



SimBee

Teacher's Guide

Classroom companion to the honeybee colony simulation

V1.0

A model of the colony as a superorganism - division of labor, the waggle dance, homeostasis, seasons, parasites, and emergence

Recommended for Grades 6-10 · Life Science / Biology
with extensions for Grades 5 and 11-12, math, and computer science

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1 · How to use this guide

This guide turns SimBee into teachable material. The game ships with a thorough user manual and an in-game field guide, but those are written for a player, not a teacher. This document does the translation: it maps what students see on screen to the science standards behind it, supplies ready-to-run lessons, and flags the practical details that decide whether a lab period goes smoothly.

You do not need to be a beekeeper. Each lesson includes the background you need, and Section 4 is a concept primer you can read in fifteen minutes. You also do not need to play through the whole game first - the suggested lessons each use one slice of it.

Pick what fits your time:

- **One class period:** run any single lesson in Section 6 - they are self-contained.
- **A short unit (1-2 weeks):** sequence Lessons 1 through 5; add the capstone in Section 7.
- **A demo / station / sponge activity:** the dashboard, the waggle-dance mini-game, and the hive interior each work as a standalone 10-minute station.

What SimBee is - in one paragraph

SimBee is a real-time 3D simulation of a single honeybee colony (*Apis mellifera*) across the four seasons. Students watch tens of thousands of individual bees fly, forage, and tend the hive; click any bee to read its caste, age, and job; step inside the comb to watch an egg grow into an adult; decode a real waggle dance as a measurement puzzle; and spend earned research points to shape the colony's traits. There are no enemies to beat and no way to "lose" - it is a sandbox for observing how a colony works as a single living system.

A note on the model (read this - it is also a teaching tool)

SimBee is a model, and like every model it simplifies. Resources are in abstract units rather than kilograms; a simulated year passes in a couple of minutes; the colony cannot actually die; and several real bee behaviors are described in the game but not animated. None of this is a flaw to hide from students - comparing a model to the real system it represents is one of the core science practices (NGSS SEP-2, "Developing and Using Models"). Section 9 lists exactly where the model bends, with discussion prompts that turn each one into a thinking exercise.

2 · Why this game is worth a class period

Most "ecosystem" software asks students to balance numbers on a panel. SimBee is different in three ways that matter pedagogically:

It makes an abstract idea visible. The hardest concept in social-insect biology - that intelligent, coordinated behavior can arise with no one in charge - is something students can literally watch. The defensive "heat ball," where workers cook an attacking hornet to death, unfolds on screen, and no individual bee "knows the plan." That is emergence you can point at.

It has a genuine reasoning task built in. The waggle-dance decoder is not a quiz; it is a measurement problem. Students read an angle relative to the sun and a duration that encodes distance, then commit to a guess and get scored on their error. It pulls geometry and proportional reasoning into a biology lesson without anyone announcing "now we do math."

It rewards observation over twitch skill. Because there is no fail state and the camera works while the simulation is paused, students can slow down, look closely, and form questions - the exact stance you want in an inquiry lesson.

Connections across subjects: the colony is, in computer-science terms, an agent-based model - simple per-bee rules producing complex group behavior. If you team-teach with a CS or math colleague, Lesson 6 leans into that explicitly.

3 · Grade levels and standards alignment

Recommended grade band

Primary fit: Grades 6-10 life science and biology. The colony's division of labor, life cycle, energy flow, and predator/parasite pressures sit squarely in middle-school life science, while homeostasis, group behavior, and natural selection give the same software real traction in a high-school biology course.

How to stretch it:

- **Grade 5 (and curious 4th):** use the visual systems only - watch foragers, inspect a bee's job, and watch a cell grow up in the hive interior. Skip the dance math and the research economy.
- **Grades 11-12 / AP-style:** push on quantitative and evolutionary angles - model the mite population as exponential growth, treat research choices as selection pressures, and critique the model's assumptions formally (Section 9).
- **Math classrooms (Gr 7-10):** the waggle dance alone is a strong angles-and-proportions lesson (Lesson 2).
- **CS / computational-thinking:** the whole sim is an agent-based model; Lesson 6 connects it to emergence and to how multi-agent systems are built.

Standards alignment (NGSS)

These are strong alignment targets, not an official crosswalk. NGSS is used here as a common reference; please confirm exact codes and wording against the standards your state or district has adopted.

Middle school life science

Performance expectation (NGSS)	How SimBee gives students something to work with
MS-LS1-4 - behaviors & structures that affect reproductive success	The queen, drones, and the waggle dance that recruits foragers are all behaviors/structures tied to colony survival and reproduction.

Performance expectation (NGSS)	How SimBee gives students something to work with
MS-LS1-5 - factors that affect growth of organisms	Caste is set by diet; brood needs warmth and pollen-protein; the hive interior shows a cell develop egg → adult.
MS-LS1-8 - sensory input → information processing → behavior	Decoding the dance is exactly this: a forager senses a food source, encodes it, and other bees act on the message.
MS-LS2-2 - patterns of interaction among organisms	Bees & flowers (pollination/foraging), bees & hornets (predation), bees & Varroa (parasitism) all appear.
MS-LS2-3 - cycling of matter & flow of energy	Nectar becomes honey (stored energy); pollen becomes brood (protein/matter); winter spends the stored energy down.
MS-LS2-4/5 - ecosystem disruption & ecosystem services	Mites and hornets disrupt the colony; foraging is a pollination service to the surrounding meadow.

High school biology

Performance expectation (NGSS)	How SimBee gives students something to work with
HS-LS1-3 - feedback maintains homeostasis	The brood nest holds ~35°C through summer heat and winter cold; the dashboard gauge makes the regulated set-point visible.
HS-LS2-6 - ecosystem stability & resilience	The colony absorbs seasonal swings and attacks; students see what keeps it stable and what tips it.
HS-LS2-8 - group behavior aids survival & reproduction	The central theme: eusocial behavior (cooperative defense, shared brood care, recruitment) outperforms going it alone.
HS-LS4-2/3/4 - natural selection & adaptation	The Genetics research line (hygienic behavior, Varroa-sensitive hygiene) models selecting for mite resistance - host-parasite coevolution.
HS-LS1-2 - interacting subsystems	Foraging, brood-rearing, thermoregulation, and defense are subsystems whose interaction is the colony.

Crosscutting concepts that run through almost every lesson: **Systems & System Models**; **Cause & Effect**; **Stability & Change**; **Structure & Function**; **Energy & Matter**; and **Patterns**.

Science & engineering practices students actually do: developing and using models, analyzing and interpreting data (the dashboard), using mathematics (the dance), constructing explanations, and arguing from evidence.

4 · Getting it running in your room

What you need

Item	Detail
Device	Any reasonably modern laptop, desktop, or Chromebook with a current browser (Chrome, Edge, Firefox, Safari). Tablets work but the controls are easier with a mouse and keyboard.
Graphics	The game uses 3D (WebGL). Most school devices handle it; on older Chromebooks expect a lower frame rate with the full swarm on screen. Test one device before the lesson.
Internet	Needed to load the game and its 3D engine the first time. See the network note below.
Accounts	None. There is no sign-in and no personal data collected.
Audio	None required. The game has no sound, so headphones are unnecessary.
Mouse	Strongly recommended. Click-to-inspect, dragging the compass dial, and the camera all feel better with a mouse than a trackpad.

Network note for locked-down school Wi-Fi

On first load the game fetches its 3D engine (`three.js`) from public code networks (`cdnjs.cloudflare.com`, with `unpkg.com` and `cdn.jsdelivr.net` as backups) and its fonts from `fonts.googleapis.com`. If a student sees "Couldn't reach the 3D engine," the network is blocking those hosts.

Fix: ask your IT team to allow those domains, or have them host a local copy of `three.js`. Once loaded, the game runs entirely in the browser with no further internet needed.

The save system - the one thing to plan around

Read this before a multi-day unit. SimBee autosaves the colony to the browser's local storage every few seconds. That is convenient for a single player on a single machine, but it has consequences in a shared lab:

- **Saves are tied to one browser on one device.** A colony started in Room 12's Chromebook #4 lives only there. A student on a different machine - or a different browser - starts fresh.
- **There is one save slot, shared by whoever uses that browser.** Two students rotating through the same machine will overwrite each other's colony.
- **Private/Incognito windows do not keep a save** once the window closes, and clearing site data wipes it.

Three ways to work with this rather than against it:

1. **Treat each session as a fresh sandbox.** Simplest option. Students explore for the period; nothing needs to persist. Most lessons here are built this way.

2. **Assign fixed stations** for a continuing colony. If a student must keep "their" colony across days, they return to the same device and browser each time.
3. **Make the journal the real record.** Have students log colony state on paper (Handout A) instead of relying on the save. This is more robust and doubles as assessment evidence.

No fail state - by design

The colony population has a floor, so students cannot kill it outright. This is deliberate: it keeps exploration low-stakes. The trade-off is that "your colony died" is not available as a consequence - so when you want stakes, set a goal yourself (for example, "get honey into the Thriving range before winter" or "hold mite load under 40% for a full year").

5 · Concept primer: the science, and where to see it

Seven big ideas carry the whole game. Each one below has a short briefing and a pointer to where students can watch it happen. This section is meant to be read once, by you, before teaching.

5.1 · The colony is a superorganism

A honeybee colony behaves less like a crowd of animals and more like a single body. No bee survives alone; jobs are divided the way organs divide labor; and the colony as a whole shows abilities no individual has - regulating its temperature, defending itself, and making collective decisions. Biologists call this a superorganism, and the bees' cooperative lifestyle is called eusociality.

Division of labor follows age (the technical term is temporal polyethism). A worker is not born a forager; she works through a sequence of indoor jobs first: cleaning cells (days 1-4), nursing larvae (days 4-12), building comb when her wax glands peak (days 12-18), guarding the entrance (days 18-21), and only then flying out to forage (day 21+). Drones are males who do not work; their role is to mate. The single queen lays the eggs and releases a pheromone that holds the colony together - but she does not give orders.

See it in SimBee

Inspector: click any bee to read its caste, age, and the job that age implies, with a short note explaining that role. **Dashboard** → **Population:** shows the colony broken into cleaners, nurses, builders, guards, foragers, drones, and the queen, with the mix shifting by season.

5.2 · The waggle dance: a symbolic language

A returning forager can tell her sisters where she found food by dancing. She runs in a straight line while wagging, then loops back, tracing a figure-eight. Two things are encoded: the **angle** of the straight run (measured against straight-up = the direction of the sun) gives the **direction** to the food, and the **duration** of the waggle (roughly one second per kilometer) gives the **distance**. Karl von Frisch won a Nobel Prize for decoding this; it is the only known symbolic "language" outside the primates.

A subtle, beautiful detail: real dances carry a built-in 10-15° of scatter. That looks like sloppiness, but it spreads recruits across a whole flower patch instead of crowding one point - the imprecision is adaptive.

See it in SimBee

Decode a waggle dance: when a forager unloads at the hive she may dance on the landing board. Open the mini-game, watch the run, set a compass dial to the direction and a slider to the distance, and submit. You are scored on angle error and distance error; a clean read recruits foragers and earns research points. The **Dance Accuracy** research upgrade widens your margin for error.

5.3 · Homeostasis: holding the brood at 35°C

Developing brood must be kept near 35°C (95°F) - too cold and they develop wrong or die, too hot the same. The colony regulates this with no thermostat and no manager. When it is cold, bees cluster and shiver their flight muscles to make heat; when it is hot, they fetch water and fan their wings to cool by evaporation. This is a textbook negative-feedback loop, and a clean entry point to homeostasis in general (it works the same way your body holds 37°C).

See it in SimBee

Dashboard → **brood-nest temperature gauge**: a needle on a scale around the 35°C set-point, labeled Stable / Regulating / Stressed. The **Climate Adaptation** research upgrade improves how tightly the colony holds the line. The winter season visibly stresses it.

5.4 · Energy and matter: the foraging economy

A colony runs on two intakes. **Nectar** is sugar - the energy supply - which bees concentrate into **honey** for storage. **Pollen** is protein, the raw material for raising brood. **Water** is used for cooling and to dilute food, and **wax** (made from honey) builds the comb. Tracking these is a concrete way to see matter and energy flow through a living system: sunlight → flower nectar → honey → the muscle energy of the next forager.

See it in SimBee

Dashboard → **Stores** shows honey, pollen, water, and wax against seasonal targets; **Activity** shows foragers currently out and loads delivered today. The **Foraging** research line raises yield per trip. Watch stores build through summer and draw down through winter.

5.5 · Life cycle, metamorphosis, and the seasons

Bees undergo complete metamorphosis - egg, larva, pupa, adult - and which kind of bee an egg becomes is set by diet, not genetics alone: a female larva fed only royal jelly becomes a queen; the same egg fed worker food becomes a sterile worker. The colony's whole year is a race: build population and stores in spring and summer, then survive winter on what was banked, with a much smaller, longer-lived "winter bee" workforce.

See it in SimBee

Look inside the hive: click a brood cell and watch it animate through egg → larva → capped pupa → emerging adult, with a stage label; population ticks up when she emerges. The **season clock** cycles spring → summer → fall → winter, and the **Skip to next season** button jumps ahead. *Pacing note: a full simulated year takes only about 2½ minutes at 1× speed - roughly 30 seconds at 5× - so seasons turn over quickly. Use the speed buttons deliberately.*

5.6 · Threats, social immunity, and natural selection

The colony's deadliest real enemy is a parasite the size of a pinhead: the **Varroa** mite, which feeds on bees and spreads viruses, and whose population can double in a month. Colonies fight

back with **social immunity** - most powerfully **hygienic behavior**, where workers detect and remove infested brood. Breeding bees for this trait (the "Varroa-sensitive hygiene" line) is real, ongoing work, and it is a clean classroom example of natural selection and host-parasite coevolution. Bigger predators, like giant hornets, trigger a spectacular group defense (see 5.7).

See it in SimBee

Dashboard → **Threats & defense**: a mite-load bar that climbs (fastest in late summer/fall) and starts costing population if it gets high, plus a **Simulate hornet attack** button. The **Genetics** research line (Hygienic Behavior → VSH Trait) suppresses mites - i.e., you select for resistance. *Aside worth sharing: scientists once thought Varroa fed on bee "blood"; recent work showed it feeds on the fat body - a nice example of science correcting itself.*

5.7 · Emergence: complex order with no one in charge

This is the payoff idea. The colony's smartest behaviors are not directed by anyone - not the queen, not a "lead" bee. They emerge from many individuals each following simple local rules. The clearest case is the defensive heat ball: when a hornet attacks, hundreds of workers pile onto it and vibrate, raising the temperature to around 47°C - hot enough to kill the hornet (which dies near 44°C) but survivable for the bees. No bee decides on this strategy; it falls out of "approach the intruder" plus "vibrate when crowded." Foraging allocation, nest-site choice, and ventilation work the same way. For a CS class, this is exactly an agent-based model.

See it in SimBee

Heat-ball defense is the one emergent behavior you can watch happen: research **Heat-Ball Defense** first, then trigger a hornet attack and watch the ball form and the temperature climb in the banner. The everyday swarm flight - foragers arcing out and back, the dancer's figure-eight - is itself emergent from per-bee rules.

6 · Lesson plans

Six modular lessons, each about one class period and each self-contained. Run one as a stand-alone, or sequence 1-5 (plus the capstone in Section 7) into a short unit. Times assume a 45-50 minute period; adjust freely. Each lesson lists the in-game tasks students do, so you can preview them yourself in a few minutes.

Reusable routine for every lesson

Open → **Explore** → **Notice** → **Explain**. Students open the relevant part of the game, do the listed tasks, record what they notice (use the matching handout), then explain it in their own words. The "Discuss" prompts work as a whole-class wrap-up or as journal questions.

Lesson 1 · Meet the superorganism

Grades	6-10 (core); usable in 5
Time	~45 min
Grouping	Pairs at one device
Standards	MS-LS1-4, MS-LS1-5; HS-LS2-8
Handout	A - Colony Observation Journal

Objectives

- Describe the three castes (queen, workers, drones) and what each does.
- Explain that worker jobs change with age (temporal polyethism) rather than being assigned by a boss.
- Argue, from what they observe, why a colony is called one "superorganism."

Hook (5 min)

Ask: "A beehive has 40,000 bees and no manager. Who decides who does what job?" Take a few guesses and write them on the board to revisit at the end. (The answer - nobody decides; it follows age - is usually surprising.)

Explore (20 min)

1. Let the simulation run at 1× or 2×. Watch the entrance: bees leaving are foragers, the colony's oldest workers.
2. Click five different bees. For each, record in the journal its caste, age, and job, plus what it is doing right now.
3. Open the Colony Dashboard and find the Population card. Note how many bees are in each job, and which job has the most.
4. Find the queen (Dashboard lists exactly one) and at least one drone. Read the notes on each.

Discuss (12 min)

- Put your five bees in age order. What is the pattern between a worker's age and her job?

- The queen lays every egg but gives no orders. In what sense is she "in charge," and in what sense is she not?
- Drones do not work. Why would a colony "spend" food on bees that only mate? (Connects to reproduction, MS-LS1-4.)
- **Closer:** revisit the board guesses. Why does "jobs change with age" let a colony run with nobody in charge?

Check for understanding

Exit ticket: "Name the five worker jobs in the order one bee does them over her life, and name one job you saw in the game." A correct sequence (cleaner → nurse → builder → guard → forager) shows the core idea landed.

Differentiate

- **Support:** give the five job names on a card; students just put them in order and match to bees.
- **Stretch:** "If a colony suddenly lost all its young bees, which jobs would go undone first, and what would happen?"

Lesson 2 · Cracking the code: the waggle dance

Grades	6-10 (biology); 7-10 (math focus)
Time	~50 min
Grouping	Pairs; individual decoding
Standards	MS-LS1-8; HS-LS2-8 · math: angles, proportional reasoning
Handout	B - Waggle Dance Decode Log

Objectives

- Explain what information the waggle dance carries and how (angle = direction from the sun; duration = distance).
- Decode at least three dances and quantify their own error in degrees and distance.
- Interpret the bee's natural 10-15° scatter as a feature, not a mistake.

Hook (6 min)

Pose the problem with no bees: "You found a great taco truck. Without your phone, and without saying or writing any words, how would you tell a friend exactly which direction and how far?" Let the difficulty sink in - then reveal that a bee solves it with a dance.

Mini-lesson (8 min)

Show the two rules: the straight waggle run's angle from vertical equals the angle from the sun, and one second of wagging \approx one kilometer. Do one decode together on the projector so the class sees how to read the run and set the dial and slider.

Explore (20 min)

1. Open Decode a waggle dance. Watch the full figure-eight at least twice before guessing.
2. Set the compass dial to your estimated direction; set the slider to your estimated distance; submit.
3. Record the true vs. your value for both angle and distance, and your error, in the log. Do this for at least three dances.
4. After three reads, unlock Dance Accuracy in the research tree and notice how the scoring margin widens.

Discuss (10 min)

- Which was easier to read accurately - direction or distance? Why might that be?
- Real bees are off by 10-15° every time. Why would evolution keep that "error" instead of perfecting the dance? (Hint: a flower patch is wider than a single point.)
- This is called a symbolic language. What does the dance have in common with words, and how is it different?

Check for understanding

Collect the decode logs; a student who can state their own average angular error and explain what the run's direction encodes has met the objective. Quick prompt: "If a dance pointed 90° to the right of straight-up, where is the food relative to the sun?"

Differentiate

- **Support (math scaffold):** overlay a clock face or hand out a protractor; have students read the angle as "o'clock" first, then degrees.
- **Stretch:** have students compute their mean error across all reads and discuss whether more practice reduced it - an informal look at measurement error.

Lesson 3 · Holding 35°C: homeostasis & feedback

Grades	7-10; strong HS fit
Time	~45 min
Grouping	Pairs or small groups
Standards	HS-LS1-3 (homeostasis & feedback); MS-LS1-8
Handout	A - Colony Observation Journal (temperature rows)

Objectives

- Identify the brood-nest temperature set-point and describe what the colony does when it drifts.
- Diagram the regulation as a negative-feedback loop (sensor → response → effect).
- Connect colony thermoregulation to homeostasis in their own bodies.

Hook (5 min)

Ask how their body keeps ~37°C on a hot day and a cold day (sweating; shivering). Then: "A hive does the same thing at 35°C - with no brain running it. How?"

Explore (20 min)

1. Open the Dashboard and find the temperature gauge. Record the reading and its status (Stable / Regulating / Stressed).
2. Use Skip to next season to move into winter; watch the gauge and status, and record what changes.
3. Cycle on to summer and record again. Note when the status reads "Regulating" vs. "Stressed."
4. Unlock Climate Adaptation in the Ecology research line; observe whether the colony holds the set-point more tightly afterward.

Discuss (12 min)

- What is the set-point, and what are the two opposite problems the colony must correct (too cold, too hot)?
- Real bees shiver to warm the nest and fan/evaporate water to cool it. Match each to "what your body does."
- Draw the loop: what senses the drift, what responds, and how the response feeds back to fix it? Why is it called negative feedback?

Check for understanding

Students sketch a labeled feedback loop for one case (heating or cooling) with arrows. Look for the closing arrow - the response reducing the original drift - which is the heart of negative feedback.

Differentiate

- **Support:** provide the loop diagram with blank boxes to fill in.
- **Stretch:** "Climate Adaptation tightened control. In a real apiary, how could a beekeeper help a colony thermoregulate - and what does that tell you about limits of the model?"

Lesson 4 · Honey economics: energy, matter & the seasonal budget

Grades	6-10
Time	~50 min
Grouping	Pairs
Standards	MS-LS2-3 (matter & energy); MS-LS2-4; HS-LS2-6
Handout	A - Colony Observation Journal (stores rows)

Objectives

- Trace energy and matter through the colony: sunlight → nectar → honey → bee activity; pollen → brood.
- Explain why a colony must store a surplus in summer to survive a winter with no foraging.
- Use dashboard data to describe how stores change across the seasons.

Hook (5 min)

"A colony makes no food in winter for months - no flowers. So how is it still alive in March?"
Lead them to the idea of stored energy, then connect honey = stored summer sunlight.

Explore (22 min)

1. In spring, open the Dashboard and record honey, pollen, water, and wax, plus foragers out.
2. Advance through summer and fall, recording stores at each season. Watch honey build toward its target.
3. Advance into winter. Record stores again - foraging stops, so watch honey draw down.
4. Unlock Flower Memory (Foraging line) and, if you can afford it, Propolis Sealing (Architecture). Note their stated effects on yield and on winter honey use.

Discuss (12 min)

- Where does the energy in honey originally come from? Trace the chain back to its source.
- Nectar becomes honey (energy) and pollen feeds brood (protein/matter). Why does the colony need both, not just one?
- Propolis Sealing cuts winter honey use. In energy-budget terms, is that earning more or spending less - and why do both help survival?

Check for understanding

Exit ticket: a four-box flow diagram - Sun → ? → ? → bee activity - filled in correctly (flower nectar → honey). Bonus: one sentence on why winter is a "spending" season.

Differentiate

- **Support:** pre-label the flow boxes; students place honey/nectar/sunlight in order.
- **Stretch:** graph honey vs. season from the recorded data and describe the shape; predict what a second winter would look like.

Lesson 5 · Mites, hornets & natural selection

Grades	7-10; strong HS fit
Time	~50 min
Grouping	Pairs
Standards	MS-LS2-2 (interactions); HS-LS4-2/3/4 (natural selection)
Handout	C - Research Investment / Hypothesis Sheet

Objectives

- Describe Varroa mites as parasites and explain how a high mite load harms the colony.
- Explain hygienic behavior / VSH as a heritable trait that can be selected for - framing research choices as selection pressure.
- Make and test a prediction about a research upgrade's effect (a small experiment).

Hook (6 min)

Show the mite-load bar climbing. "This pinhead-sized parasite is the number-one killer of honeybee colonies worldwide. Bees can't spray pesticide - so how does a colony fight back over generations?" Lead toward "some bees are naturally better at removing infected brood."

Explore - a small experiment (22 min)

1. On the hypothesis sheet, record the current mite load and write a prediction: "If I research Hygienic Behavior, then the mite load will... because..."
2. Advance a season WITHOUT the upgrade; record how the mite load changed (your control).
3. Unlock Hygienic Behavior (Genetics line). Advance a comparable season; record the mite load again.
4. Optional: research the hornet defense (Heat-Ball Defense), trigger a Simulate hornet attack, and watch the heat ball form - a group defense, not an individual one.

Discuss (12 min)

- Did your prediction hold? What is your evidence (your two numbers)?
- **The selection idea:** choosing "hygienic" bees is choosing which bees reproduce. Over real generations, how would that change the whole population? (HS-LS4.)
- The mite and the bee are in an arms race - each adapts to the other. What might the mite "evolve" in response to resistant bees?
- The heat ball cooks the hornet at a temperature the bees barely survive. Why is this only possible as a group, never by one bee?

Check for understanding

Collect hypothesis sheets. Look for a stated prediction, two comparable data points, and a conclusion that uses the word evidence. For HS, look for a correct link between selecting a trait and changing allele frequency over generations.

Differentiate

- **Support:** provide sentence frames for the prediction and conclusion.

- **Stretch:** "Mite populations can double monthly. If you start at 2% and it doubles each month, when does it cross the danger line? Model it." (Exponential growth.)

Lesson 6 · Nobody's in charge: emergence & complex systems

Grades	8-12; great CS / math crossover
Time	~50 min
Grouping	Small groups + discussion
Standards	HS-LS2-8; crosscutting: Systems & System Models

Objectives

- Define emergence: complex group behavior arising from simple individual rules with no central control.
- Identify emergent behaviors in the colony and state the simple local rule each might come from.
- (CS extension) Connect the colony to an agent-based model - many simple agents, no controller.

Hook (6 min)

Play a 60-second "no-talking" ordering game: students silently line up by birthday using only gestures. It works - with no leader. Name the feeling: organized behavior, no one in charge. That is emergence.

Explore (20 min)

1. Research Heat-Ball Defense, then trigger a hornet attack. Watch the ball form and the temperature climb. Note: which bee "decided" to do this?
2. Watch the open-field swarm for two minutes: foragers arcing out and back, the dancer's figure-eight. For each, propose the simple per-bee rule that could produce it.
3. In the journal, list three behaviors that look "planned" and, beside each, the simple rule that might explain it with no planner.

Discuss (14 min)

- The heat ball reaches a temperature that kills the hornet but spares the bees - a razor-thin margin. No bee measures it. How can the right temperature emerge anyway?
- What is the difference between "the colony decided" and "a decision emerged"? Does the distinction matter?
- **CS bridge:** if you wrote a program where each bee follows three rules, would you expect the colony's behavior to be in your code, or to appear when you run it? Where does the "intelligence" live?
- **Bigger picture:** name another system that is smart as a whole but has no one in charge (markets, traffic, brains, the internet, an ant trail).

Check for understanding

Each group presents one emergent behavior and the simple rule behind it. A strong answer states a local, individual rule (no global knowledge, no leader) and explains how repetition across many bees yields the group pattern.

Differentiate

- **Support:** give three behaviors and three candidate rules to match up.

- **Stretch (CS):** sketch pseudocode for one bee (a few if-statements) and argue what colony-level pattern would emerge if 10,000 ran it at once.

7 · Capstone project: the colony stewardship report

A culminating task that pulls the whole unit together and produces a gradeable artifact. Plan two class periods plus writing time.

The task

Students "steward" one colony through a full simulated year and write a short **evidence-based report** on the decisions they made and why. The report must (1) describe the colony as a system using correct vocabulary, (2) justify at least three research choices with reasoning, and (3) support claims with data the student recorded from the dashboard.

Suggested prompt for students

"You are the steward of a honeybee colony. Guide it through one full year. Keep a log of your colony's population, stores, temperature, and mite load each season, and of every research choice you make. Then write a 1-2 page report that explains how your colony works as a single living system, defends three decisions you made using your own data, and identifies the moment in the year your colony was most at risk - and what kept it stable."

What makes this rich

- It forces a system view: no single number wins; honey, population, mites, and temperature interact.
- It is genuinely argumentative - there is no single correct research path, so students must defend choices with evidence.
- Because there is no fail state, the grade rests on reasoning quality, not on "winning."

Sample 4-point rubric

Criterion	4 - Exceeds	3 - Meets	2 - Developing	1 - Beginning
Systems understanding	Explains how subsystems interact and trade off; uses vocabulary precisely	Describes the colony as a system with correct terms	Lists parts but few connections	Parts named with errors
Use of evidence	Specific recorded data support every claim; compares across seasons	Data support most claims	Some data, loosely tied to claims	Little or no data
Reasoning on decisions	Defends 3+ choices with cause-and-effect reasoning and trade-offs	Defends 3 choices with reasons	Defends choices weakly	Choices listed, not justified

Criterion	4 - Exceeds	3 - Meets	2 - Developing	1 - Beginning
Communication	Clear, organized, audience-aware	Organized and understandable	Some organization issues	Hard to follow

Alternative capstones

- **Model critic (HS/AP):** instead of stewardship, write a critique - "Where does SimBee model real bees well, and where does it bend the truth? Use Section 9 ideas and cite three specific simplifications." Targets the modeling practice directly.
- **Teach-it-back:** student pairs build a 3-minute explainer (poster, slides, or video) on one concept from Section 5, using the game as their visual aid.

8 · Discussion, writing & assessment bank

Mix-and-match prompts beyond the per-lesson ones. Use as bell-ringers, exit tickets, journal entries, or discussion seeds.

Quick formative checks (5 minutes or less)

- Name the five worker jobs in life-cycle order.
- A dance points straight up. Where is the food, relative to the sun?
- What is the brood-nest set-point temperature, and one thing bees do when it is too cold?
- Honey is made from _____, not pollen. Pollen feeds _____.
- Give one example of an emergent behavior and the simple rule behind it.

Discussion / Socratic prompts

- Is the queen a ruler, a parent, or an organ of the colony - and what evidence supports your choice?
- Why might a colony be better thought of as one organism than as 40,000 organisms?
- The bee dance is imprecise on purpose. Where else in nature might "imperfect" be better than "perfect"?
- If you could only research one upgrade all year, which serves the colony best - and what are you giving up?
- Should a beekeeper intervene against mites, or breed for resistance and wait? What does each choice cost?

Extended writing prompts

- Write a "day in the life" from the point of view of one worker bee as she ages from cleaner to forager.
- Explain to a younger student how a hive stays warm in winter with no heater and no boss.
- Argue: "The smartest thing about a bee colony is that no bee is smart." Defend or refute, with examples.
- Compare colony homeostasis to homeostasis in the human body - two ways they are alike, one way they differ.

Cross-curricular hooks

- **Math:** average your dance-decode errors; model mite doubling as exponential growth; convert "seconds of waggle" to km.
- **CS:** describe the colony as an agent-based model; sketch the rules one bee would need.
- **ELA:** the von Frisch discovery as a story of decoding a hidden language; persuasive essay on protecting pollinators.
- **Art / design:** the hexagon as the optimal shape for storage - why comb is built the way it is.

9 · Where the model bends (and how to use that)

Every simulation simplifies. Naming these out loud builds exactly the habit NGSS wants - evaluating a model against the system it represents (SEP-2). Each row pairs a simplification with a discussion prompt that turns it into thinking.

The model says...	In reality...	Turn it into a question
Resources are abstract units (honey "/60").	Colonies store honey in kilograms; needs are measurable.	What would change if we tracked real mass? What would get harder to show?
A full year passes in ~2½ minutes.	A real colony year is 365 days of slow change.	What does speeding up time help you see? What does it hide?
The colony can't die (population has a floor).	Real colonies absolutely can collapse.	If you can't lose, what is the game actually for? How would a fail state change how you'd play?
Some behaviors are described but not animated (washboarding, festooning, swarming, nest-site voting).	These are real, observed behaviors.	Why might a designer describe a behavior but not simulate it? Which would you add, and how?
Pheromones are not shown as a visible layer.	Scent is a primary channel of colony communication.	How would you represent an invisible chemical signal on screen?
Research "points" buy traits instantly, like a tech tree.	Traits like mite resistance come from selection over many generations.	Is a tech tree a fair way to model evolution? What is misleading about it?

The meta-lesson

If students leave able to say "SimBee is a useful model, and here are three ways it differs from real bees," they have demonstrated one of the most transferable skills in all of science. That sentence is worth more than memorizing every caste.

10 · Common misconceptions to head off

Students (and many adults) arrive with these. The game is a good place to confront them - the right view is usually visible on screen.

Common belief	What's actually true	Where the game helps
"The queen rules the colony and gives orders."	She lays eggs and emits a cohesion pheromone. She directs no labor; jobs self-organize by age.	Inspector shows jobs follow age; the queen is just one bee among tens of thousands.
"Bees consciously decide / vote like a committee."	Group decisions emerge from simple individual rules; no bee compares all options.	The heat ball and swarm flight show order with no decider.
"Bees make honey from pollen."	Honey is concentrated nectar (energy). Pollen is protein for brood.	Dashboard tracks honey and pollen as separate stores with different roles.
"All bees sting, and they can sting many times."	Only workers have a (barbed) sting and die after using it; drones can't sting. Bees are not wasps/hornets.	Drones in the inspector are flagged as having no sting; hornets appear as a separate threat.
"The waggle dance is a taught language like ours."	It is innate symbolic communication. Dialects exist, but it isn't taught the way words are.	The decode mini-game shows fixed rules (angle, duration), not learned vocabulary.
"Drones are lazy and useless."	Their role is reproduction (mating with a queen). "Useless" is a value judgment, not biology.	Inspector note reframes the drone's purpose.
"Varroa mites suck bee blood."	They feed on the fat body - a correction from recent research.	A chance to model how science updates (see 5.6).
"A bigger colony is always better."	Beyond a point, congestion triggers swarming; balance matters.	Population swings across seasons show there's no "just grow forever."

11 · Vocabulary

Front-load the starred terms; the rest can emerge in context. Plain-language definitions for students.

Term	Student-friendly definition
Superorganism ★	A colony that works like one living body - individuals can't survive alone.
Eusociality	The bee lifestyle: cooperative care of young, overlapping generations, and a division of labor.
Caste ★	A type of bee with a set role: queen, worker, or drone.
Temporal polyethism ★	The way a worker's job changes as she ages (cleaner → nurse → builder → guard → forager).
Forager	An older worker that flies out for nectar, pollen, and water.
Drone	A male bee whose role is to mate with a queen; does not work or sting.
Queen	The single egg-laying female; releases a pheromone that holds the colony together.
Waggle dance ★	A figure-eight dance that tells other bees the direction and distance to food.
Pheromone	A chemical signal bees use to communicate (alarm, cohesion, "feed me," etc.).
Brood	The colony's young: eggs, larvae, and pupae.
Metamorphosis	The change from egg → larva → pupa → adult.
Nectar / Honey	Nectar is flower sugar; bees concentrate it into honey to store energy.
Pollen	Flower protein; the raw material for raising brood.
Wax / Comb	Workers make wax from honey and build it into the hexagonal comb.
Thermoregulation ★	Keeping the brood nest near 35°C by shivering (warm) or fanning water (cool).
Homeostasis ★	Holding an internal condition steady despite outside change.
Negative feedback	A loop where a response reduces the very change that triggered it.
Varroa mite	A parasitic mite that weakens bees and spreads viruses - a top colony killer.
Hygienic behavior / VSH	Workers detecting and removing infested brood; a heritable defense bred for in real bees.

Term	Student-friendly definition
Emergence ★	Complex group behavior that arises from simple individual rules, with no one in charge.

12 · Quick reference (printable)

Controls at a glance

Action	How
Rotate / pan / zoom the view	Drag to rotate; right- or middle-drag to pan; scroll wheel to zoom.
Inspect a bee	Click it (a click that doesn't drag) to open the inspector.
Follow / become a bee	Inspector buttons: Follow (camera tracks it) or Become (fly first-person from it).
Fly first-person	WASD to move, mouse to look, Space/Shift to rise/descend, Esc to exit.
Pause / resume	Play-Pause button, or Space bar in the overhead view.
Speed	1× / 2× / 5× buttons, or keys 1 / 2 / 3.
Skip a season	"Skip to next season" jumps the clock ahead.
Open panels	Buttons for Colony dashboard, Research tree, Look inside the hive, Decode a waggle dance.

Where each concept lives in the game

To show students...	Go to...
Castes & age-based jobs	Click bees (Inspector) + Dashboard → Population
The waggle dance	Decode a waggle dance (mini-game)
Homeostasis / 35°C	Dashboard → temperature gauge
Energy & matter / stores	Dashboard → Stores and Activity
Life cycle / metamorphosis	Look inside the hive → click a brood cell
Mites & resistance	Dashboard → Threats; Research → Genetics
Group defense / emergence	Research Heat-Ball Defense → Simulate hornet attack

Time & scale facts

Quantity	Value
Starting colony	~12,000 bees, early spring
One simulated day	~3 seconds at 1× speed
One season	12 days ≈ about 40 seconds at 1× (~8 s at 5×)
A full year	~2½ minutes at 1× (~30 s at 5×)
Population range	Floors around 11,500; tops out around 62,000

Quantity	Value
Brood-nest set-point	35°C (95°F)
Dance distance rule	~1 second of waggle \approx 1 kilometer

Appendix · Reproducible student handouts

Three ready-to-copy handouts follow, one per page: a colony observation journal, a waggle-dance decode log, and a research/hypothesis sheet. They map to the lessons in Section 6.

Reproducible - photocopy freely · SimBee Teacher's Guide

Handout A · Colony Observation Journal

Watch your colony across the seasons. Record what the dashboard shows, then add what you notice.

Name: _____ Class: _____ Date: _____

Season / Day	Population	Honey	Temp & status	One thing I noticed

A bee I inspected:

Caste & job:
Age & what it was doing:

A question I now have about the colony:

Reproducible - photocopy freely · SimBee Teacher's Guide

Handout B · Waggle Dance Decode Log

Open "Decode a waggle dance." Watch the run, make your guess, submit, then record the true values and your error.

Name: _____ Class: _____ Date: _____

Dance #	True direction	My direction	Angle error (°)	True distance	My distance	Dist. error	Verdict

My average angular error across all dances: _____°

Real bees are off by 10-15° on every dance. Why is that "error" actually useful to the colony?

Handout C · Research & Hypothesis Sheet

Run a small experiment on a research upgrade. Predict first, then test against a "control" season.

Name: _____ Class: _____ Date: _____

1. The upgrade I am testing:

2. Current reading before I start (e.g., mite load, honey, population):

3. My prediction:

If I research _____, then _____ will

_____.

because

_____.

4. CONTROL - reading after one season WITHOUT the upgrade:

5. TEST - reading after one comparable season WITH the upgrade:

6. My conclusion (did the evidence support your prediction? quote your two numbers):