BBKA MODULE 5 · HONEY BEE BIOLOGY

The whole course on one page at a time

End-of-course summary of the study-group sessions

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SUMMARY

01 · min 3–8
Origins and digestion
Evolution, gut, excretion

02 · min 8–15
Breath, blood, glands
Tracheae, haemolymph, pheromones

03 · min 15–21
Nerves and senses
Brain, ganglia, sensilla, eyes

04 · min 21–30
Hormones and seasons
Endocrine glands, winter bees, fat body

05 · min 30–39
Reproduction and caste
Queen, drone, genetics, royal jelly

06 · min 39–43
Development
Egg, larva, pro-pupa, pupa, imago

07 · min 43–47
The body wall
Cuticle and exoskeleton

08 · min 47–56
Tools of the bee
Wings, legs, mouthparts, sting

01 · ORIGINS

Where the honey bee sits

Arthropoda → Insecta → Hymenoptera → Apidae → Apis → **mellifera, the honey maker**

100 MYA
first bees: wasp-like carnivores

37 MYA
honey bee fossil: a pollen feeder

8 species
in the genus Apis

A eusocial superorganism: overlapping generations, cooperative brood rearing, reproductive division of labour, polyandry and genetic diversity.

The alimentary canal: one tube, three origins

Foregut · stomodeum
Mouth to crop
Cibarial pump, oesophagus with peristalsis, crop holding up to about 40 mg of nectar

→

The gatekeeper
Proventriculus
Four spined flaps gulp pollen out of nectar and pass it on as a bolus

→

Midgut · mesenteron
Ventriculus
Main site of digestion and absorption; lined by the peritrophic membrane

→

Hindgut · proctodeum
Ileum to anus
Small intestine, then rectum holding faeces until a cleansing flight

Ventriculus enzyme	What it does
Invertase (sucrase)	Sucrose to glucose and fructose; also added to nectar by foragers
Amylase (diastase)	Breaks down starch
Lipases · proteases	Fats to fatty acids and glycerol · proteins to amino acids

01 · EXCRETION

Malpighian tubules filter, the rectum reclaims

1

Filter

Waste taken from the haemolymph at the free ends of the tubules

2

Reabsorb

Useful substances, water and salts returned to the haemolymph

3

Pass on

Remaining waste enters the gut at the pylorus

4

Remove

Held in the rectum and voided through the anus

Main waste

Nitrogen excreted as uric acid.

Six rectal pads

Reabsorb over 90% of the water and salts.

Air goes straight to the cells

Spiracles
10 pairs: 3 thoracic, 7 abdominal; valved

Tracheae
Held open by spiral taenidia

Air sacs
No taenidia; balloon-like bellows

Tracheoles
0.1–1 µm; end in fluid-filled alveoli by the tissues

At rest

CO_2 triggers abdominal pumping. Air enters mainly by the 1st thoracic spiracle and leaves by the 2nd.

In flight

In through the 1st thoracic spiracle, out through the abdominal spiracles, valves working in step.

Gas exchange

Oxygen dissolves in alveolar fluid and diffuses into the tissue; CO_2 leaves the same way.

An open system bathed in haemolymph

The pump

- Dorsal vessel: heart in the abdomen, aorta through the thorax to the brain
- 5 pairs of ostia act as one-way valves
- Dorsal and ventral diaphragms ripple to drive flow
- Antennal vesicles supply the antennae

The fluid

- Plasma: salts, sugars, amino acids, proteins, lipids, uric acid
- Haemocytes engulf bacteria and parasites
- Colourless; content varies with age and condition

The jobs

- Carries food, waste and hormones
- Hydrostatic support
- Fluid balance
- Defence by phagocytosis
- Growth and repair

Flow: forward along the back through the heart and aorta, then back towards the abdomen below the gut.

The colony’s chemical language

Gland	Where	Secretion and role
Hypopharyngeal	Head, beside the pharynx	Brood food in nurses; invertase and glucose oxidase in foragers
Mandibular	Above the mandibles	Worker: brood-food lipids, 2-heptanone · Queen: QMP (9-ODA, 9-HDA, HOB, HVA)
Salivary (labial)	Head and thorax	Dissolve dry food, groom the queen
Nasonov	Under tergite A7	Geraniol and nerol: orientation, swarm marking
Koschevnikov	Sting chamber	Isopentyl acetate alarm pheromone (“bananas”)
Dufour’s	Sting chamber	Esters in queens, hydrocarbons in workers: a fertility signal
Arnhart (tarsal)	5th tarsomere	Footprint pheromone; part of queen substance
Wax glands	Sternites 4–7, 4 pairs	Wax scales on the mirrors; about 8 lb honey per 1 lb wax at 35 °C
Renner-Baumann	Queen tergites	Queen-only tergite pheromone

A brain, a chain of ganglia, and synapses between

Protocerebrum
Optic lobes, mushroom bodies, central complex

Deutocerebrum
Antennal lobes: smell, taste, touch

Tritocerebrum and SEG
Links to the gut; mandibles, mouthparts, taste

Ventral nerve cord
2 thoracic + 5 abdominal ganglia

Ganglia
Relay stations that can run their segment without the brain; cell bodies outside, neuropil inside.

Fusion
Some ganglia sit a segment ahead of the region they serve (Snodgrass).

Synapses
Electrical impulse along the axon, chemical transmitter across the gap.

Sensilla: the cuticle turned into sense organs

Sensillum	Shape	Main sense
Placodea	Pore plate	Smell (the main one)
Trichodea	Long hair	Smell, touch, airflow
Basiconica	Short peg	Smell and taste
Chaetica	Bristle	Taste and touch
Coeloconica	Peg in a pit	Humidity, temperature
Coelocapitular	Knob in a pit	Humidity, temperature
Ampullacea	Peg in a flask	Probably CO_2
Campaniformia	Dome	Strain in the cuticle

The antenna

- Scape, pedicel, flagellum
- 10 flagellomeres in queen and worker, 11 in the drone
- Johnston’s organ in the pedicel: about 300 scolopidia sensing vibration, sound and airspeed

Two eye systems with different jobs

≈ 5,500
ommatidia per worker eye; up to 8,600 in drones

UV · blue · green
trichromatic but red-blind

≈ 200 Hz
flicker fusion, about 5× ours

Compound eyes: the image

Each ommatidium: corneal lens, crystalline cone, pigment cells, retinula cells around a rhabdom. Dorsal rim reads polarised skylight.

Three ocelli: the horizon

One thick lens each, focused behind the retina. They read light level and horizon to stabilise flight.

Four centres, two hormones that do the work

Neurosecretory cells

Brain (pars intercerebralis and lateralis): PTTH, allatotropin, insulin-like peptides

Corpora cardiaca

Behind the brain on the aorta: store and release brain hormones

Corpora allata

The only source of juvenile hormone (JH III)

Prothoracic glands

Ecdysone; larva and pupa only, gone soon after emergence

Ecdysone decides when

Stimulus → brain makes PTTH → released from corpora cardiaca → prothoracic glands → ecdysone → apolysis.

JH decides what

High JH: the moult stays larval. Low JH: pupa, then adult.

One see-saw, three changes

	Nurse to forager	Summer to winter bee	Laying workers
Trigger	Fewer foragers, less brood	Less pollen, shorter days, brood stops	Queen and open brood both lost
Brain	Octopamine up; allatotropin	Pars intercerebralis damps the CA	Dopamine signalling released
Juvenile hormone	Rises	Stays low	Rises
Vitellogenin	Falls	Stays high	Diverted to own ovaries
Outcome	Short-lived forager	Long-lived winter bee	Unfertilised eggs: drones

The rule: JH and vitellogenin suppress each other. Knock vitellogenin down and JH rises, sending bees out to forage early.

04 · SEASONS

A winter bee is a nurse bee with no brood to feed

Trait	Summer bee	Winter (diutinus) bee
Lifespan	About 4–6 weeks	Several months, up to about 8
Fat body	Small in foragers	Enlarged, rich in lipid and protein
Hypopharyngeal glands	Shrink once foraging starts	Large and well developed
Hormones	JH rises, Vg falls in foragers	JH low, Vg high all winter
Mushroom bodies	Grow with foraging	Hold steady, grow again in spring

Treat Varroa early
Parasitised pupae emerge with less Vg.

Watch autumn pollen
It sets how well winter bees are made.

In spring
The switch reverses: JH up, Vg down.

04 · FAT BODY

Liver and larder in one tissue

Where: loose sheets in the abdomen, bathed in haemolymph. The parietal layer lines the body wall; the perivisceral layer wraps the gut.

Cells: trophocytes (mesoderm) store and make proteins; oenocytes (ectoderm) handle lipids, hydrocarbons and detoxifying.

Reserves
Triglycerides, glycogen, protein

Vitellogenin
Brood food, antioxidant, long life

Energy
Makes trehalose, the blood sugar

Immunity
Apidaecin, abaecin, defensin

Detoxifying
P450 enzymes clear pesticides

Signalling
Insulin/TOR and JH links

Through life: builds in the larva, fuels the non-feeding pupa, peaks in nurses and winter bees, runs down in foragers.

An egg factory with a sperm bank

Ovaries
150–180 ovarioles each; fill two-thirds of the abdomen

Oviducts
Two lateral oviducts join the median oviduct

Spermatheca
About 1.1 mm sphere; gland, duct and sperm pump

Vagina
Valve fold, bursa copulatrix, bursal pouches

Inside an ovariole

Terminal filament, germarium, vitellarium (oocytes fed by nurse cells), pedicel. Follicle cells lay down the chorion.

Her choice, egg by egg

The valve fold presses each egg to the spermathecal duct. Sperm released: a female. None: a drone.

Built for one flight

Testes
All sperm made before emergence; shrink by day 12

→

Vasa deferentia
Coiled tubes to storage

→

Seminal vesicles
Sperm mature here, days 6–14

→

Mucus glands
Mucus drives semen out; forms the mating sign

→

Endophallus
Bulb, cervix, vestibule with cornua, phallotreme

≈ 7 million
sperm per drone, peaking near day 20

10–20
drones mate with one queen

5–7 million
end up in her spermatheca

Mating is fatal: the endophallus everts under haemolymph pressure, tears, and is left in the queen.

Haploid males, diploid females

2n = 32

Queen and worker

From fertilised eggs

n = 16

Drone

From unfertilised eggs: arrhenotoky

csd

Sex gene

Two different alleles: female. Two matching: diploid male, removed by workers within about 6 hours

Modified meiosis in drones

The first division aborts and the second is unequal, so each cell gives one sperm and every sperm is identical.

Mendel still applies

Segregation and independent assortment in queens; workers with the same father share 75% of genes.

Same egg, different diet

	Royal jelly	Worker jelly
Gland mix	More mandibular	Mostly hypopharyngeal
Sugar, days 1–3	About 3–4× higher	Lower, rises later
Pollen	Almost none	Added after day 3
Amount	In excess, throughout	Rationed
Result	Queen: 16 days, 150–180 ovarioles	Worker: 21 days, 2–12 ovarioles

From diet to queen

1 Rich diet in the first 3 days

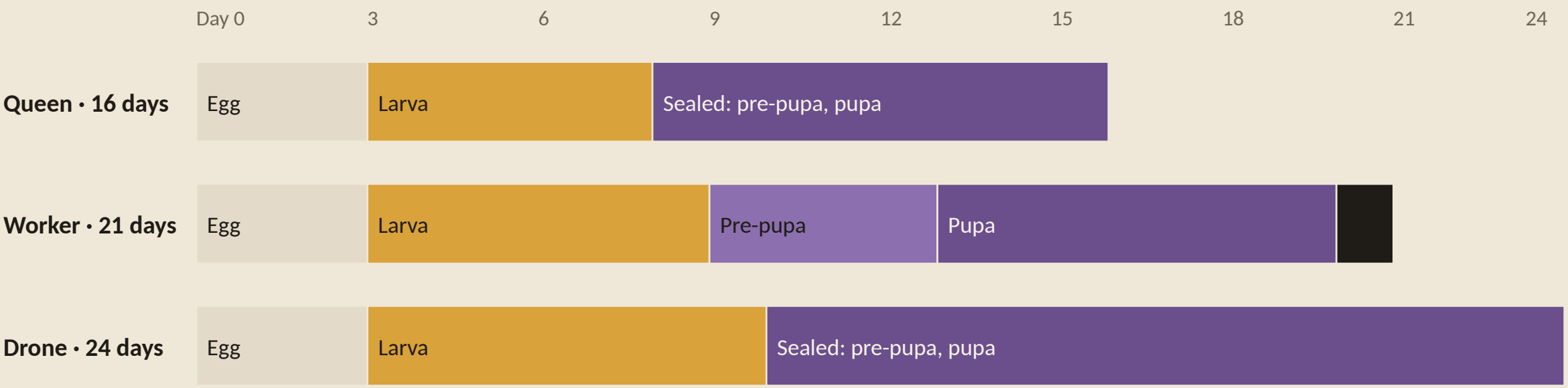
2 Insulin/TOR sensing; SNS and brain signal the CA

3 JH peaks in the 4th–5th instar

4 Kr-h1 switched on; DNMT3 methylation changes

No single magic ingredient: sugar and quantity matter; royalactin is disputed. Larval age, cell type and colony signals also count.

Egg to adult: 16, 21 and 24 days



Worker key days

Hatch 3, sealed 9, pupa 13, final moult 20, emerge 21.

Black end-block

The adult, moulted but still in its cell.

Complete metamorphosis in six moults

Larva

Head and 13 segments; 5 instars. Midgut closed off from hindgut; 4 Malpighian tubules; 10 pairs of open spiracles.

Pro-pupa

Cell sealed. JH falls, ecdysone rises; silk glands spin the cocoon. Gut joins and waste is voided.

Pupa

Exarate: legs and wings free. Eyes pink to purple, cuticle darkens; drone sperm move to the vesicles.

Imago

Final moult in the cell, then chews out through the capping as a pale callow bee.

Apolysis

Ecdysone rises and the epidermis separates from the old cuticle; a new one forms beneath.

Ecdysis

The old cuticle splits and is shed; the new one expands and hardens.

One body wall, folded inwards

Epicuticle
Cement, wax and cuticulin: waterproofing

Exocuticle
Hardened by sclerotisation

Endocuticle
Chitin fibres in protein; flexible

Epidermis
Living cells on a basement membrane

Invaginations

Cuticle lines the foregut, the hindgut and the tracheae (as taenidia), so all are shed at a moult.

Making a new cuticle

Apolysis, then new epicuticle first, procuticle beneath, old endocuticle digested and recycled, ecdysis, hardening.

07 · THE EXOSKELETON

Hard plates, soft joints

Each segment is a ring: tergum above, pleura at the sides, sternum below, joined by flexible membrane. The worker's visible abdomen shows 6 tergites and 6 sternites.

It grows inwards too: apodemes brace the body and anchor muscles: the tentorium in the head, phragmata and furcae in the thorax.

Support
Shape without bones

Muscle anchorage
Levers for walking and flight

Protection
Armour against knocks and pathogens

Waterproofing
Waxy epicuticle cuts water loss

Sensing
Hairs, pits and pore plates

Tools
Baskets, cleaners, wax mirrors, sting

The price: it cannot grow, so only the larva moults; and its soft joints let Varroa feed and tracheal mites enter.

A spring-loaded box drives the wings

≈ 20
hamuli hook hindwing to forewing

≈ 230
wingbeats a second

≈ 30 °C
thorax needed for take-off

Indirect muscles: power

DVM pull the tergum down (wings up); DLM bow it up (wings down). Asynchronous: one impulse, many beats.

Direct muscles: control

At the wing base they twist, steer and fold the wings, and can unlock them from the motor.

In the colony: shivering heats brood to 35 °C and the winter cluster; fanning cools, ventilates, dries nectar and spreads Nasonov scent.

One ground plan, three tool kits

Coxa · Trochanter · Femur · Tibia · Tarsus: basitarsus + 4 · **Pretarsus: claws, arolium**

Foreleg (T1)

Strigilis: a comb-lined notch on the basitarsus closed by the velum, for cleaning antennae.

Midleg (T2)

Support on the flower; brush passes pollen back; tibial spur levers pellets off.

Hindleg (T3)

Pollen combs, rastellum and auricle press pollen into the corbicula: 10–30 mg a pair.

Feet: claws grip rough surfaces, the arolium unfolds on smooth ones; tarsal sensilla taste sugar and Arnhart's glands leave the footprint scent.

Chew, lap, sense

Mandibles

Worker: smooth and spoon-shaped, with a groove for gland secretion; moulds wax, cleans, uncaps.

Proboscis

Galeae and labial palps form a tube round the hairy glossa, 6–7 mm in workers. Lap, retract, suck by the cibarial pump.

Antennae

Scape, pedicel, flagellum: smell, touch, taste, and hearing through Johnston’s organ.

Setae

Made by a trichogen cell (hair) and tormogen cell (socket). Branched hairs trap pollen; sensory hairs feel touch and airflow; hair plates sense posture.

Many jobs

Feeding, trophallaxis, feeding brood, building comb, grooming and handling propolis all use the mouthparts.

Queen, worker and drone compared

	Queen	Worker	Drone
Mandibles	Large, deep notch	Smooth, spoon-shaped	Small, small notch
Tongue	Short	Longest, 6–7 mm	Short
Antennae	10 flagellomeres	10 flagellomeres	11, many more pore plates
Compound eyes	Smaller	≈ 5,500 facets	Up to ≈ 8,600; meet on top
Hind legs	No pollen kit	Corbicula, press, combs	No pollen kit
Wings	Short for her abdomen	Cover most of abdomen	Large, strong fliers
Sting	Smooth, curved, reusable	Barbed, torn out	None

An ovipositor turned weapon

Structure

Oblong, quadrate and triangular plates each side; protractor and retractor muscles; a stylet and two barbed lancets in a sheath.

Mechanics

The protractor pulls the quadrate plate onto the triangular plate, which swings and drives each lancet down in turn.

Venom delivery

Two gland tubules fill the venom sac; lancet valves pump venom down the canal: 50–140 µg a sting.

Autonomy

Barbs lock in skin; the apparatus and its terminal ganglion tear free and keep pumping.

Venom: melittin (bursts cells, releases histamine), phospholipase A (pain, cell damage), hyaluronidase (opens tissue for the rest).

PULLING IT TOGETHER

Four threads run through every session

The cuticle

Skeleton, gut and tracheal lining, sensilla, wings, pollen baskets and sting: all one material.

JH against vitellogenin

Caste, nurse to forager, winter bees and laying workers.

Nutrition

Glands make brood food, diet sets caste, the fat body stores it for winter.

The superorganism

Pheromones and shared food make thousands of bees act as one.

Questions?

Go back to the session decks for the full diagrams. Good luck in the exam.

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