness; a matchstick test on discolored capped larvae for ropiness; odor; the position of dead larvae; and the adherence of any scale, which together exclude or raise American and European foulbrood. Look for chalkbrood mummies, sacbrood and evidence of chilled brood. Confirm the queen is present and laying with single centered eggs. Then take a quantitative mite count, an alcohol wash of about 300 nurse bees from a brood frame. The combination of deformed wings, spotty brood and adequate stores points strongly to heavy Varroa infestation with deformed

wing virus, and a count above the action threshold confirms it. The response is prompt treatment with a product appropriate to the temperature and to whether supers are present, followed by a post-treatment count to verify efficacy.

Rationale: The examinable habit is excluding foulbrood before concluding, because the consequences of missing it are severe, and measuring mites rather than inferring them.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

343. (MC) Scenario continued: the mite count in the previous scenario is 12 mites per 300 bees, honey supers are on, and daytime highs are near 95 degrees F. The most defensible action is:

Answer: D) Recognize the count as 4 percent, determine which products may lawfully be used with supers on and suit the temperature, and if none does, pull the supers and treat

Rationale: Applying formic acid at once ignores the label temperature limit, which at 95 degrees F is exceeded (the Formic Pro label limit is 85 degrees F daytime highs) and risks brood mortality, queen loss and absconding. Lawful supers-on options remain: the Honey Bee Health Coalition's 9th edition lists the extended-release VarroSan oxalic acid strip, applied for its labeled 42 to 56 days so that it works through the brood cycles (with supers on only if at least one box separates the treated brood chamber from any honey to be extracted), and HopGuard 3, labeled for use to 100 degrees F; the newer MBG2X5G and OrganiShield products are also labeled for use with supers on; a single oxalic dribble would reach only the mites on adult bees. Waiting until autumn allows the mite population to compound through the very period when the winter bees are being reared. Increasing the dose is unlawful and increases harm. The reasoning expected is that colony survival outranks the remaining crop, and that the label governs which product may be used and under what conditions.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; product labels; 7 U.S.C. 136 et seq.*

344. (SA) Scenario: In spring you find, in one colony, a small area of brood with sunken, greasy, perforated cappings, and a probe drawn from one cell produces a brown ropy strand about an inch long. Set out exactly what you do, in order, and what you must not do.

Model answer: Close the colony without transferring any frame, bee or tool to another hive; work that colony last or clean and disinfect the hive tool and gloves before touching any other. Record the hive identification, location and findings, and photograph the comb. Notify the state apiary inspector promptly and request confirmation, submitting a comb sample as directed, wrapped in paper rather than plastic, in a cardboard box. If robbing or collapse seems likely, reduce or close the entrance to prevent the colony being robbed out and its spores distributed. Await instruction, since destruction, treatment and movement are governed by state law. What must not be done: move frames or bees to other colonies, feed honey from the colony to any colony, extract or sell its honey, sell or give away its equipment, or attempt to resolve the problem with antibiotics.

Rationale: The containment rule is the substantive answer. The interval between suspicion and confirmation is when most apiary-wide outbreaks are created, and it is entirely within the beekeeper's control.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; state apiary act notification requirements.*

345. (MC) Scenario: A queen introduced eleven days ago into a colony made queenless the same day is found dead in her cage, and the colony now has several capped queen cells on the comb face. What most likely happened?

Answer: D) The colony was not truly queenless or retained young brood, so it reared its own cells and rejected her; the response is to remove every cell and any virgin, then reintroduce in a candy-plug cage

Rationale: The presence of queen cells is the diagnostic fact: a colony with cells or an unnoticed virgin will almost always reject an introduced queen. The failure was procedural, namely not verifying queenlessness and not removing all cells at introduction and again about a week later. Reintroducing without dealing with the cells simply repeats the error.

References: *Laidlaw & Page, Queen Rearing and Bee Breeding, Wicwas, 1997; Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

346. (SA) Scenario: A colony is found dead in late winter with a fist-sized cluster of dead bees, heads in cells, five frames of capped honey on the outer walls of the same box, several dead bees with deformed wings, and white specks on the upper inner walls of empty brood cells. Give the proximate and underlying causes and state the management change required.

Model answer: The proximate cause is isolation starvation: the cluster consumed the stores immediately around it and could not move laterally to the remaining honey during cold weather, shown by the heads-in-cells posture with honey still present in the box. The underlying cause is Varroa and deformed wing virus: the deformed wings and the white mite fecal deposits in vacated brood cells show that the autumn brood was reared under heavy mite pressure, so the winter bees were short-lived and the cluster dwindled below the size needed to bridge to its stores. The management change is to complete effective mite control before the autumn bees are reared, monitoring in late summer and treating promptly if thresholds are exceeded, and verifying efficacy with a post-treatment count rather than assuming it.

Rationale: A candidate who reports only starvation has stopped at the proximate cause and would respond by feeding more the following year, which would not prevent a recurrence.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Dainat, Evans, Chen, Gauthier & Neumann, PLoS ONE 7:e32151 (2012).*

347. (MC) Scenario: In the midsummer dearth you find bees flying erratically around several hives, fighting on landing boards, and wax flecks scattered in front of one colony. Your first action should be to:

Answer: B) Reduce that colony's entrance to a very small opening or fit a robbing screen at once, remove exposed comb and spilled feed, and close or move it if the attack persists

Rationale: Wax flecks from torn cappings, fighting and searching flight along the hive body are diagnostic of robbing, as distinct from orientation flights in which young bees face the hive, hover without fighting and belong to that colony. Robbing accelerates through positive feedback, so speed matters, and opening the colony to inspect makes it worse. Prevention through entrance management before the dearth is far better than response during it.

References: *Free, Bee World 35:206-210 (1954); Graham (ed.), The Hive and the Honey Bee, Dadant, 2015.*

348. (SA) Scenario: In late July a colony in the coastal plain has a mite count of 3 percent, a full brood nest and no honey supers. Compare a single oxalic acid dribble with the extended-release oxalic acid strip (VarroXSan) for this colony, and state how you would confirm the result.

Model answer: A single dribble acts only on mites on adult bees. In a colony with a full brood nest only about a sixth to a quarter of the mites are on adult bees at any moment; the rest are reproducing under cappings, where oxalic acid does not reach. One dribble therefore kills a minority of the population, and mites emerging over the following two weeks restore the count; repeating dribbles at short intervals harms the bees, so the dribble is the right tool only in a broodless or nearly broodless colony or after a deliberate brood break. The extended-release strip holds oxalic acid in a glycerin matrix in the brood nest for its labeled 42 to 56 days, which spans two or more 21-day worker brood cycles, so mites are contacted as they emerge from their cells throughout that period, which is why it suits a colony that is never broodless. To confirm the result, take an alcohol wash before treatment and a second wash when the strips are removed at the end of the labeled period; a count that has not fallen well below the 2 percent late-summer threshold calls for a different mode of action, while a low count that later rises points to reinvasion.

Rationale: The item tests the match between a product's mode of action and the colony's brood status, the constraint that dominates Varroa treatment in a region where colonies rarely go broodless. The same reasoning explains why a broodless midwinter oxalic acid application is dependable in the North and unreliable in much of the southeastern US.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Rademacher & Harz, Apidologie 37:98-120 (2006); product labels.*

349. (MC) Scenario: A grower asks you to supply 60 colonies for a crop blooming in eight days. Your colonies currently average five frames of bees. The most professional response is to:

Answer: B) Decline or renegotiate, explaining that strength determines foraging force, and offering fewer colonies at an agreed standard, a later delivery, or an adjusted price

Rationale: Building takes brood cycles (worker eggs need 21 days to become adults), so feeding cannot compress the timeline: five frames of bees eight days before bloom will still be about five frames when the bloom opens. Adding empty supers to create an appearance of strength is misrepresentation. The professional response treats colony strength as the substance of what is being sold, puts the standard in writing, and preserves the relationship, which for a pollination business is the principal asset.

References: Delaplane & Mayer, *Crop Pollination by Bees*, CABI, 2000; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

350. (SA) Scenario: A package installed three weeks ago has a released queen but no eggs, no larvae, no queen cells, and only two frames of drawn comb. Diagnose and state your next steps.

Model answer: The likely possibilities are that the queen was lost or killed after release, or that she is present but failing. The absence of queen cells is informative: a queenless colony with eggs or young larvae would normally have started cells, so their absence together with no brood suggests the colony never had eggs to work with, consistent with the queen never having laid. Next steps: search carefully for the queen; if she is not found, insert a test frame of eggs and young brood from a healthy colony and check in three to four days for emergency cells, which confirms queenlessness. Meanwhile feed continuously, since a package on foundation cannot draw comb without a flow or feed and slow comb drawing points to underfeeding (though a package with no laying queen and no young bees also draws comb slowly), so check the feeding record, and reduce the entrance against robbing and beetles. If queenless, introduce a mated queen promptly rather than letting the package dwindle further.

Rationale: The additional lesson is that two frames of comb in three weeks is low for a package and calls for a check of feeding as well as the queen, and both must be addressed.

References: Sammartaro & Avitabile, *The Beekeeper's Handbook*, 5th ed., Cornell Univ. Press, 2021; Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015.

351. (MC) Scenario: You are called to a suburban yard where a basketball-sized cluster of bees hangs from a low branch. The most appropriate response is to:

Answer: A) Recognize it as a swarm, typically docile; reassure the homeowner, capture it, then keep it separate while observing health and temperament, and consider requeening

Rationale: Swarm calls are the most common public interaction a beekeeper has, and handling them well builds goodwill for beekeeping generally. The isolation and observation period addresses disease, mites and temperament, and in parts of the southeastern US where African-derived bees occur, temperament assessment and requeening with known stock are matters of public safety as well as management preference.

References: Graham (ed.), *The Hive and the Honey Bee*, Dadant, 2015; Schneider, DeGrandi-Hoffman & Smith, *Annu. Rev. Entomol.* 49:351-376 (2004).

352. (SA) Scenario: An apiary of twelve colonies has produced a good crop, but three colonies have consistently shown mite counts roughly triple the others under identical management. Describe how you would investigate and respond.

Model answer: First verify the counts by repeating them with consistent methodology, sampling nurse bees from brood frames in each colony, since sampling error and differences in colony size or brood status can produce apparent differences. Consider position effects: colonies at the ends of rows or nearest a neighboring apiary accumulate drifted bees and mites, so note where the three sit. Review their queen age, source and history, and whether they have swarmed or superseded. Treat all colonies

as needed by their measured counts, treating the three promptly since they are both at risk themselves and a mite source for the yard. Then respond to the pattern: if the three continue to differ after position and sampling are controlled for, requeen them with stock from a source with documented resistance traits, and consider whether apiary layout is contributing to drift.

Rationale: The examinable habit is verifying before explaining, and recognizing that a colony with a much higher count is a reinvasion risk to its neighbors as well as a problem in itself.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Frey & Rosenkranz, J. Econ. Entomol. 107:508-515 (2014).*

353. (MC) Scenario: Two colonies in early autumn each cover four frames, both queenright, with adequate stores, low mite counts and no disease. The most sensible action is to:

Answer: D) Combine them over newspaper after removing one queen, or winter them as a paired double nucleus with separate entrances, since sharing heat improves survival

Rationale: The condition attached to combining is exactly what the scenario supplies: verified absence of disease and mite problems, since uniting a diseased colony into a sound one spreads the problem. Adding a second brood box to each is counterproductive, since it increases the volume each small cluster must maintain and creates undefended space that small hive beetle will exploit in this region.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Cooperative Extension apiculture publications, southeastern US.*

354. (SA) Scenario: While uncapping drone brood you see small, reddish-brown mites, clearly longer than they are wide and much narrower than Varroa, running quickly over the comb. The brood pattern is irregular and a few emerging bees have malformed wings. Explain what you may have found, why it matters, and what you do.

Model answer: The description fits *Tropilaelaps*, most likely *Tropilaelaps mercedesae*, an Asian brood mite that is not established in the United States. Varroa is broader than it is long, crab-shaped and relatively slow; *Tropilaelaps* is about a millimeter long, elongate and fast-running. It matters because *Tropilaelaps* reproduces faster than Varroa, lives almost entirely in brood, and in a region where colonies rear brood nearly all year could build populations quickly; no product is registered against it in the United States, and early detection is the only realistic chance of eradication. What to do: stop all movement of bees, brood, equipment and tools out of the apiary; collect specimens into alcohol from the uncapped brood and photograph them; record the hive and location; and notify the state apiary inspector the same day, who will involve the federal authorities and direct further sampling. Do not treat, move or destroy the colonies on your own initiative, since that can spread the mite or destroy the evidence the investigation needs.

Rationale: Two further points distinguish a capable answer. First, the standard alcohol wash of adult bees is a poor screen for *Tropilaelaps*, because the mite spends little time on adult bees; uncapping brood is the more sensitive method, which is how this finding was made. Second, the risk is not hypothetical: a 2026 report (*Frontiers in Insect Science*) documented the July 2025 interception of an *Apis dorsata* swarm carrying *T. mercedesae* on a cargo vessel bound for the United States.

References: Ramirez, Tembrock, Zink et al., *Front. Insect Sci.* 6:1829350 (2026); Anderson & Morgan, *Exp. Appl. Acarol.* 43:1-24 (2007); state apiary act notification requirements.

355. (MC) Scenario: Six of eighteen colonies in one apiary die between late autumn and midwinter. Post-mortem shows abundant stores, small clusters, no mites visible, no mite feces in brood cells, no deformed wings, and no foulbrood signs; August mite counts were below 1 percent in all six. The most appropriate response is to:

Answer: A) Investigate the alternatives systematically: autumn queen events, *Vairimorpha* (Nosema), the autumn population's size and age, late-season nutrition, and any factor specific to the site

Rationale: The evidence positively excludes the commonest cause, so a structured differential is the correct response rather than a default attribution. The apiary-specific pattern, six of eighteen at one location, is itself informative and directs attention to factors common to that site. Retained records and samples are what make such an investigation possible after the fact, which is an argument for keeping both.

References: vanEngelsdorp et al., *J. Apic. Res.* 51:115-124 (2012); Fries, *J. Invertebr. Pathol.* 103:S73-S79 (2010).

356. (SA) Scenario: You extract 30 supers over two days. Ten days later, jars from one lot show foam at the top and a faint fermented smell, while other lots are unaffected. Diagnose, explain the selective effect, and state the immediate response and the process change.

Model answer: The honey has fermented, caused by osmophilic yeasts growing in honey of excessive moisture. Only one lot was affected because the supers contributing to it included uncapped or partly capped combs whose moisture was above the safe range (fermentation risk begins above about 17.5 percent, depending on yeast count and storage temperature, and fermentation is likely above about 19 percent), and because moisture was not tested before bottling; blending diluted the problem in other tanks but not in this one. Immediate response: withhold the lot from sale, recall any product already distributed under that lot code, test the retained honey, and either destroy it or put it to a non-food use; do not sell it as honey, and do not feed it back to colonies, since fermented stores cause dysentery. Process change: assess capping before extraction and set aside uncapped combs; measure moisture with a temperature-corrected refractometer on each tank rather than on a single composite; dry high-moisture honey with warm moving air rather than heat; and maintain lot coding so a defect can be isolated.

Rationale: Lot coding is what makes the response proportionate; without it, one bad tank calls the whole season's output into question and offers no way to trace recipients.

References: White, in Crane (ed.), *Honey: A Comprehensive Survey*, Heinemann, 1975; US FDA *Preventive Controls for Human Food* (21 CFR 117).

357. (MC) Scenario: A beekeeper reports that an amitraz treatment applied per label reduced mite counts from 7 percent to only 6 percent, measured immediately at strip removal. The most likely explanation, and the way to test it, are:

Answer: B) Application error or resistance, since the prompt post-treatment count largely excludes reinvasion; test by treating a subset with a different mode of action

Rationale: Because the count was taken immediately at strip removal, reinvasion has had little opportunity to occur, which points to failure rather than immigration. Application should still be reviewed first: dose for colony size, placement relative to the cluster, duration, and product storage and age. For amitraz, however, resistance is now a leading explanation: all 39 mites screened from 18 colonies in five commercial operations with heavy losses in the 2026 investigation of the 2024–25 US colony losses carried the Y215H resistance mutation (a sample chosen for heavy losses, so not a baseline prevalence). If application was sound, treating with a different mode of action and taking paired counts confirms the diagnosis and protects the colony at the same time.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Rinkevich, PLoS ONE 15:e0227264 (2020); Lamas et al., PLOS Pathog. 22:e1013939 (2026).*

358. (SA) Scenario: A beekeeper asks which Varroa treatments may lawfully be used while honey supers are on. Name those the Honey Bee Health Coalition's current guide lists as usable with supers on and those that are not, and explain how the distinction shapes the treatment calendar in the southeastern US.

Model answer: Usable with honey supers on, within each label's temperature limits: formic acid (Formic Pro), the four registered oxalic acid products (Api-Bioxal and Api-Bioxal RTU and EZ-OX, by dribble or vapor, and the extended-release VarroSan strip, the latter provided at least one box separates the treated brood chamber from any honey to be extracted), hop beta acids (HopGuard 3), and two newer products, l-glutamic acid (MBG2X5G) and sucrose octanoate esters (OrganiShield). Not usable with supers on: amitraz (Apivar and Amiflex), the thymol products (Apiguard and ApiLife Var), tau-fluvalinate (Apistan), coumaphos (CheckMite+) and the dsRNA product Norroa (vadescana), which the guide says not to apply with supers on. The distinction shapes the calendar because supers are on through much of spring and early summer, while the decisive late-summer count falls in the heat, when formic acid is excluded once daytime highs pass its 85 degrees F label limit and the thymol products are also constrained by temperature. The workable pattern is to treat with a supers-off product in late winter before supering and again as soon as the supers come off after the flow, and to keep a supers-on product in reserve for a high count while supers are still on, rather than leaving the winter bees exposed while waiting to remove supers.

Rationale: Labels change and the product list is revised with each edition of the Coalition's guide, so the current label of the specific product is the authority. The examinable habit is checking super status and temperature before choosing a product, rather than defaulting to whatever was used last year.

References: *Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; product labels; 7 U.S.C. 136 et seq.*

359. (MC) Scenario: A colony has become progressively more defensive over six weeks. You confirm it is queenright with a laying queen, there is no evidence of predator harassment, and no dearth has begun.

The queen you introduced was marked, but the queen you now find is unmarked. The best interpretation is:

Answer: B) The colony has superseded or swarmed and requeened itself, so the current queen mated with unknown drones; requeening with known gentle stock is appropriate

Rationale: An unmarked queen where a marked one was introduced is the diagnostic fact, and it explains a temperament change that has no environmental cause. Marks can wear, but the interpretation should be tested by checking whether brood continuity suggests a gap. The response is requeening with known stock, with the change becoming apparent over about six weeks as the workforce is replaced, and full precautions in the interim.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Schneider, DeGrandi-Hoffman & Smith, Annu. Rev. Entomol. 49:351-376 (2004).*

360. (SA) Scenario: A neighboring beekeeper half a mile away does not monitor or treat for Varroa. Your colonies show sharp autumn mite increases despite good post-treatment counts. Explain how you would establish whether the two facts are connected and what you would do.

Model answer: Document your own results rigorously: paired pre- and post-treatment counts demonstrating that your treatments worked, followed by serial counts at intervals through the autumn showing when and how fast mite numbers rise. Compare colonies at different positions in your apiary and, if possible, at an apiary further from the neighbor, since a distance gradient in the rate of increase is good evidence of external immigration. Note the condition of the neighbor's colonies through the season if it can be observed, since collapse events produce robbing-driven mite influx. Then act: approach the neighbor directly and without hostility, share your data and offer to help with monitoring; involve the local association or the state apiary inspector for education or, if colonies are collapsing and diseased, for whatever regulatory response is available; and adapt your own management by monitoring more frequently, timing or repeating treatments differently, and considering relocation.

Rationale: The examinable elements are gathering evidence before accusing, recognizing that reinvasion is measurable rather than merely assumed, and beginning with cooperation.

References: *Frey & Rosenkranz, J. Econ. Entomol. 107:508-515 (2014); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

361. (MC) Scenario: A student in a class you are teaching states confidently that screened bottom boards control Varroa and that treatment is therefore unnecessary. The best response is to:

Answer: A) Acknowledge the idea is widely repeated and reasonable, then explain what controlled trials found, offer the references, and describe what screened bottoms are useful for

Rationale: How a knowledgeable beekeeper handles a confident but mistaken statement is itself a competency, since the role is largely educational and the manner of correction determines whether it is accepted. The substantive point is to separate a plausible mechanism from a tested outcome, cite evidence rather than authority, and give the student a way to check for themselves.

References: *Ellis, Delaplane & Hood, Am. Bee J. 141:813-816 (2001); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

362. (SA) Scenario: You are asked to design a first-year plan for a new beekeeper starting with two colonies in the southeastern US. Outline the checkpoints across the year and the reason for each.

Model answer: Late winter: first inspection on a warm day; confirm the queen is laying, heft for stores and feed if light, take a baseline mite count, and prepare equipment for spring. Early spring: begin inspections at about 7-day intervals for swarm cells; add space and drawn comb; consider a split for swarm control and increase; add supers ahead of the flow. Main flow: keep supers ahead of the bees; continue swarm watch; apply nothing not labeled for use with supers on. End of flow: remove and extract honey promptly; monitor and treat for mites; reduce entrances ahead of the dearth. Midsummer dearth: feed if light, guard against robbing and small hive beetle, take the critical late-summer mite count and treat if the threshold is exceeded. Early autumn: verify the treatment worked with a follow-up count; requeen failing colonies; build stores with heavier syrup while it is warm enough to be ripened; combine any colony too weak to winter. Late autumn and winter: leave colonies alone apart from hefting and emergency feeding; repair and store equipment; protect drawn comb from wax moth and beetles; and review records to plan the next season.

Rationale: The mentoring value lies in attaching a reason to each checkpoint, so the new beekeeper learns to read the season rather than following dates mechanically, and in emphasizing that the late-summer mite count is the one that determines whether the colonies survive.

References: *Cooperative Extension apiculture publications, southeastern US; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

363. (MC) Scenario: A sideline beekeeper has treated every colony with amitraz strips each August for eight years and has never taken a post-treatment count. In light of the 2026 findings on the 2024–25 colony losses, the most defensible change is to:

Answer: A) Verify each treatment with a count at strip removal, rotate to a different mode of action, and re-treat any colony whose count has not fallen

Rationale: In the investigation of the 2024–25 US colony losses, all 39 mites screened from five commercial operations with heavy losses carried the Y215H mutation in the octopamine receptor that confers amitraz resistance (about two thirds in an earlier regional survey); because those operations were sampled for heavy losses and had relied on amitraz, the figure shows resistance is widespread and serious rather than giving a baseline prevalence. A beekeeper who treats without verifying cannot tell whether the treatment worked. Raising the dose is unlawful and does not overcome target-site resistance; tau-fluvalinate is a poor substitute because pyrethroid resistance has been widespread in US mite populations since the 1990s; and nothing about resistance is confined to large operations, since mites move between apiaries by drift and robbing.

References: *Lamas et al., PLOS Pathog. 22:e1013939 (2026); Rinkevich, PLoS ONE 15:e0227264 (2020); Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

364. (TF) Scenario: Across the cases in this section, the correct answer usually depended less on recalling a single fact than on identifying which additional observation would distinguish among competing explanations before acting.

Answer: True

Rationale: This is the examination's own statement of what it has been testing. Competent practice is diagnostic: generate the plausible explanations, identify the observation that discriminates among them, weigh the consequences of each possible error, and act on the finding rather than on the first impression. A candidate who answered these scenarios by matching a remembered pattern has demonstrated something less than the examination is designed to identify.

References: *Shimanuki & Knox, Diagnosis of Honey Bee Diseases, USDA Agriculture Handbook 690, 2000; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.*

365. (SA) Final synthesis: Describe the habits of practice that most distinguish a capable beekeeper in the southeastern US from one who has read widely but managed little.

Model answer: They measure rather than assume: mite counts instead of impressions, hive weight instead of guesses about stores, and written colony records so that impressions become evidence that can be compared across colonies and seasons. They work from the local calendar rather than a book written for another region, knowing when their own flows and dearths occur and adjusting swarm control, feeding, harvesting and treatment accordingly. They diagnose before acting, distinguishing a sign such as spotty brood from its several possible causes and excluding the serious possibilities before settling on the convenient one. They read pesticide labels as binding, record what they applied, and verify that it worked. They anticipate rather than react, because the region's principal problems, swarming, robbing, small hive beetle and mite damage, are all far cheaper to prevent than to remedy. And they know the limits of their own knowledge, consult their state inspector, Extension service and local association, and give advice honestly, including saying plainly when they are not sure.

Rationale: There is no single correct answer to this item. It is assessed on whether the candidate identifies measurement, regional specificity, differential diagnosis, regulatory compliance, anticipation and intellectual honesty, and can express them clearly enough to teach them to someone else.

References: *Graham (ed.), The Hive and the Honey Bee, Dadant, 2015; Honey Bee Health Coalition, Tools for Varroa Management, 9th ed.; Cooperative Extension apiculture publications, southeastern US.*