MODULE 5 STUDY GROUP

SESSION 2

The Circulatory System

The Exocrine glands

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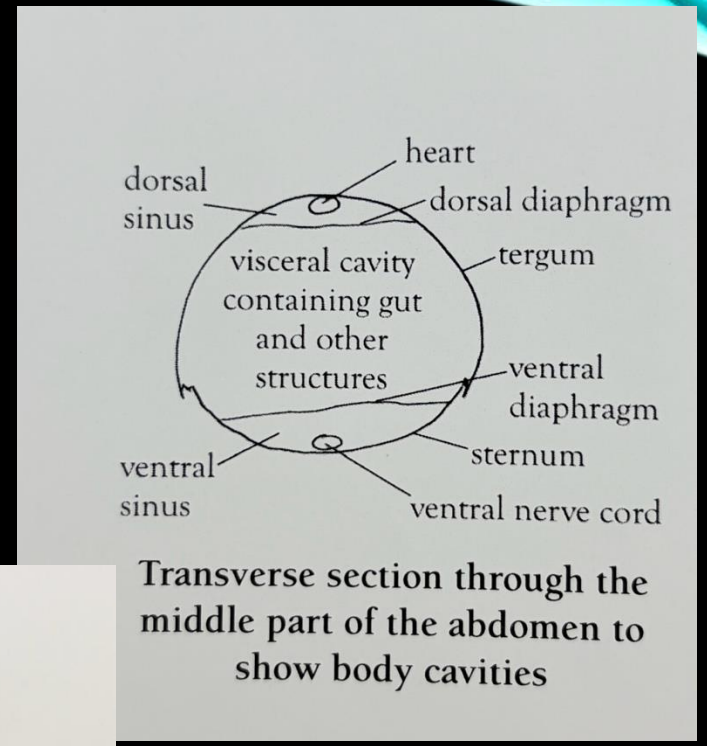
THE CIIRCULATORY SYSTEM

Open system

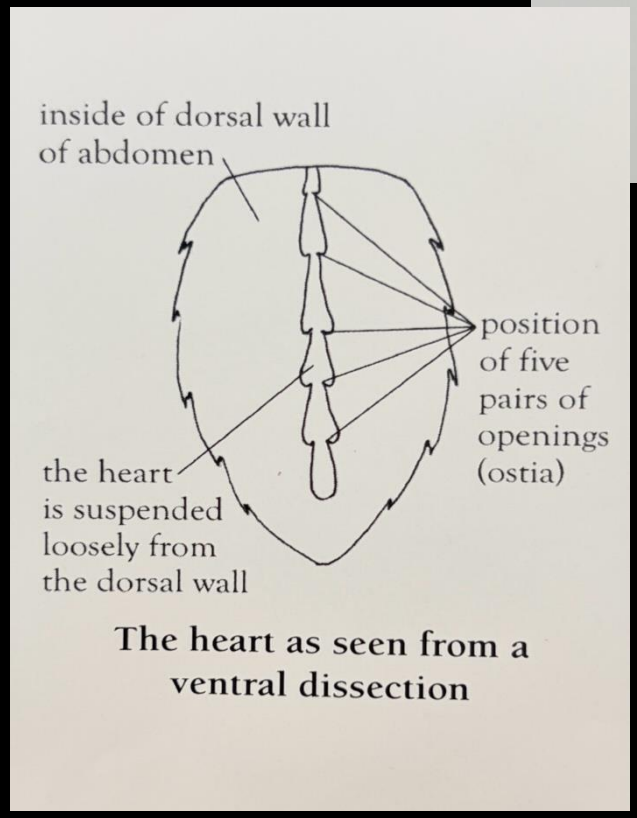
Organs suspended in cavities filled with haemolymph

Haemolymph is composed of plasma and haemocytes

Heart is a long structure with 5 pairs of valves



Transverse section through the middle part of the abdomen to show body cavities



The heart as seen from a ventral dissection

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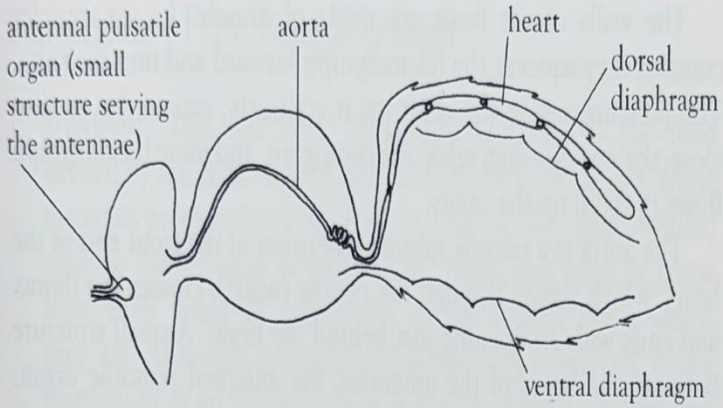
MAIN PARTS OF CIRCULATORY SYSTEM

Antennal vesicle supplies the antennae by a series of contractions controlled by the muscles in the pharynx

Aorta – carries haemolymph to the head and continuously to the brain

Heart

- **runs from T2 to A9.**
- **has 5 pairs of openings called ostia.**



Lateral (side) view of the main parts of the circulatory system

(redrawn from Dade, 1977)

Ventral and dorsal diaphragms

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Ostia act as one-way valves :

- opening to allow haemolymph to enter the heart
- closing to force it forward when the muscular walls of the heart contract.

Dorsal & ventral diaphragms

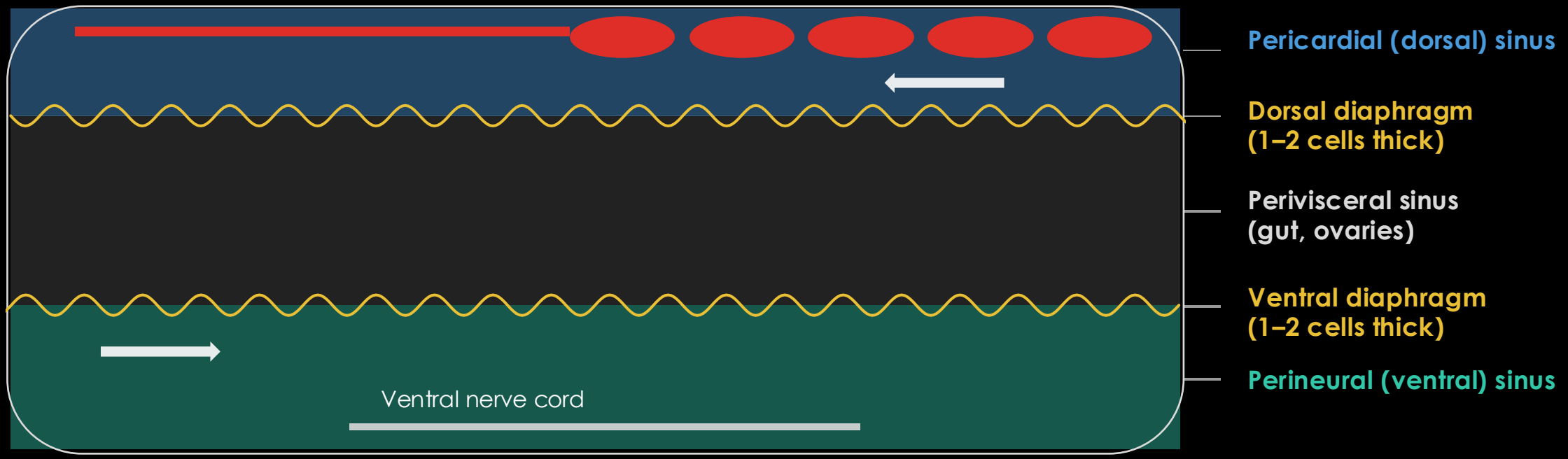
- attached to the apodemes of the tergites and sternites.
- Set up waves of muscular contractions
- Force haemolymph from thorax to abdomen (ventral) and from abdomen to thorax (dorsal)

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DIAPHRAGMS & SINUSES OF THE HAEMOCOEL

Dorsal vessel: aorta (thorax) + 5 heart chambers (abdomen)



Longitudinal section: two thin muscular diaphragms partition the haemocoel into three sinuses; the diaphragms undulate to drive haemolymph forward dorsally and rearward ventrally.

COMPOSTION OF HAEMOLYMPH

PLASMA

Colourless liquid

Contains following dissolved substances:

- Salts
- Amino acids
- Proteins
- Carbohydrates
- Uric acid and urates
- Lipids
- Fatty acids
- Other organic compounds

Varying amounts according to the age and condition of the bee

HAEMOCYTES

Colourless cells that ingest and destroy harmful bacteria

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HAEMOLYMPH FUNCTIONS

Transport of material round the body including:

- **Food**
- **Waste material**
- **Hormones**
- **Oxygen and carbon dioxide**

Provision of structural support by filling the body cavities with fluid

Maintenance of fluid balance levels in all the cells of the body

Metabolism of food

Destruction of harmful bacteria and parasites by phagocytosis*

Growth and repair of tissue

Provision of immunity

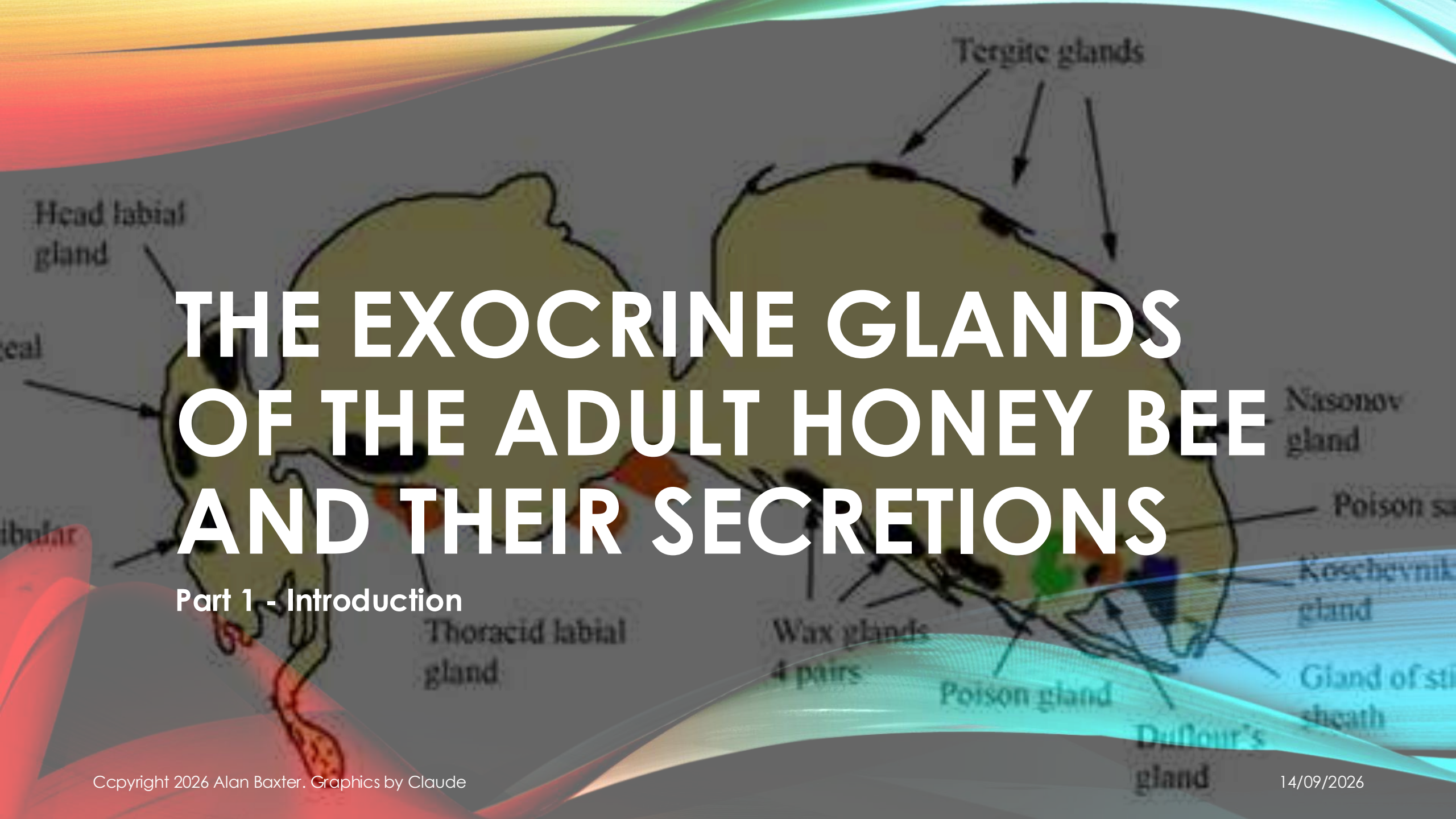
Eversion of the endophallus in the drone

*** Where one cell engulfs another**

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Any questions ?

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THE EXOCRINE GLANDS OF THE ADULT HONEY BEE AND THEIR SECRETIONS

Part 1 - Introduction

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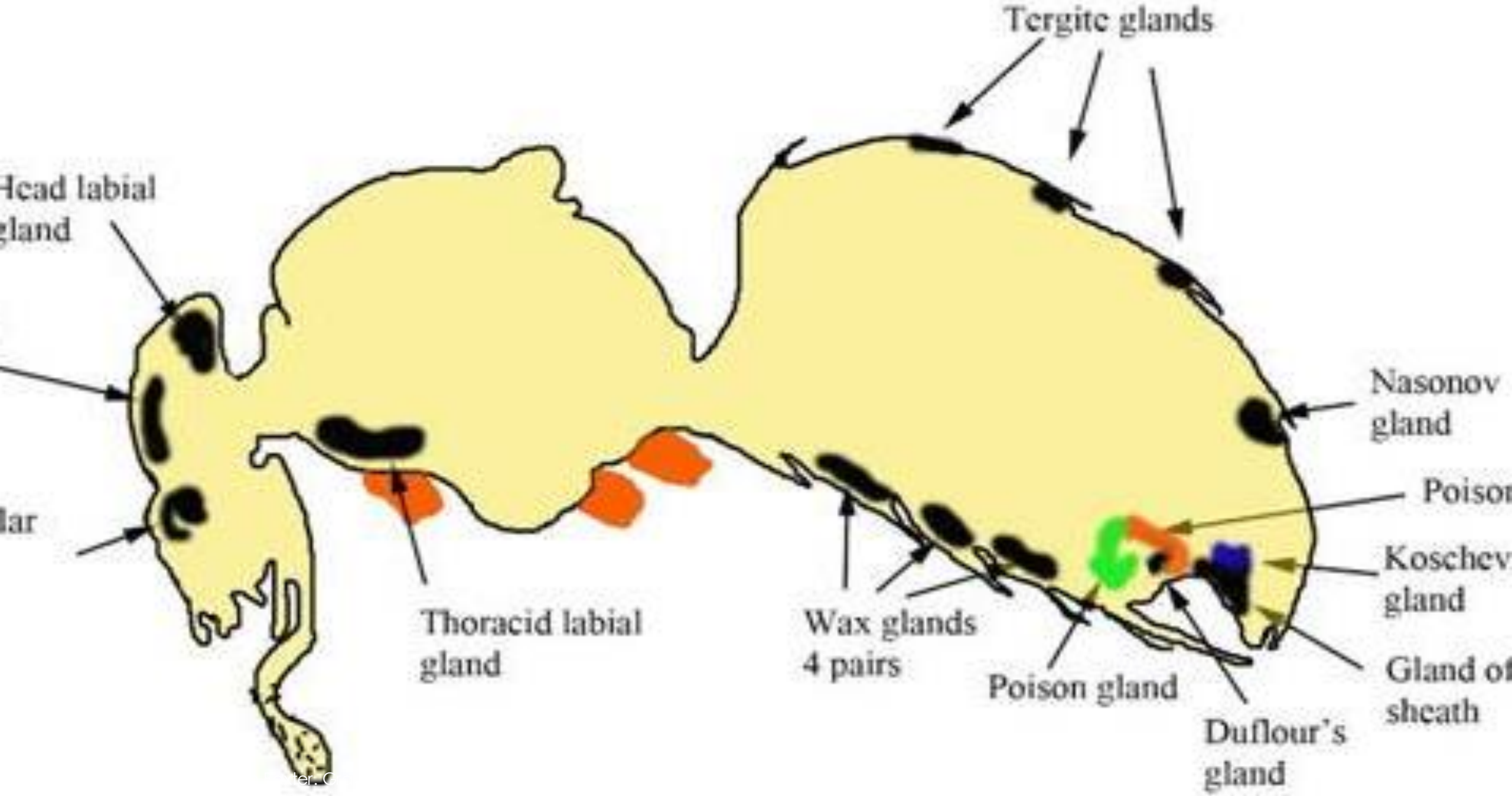
What is an exocrine gland?

- A bodily organ that secretes a substance known as a pheromone to the outside of the body through a duct.
- Pheromones are received by a second individual of the same species, or in some cases by another species
- Release a specific reaction which may be behavioral, developmental or physiological

Pheromones are divided into 2 types:

- Primer pheromones triggering long-term, irreversible physiological change.
- Releaser pheromones giving an immediate, short-term response

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Tergite glands
Head labial gland
Nasonov gland
Thoracid labial gland
Wax glands 4 pairs
Poison gland
Duflour's gland
Gland of sheath

THE EXOCRINE GLANDS

- Nasonov gland
- Poison glands*
- Mandibular gland
- Koshevnikov gland
- Dufour gland
- Arnhart or Tarsal glands
- Wax glands
- Silk glands of the larva **
- Tergite or Renner-Baumann gland of the queen

**we will consider the sting mechanism in a later lesson*

*** this will be covered in the lesson on the development of the honey bee.*

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NASANOV GLAND

Located beneath the tergum of A7

Normally hidden but can be seen when the bee stretches as a pale strip between the terga of A6 and A7

Produces Nasanov pheromone which is used for marking or orientation including :

- **During swarming to mark the entrance to the new nest**
- **Attract the queen to the hive after mating flight**
- **Recall workers after disturbance of the colony**
- **Mark the entrance for bees on orientation flights**

The worker raises her abdomen to expose the gland and fans her wings to spread the pheromone



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NASANOV PHEROMONE COMPONENTS

Complex mixture of chemicals:

Geraniol*

Nerolic acid

Geranic acid

(E)-citral

(Z)-citral

(E,E)-farnesol

Nerol**

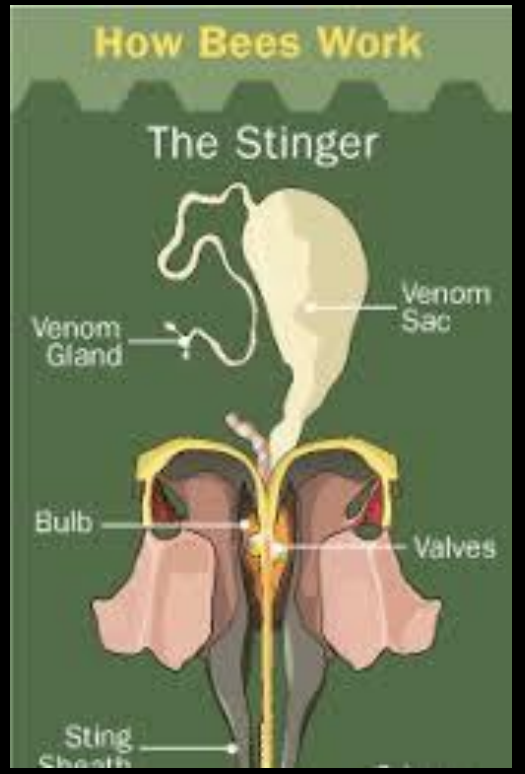
- Geraniol has the greatest volume,

** Nerol is the most potent

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THE POISON SAC OR VENOM GLAND

- Part of the sting mechanism located in a cavity in the A7 segment called the sting chamber
- Forked tubule located in the sting chamber behind the sting
- Connects to the bulb of the venom sac



Sting mechanism will be covered in a later lesson

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VENOM

Composed of the following chemicals:

Melettin	Causes rupture of the blood & mast cells Release of histamine & serotonin from the mast cells Lowers blood pressure & respiration
Phospholipase A	Breaks down of cells Cause pain Toxicity acting synergistically with Melettin
Hyaluronidase	Hydrolyses connective tissue opening up passages for other chemicals
Acid phosphate	Involved in allergic reaction
Histamine	Itching Pain

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THE GLANDS ASSOCIATED WITH THE STING & THE ALARM PHEROMONES

Mandibular glands (worker)	situated above the mandibles produce the pheromone 2-heptanone repel robbing bees at the entrance
The paired Koschevnikov glands	in the sting chamber produces alarm pheromones
The sting glands	area of hairy cuticle called the setose membrane around the lower part of the sting bulb pheromones produced by an area of glandular cells at the proximal end of the sting

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THE ALARM PHEROMONES

Main constituent	Isopentyl acetate	alerts bees at the entrance highly volatile
Others include	(Z)-ll-eicosen-1-ol	enhances and stabilizes Isopentyl acetate
	n-butyl acetate	
	n-hexyl acetate	
	2-nonyle acetate	
	eicosanol acetate	
	octanoic acid	
	1-butanol	
	1-pentanol	
	2-heptanol	
	1-octanol	

Said to smell like ripe bananas!

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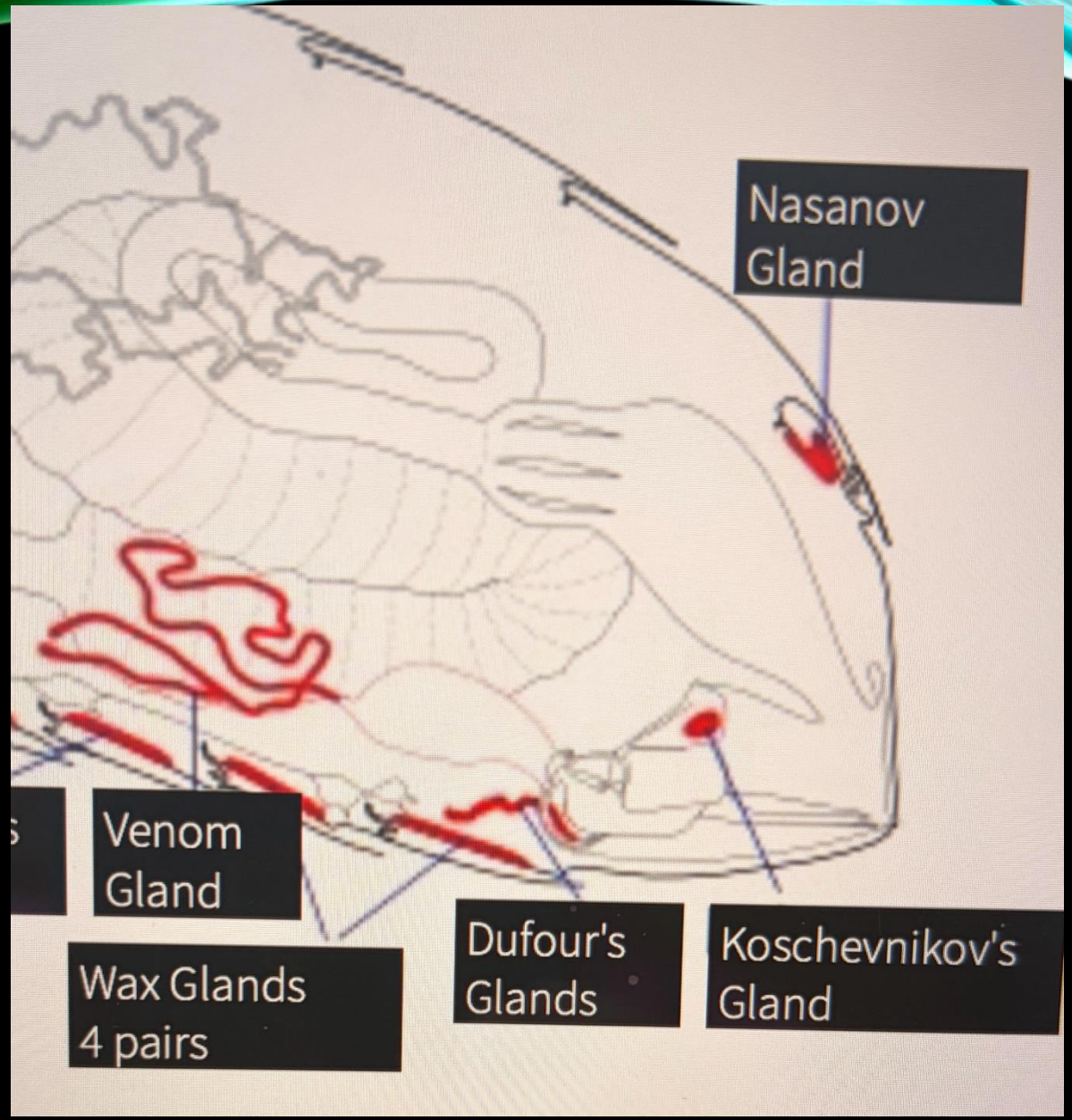
DUFOUR'S GLAND (FORMERLY THE ALKALINE GLAND)

Different in queens, workers & laying workers

Indicative of fertility and fecundity

COMPOSITION

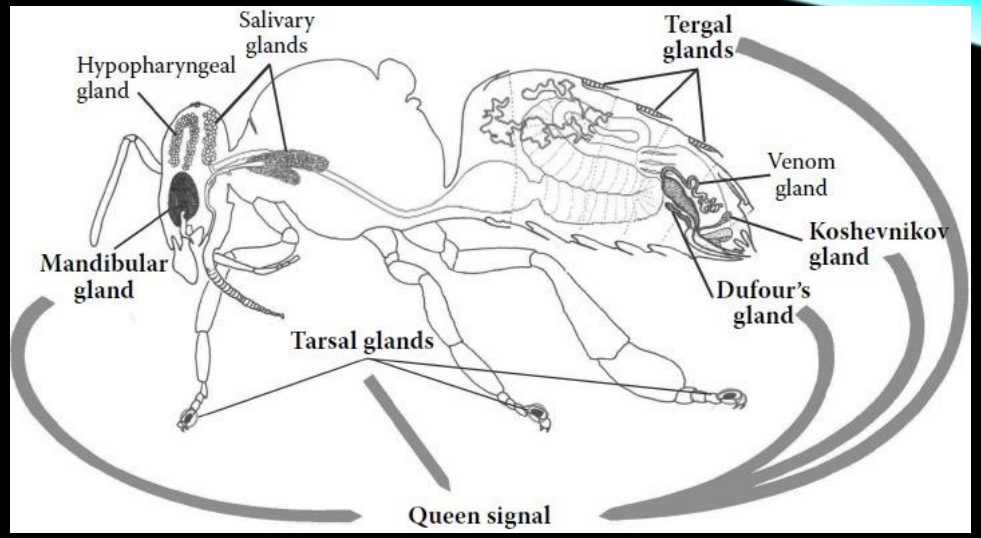
- Queens: dominated by long-chain fatty-acid esters (
- Workers: mainly saturated & unsaturated hydrocarbons
- Laying workers: shift towards the queen-like ester profile
- Minor components: free fatty acids, long-chain alcohols, aldehydes and terpenoids
- Esters act as the queen signal;
- The hydrocarbon blend lubricates the sting and marks the egg

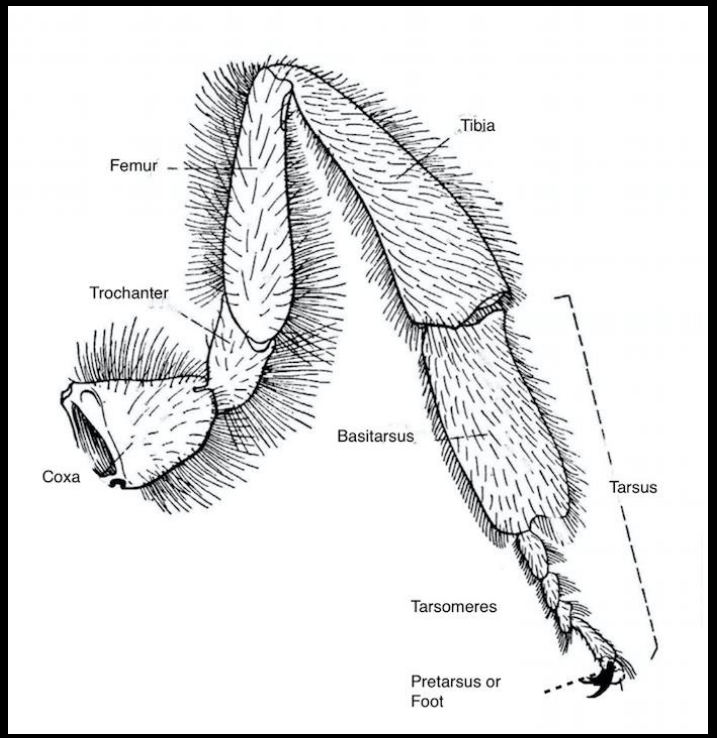


Source: Scientific beekeeping

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ARNHAT'S OR TARSAL GLANDS







Located on the 5th Tarsomere of each leg

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ARNHART'S GLAND

Produces an oily, colourless secretion of low volatility

Left by queens, workers and drones when they walk on a surface of the comb, at the entrance & and on flowers

Called footprint or trail pheromone

In queen it's an important part of queen pheromone or 'queen substance' which :

- suppresses swarming in a crowded colony
- the development of worker ovaries and
- the production of queen cells

Composed of long-chain hydrocarbons, alcohols, fatty acids, and esters.

Depends on caste.

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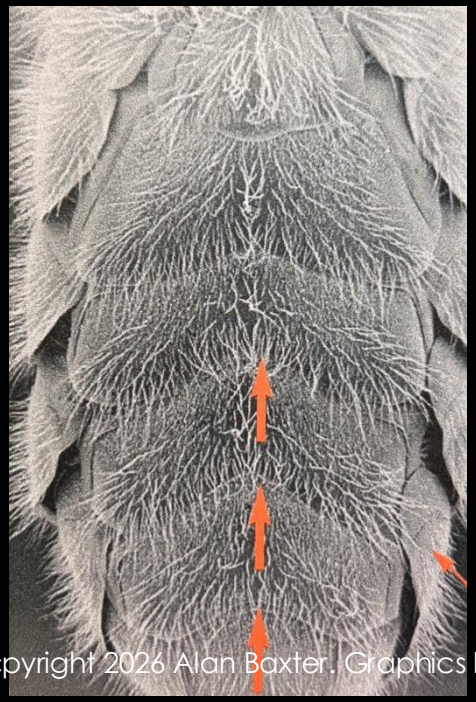
WAX GLANDS

4 pairs

Inside sterna of segments 4 – 7 inclusive

Front of each sternum so that previous sternum overlaps it







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Each gland is made of three cell types

- **Epithelial cells**
- **Oenocytes**
- **Adipocytes**

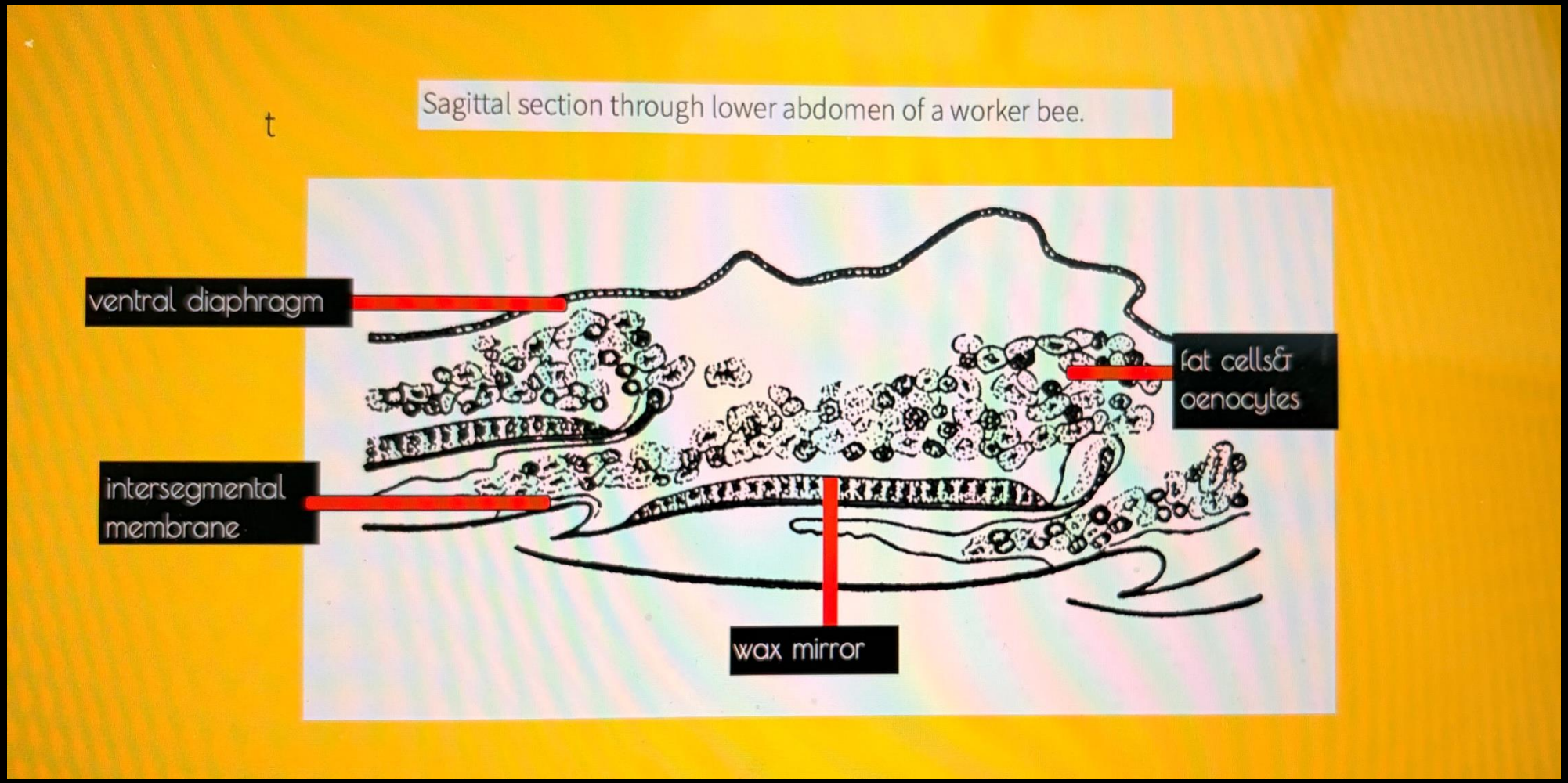
Secrete liquid wax through the cuticle onto a smooth mirror plate

Hardens into a thin scale that the bee removes with her hind legs

Passes to the mandibles for comb building.

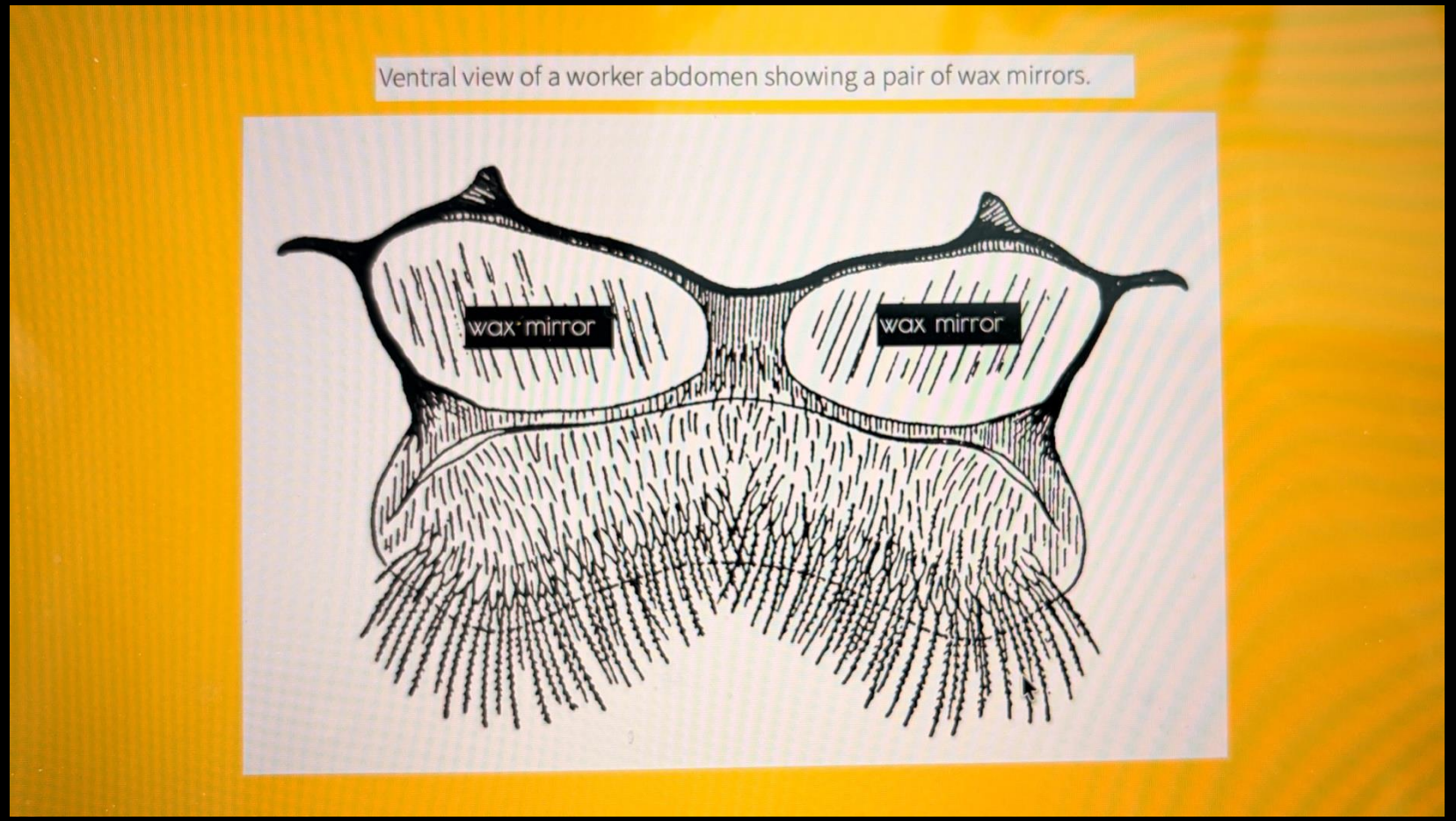
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Over each gland is a mass of epithelial cells, adipocytes and oenocytes



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Below each gland is an area of the cuticle called a wax mirror that look like specs



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MAKING WAX

- Costly to make in terms of energy and bee power.
- Roughly 8lbs honey are needed to make just one pound of wax,
- Temperature of 35°C is needed to maintain wax secretion and the flakes pliable enough for easy manipulation.
- Three types of cells involved in production:
  - epithelial cells
  - oenocytes
  - Adipocytes
- Wax is secreted through the cuticle or outer cover of these plates/mirrors rather like paste from a tube.
- Liquid wax globules join together to form a thin layer becoming the scales that we can recognise.
- They are very thin and range from 200-500 µm
- Removing each scale from the wax plates and manipulating it takes 4 minutes

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BUILDING COMB

- The flakes are removed by the enlarged tarsal joint of the hind leg and passed forward to the forelegs and mandibles
- Mixed with saliva and kneaded into a consistency suitable for building
- The bees link their legs together and hang in chains or skeins like scaffolding, passing the wax along the chain
- Using their forelegs and antennae they measure out thick piles of wax which are elongated and thinned into walls creating perfect hexagonal cells
- which link up with other workers until a continuous wall of comb is built.
- 66,000 bee hours are needed to produce 77,000 cells which can be made from 1kg of wax[1].
- Anatomy of legs and mandibles will be covered in a later session.





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QUEEN PHEROMONE

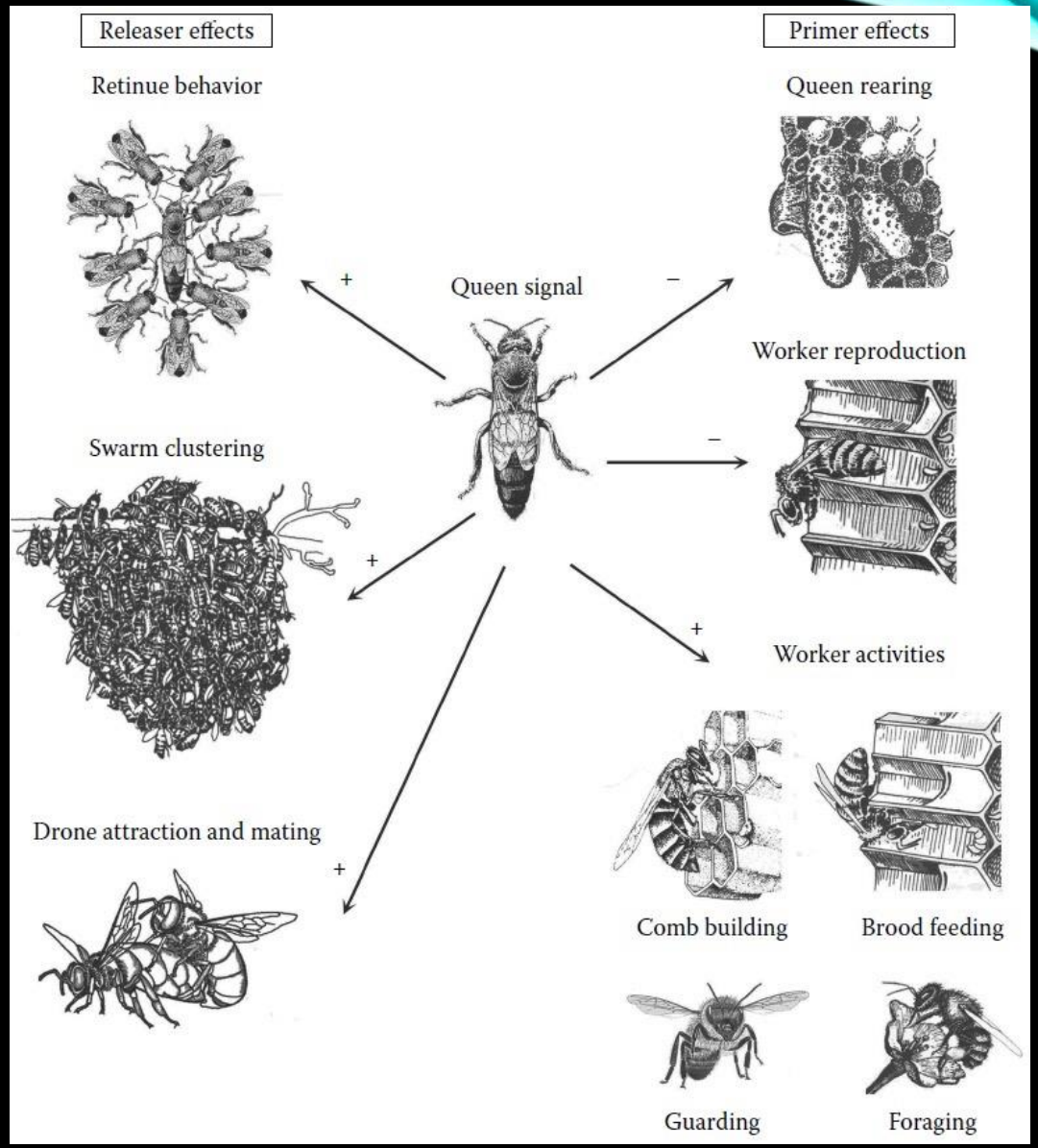
9-ODA ((E)-9-oxodecenoic acid,

9-HDA (9-hydroxydecenoic acid),

HOB (methyl 4-hydroxybenzoate),

HVA (4-hydroxy-3-methoxyphenylethanol, or homovanillyl alcohol).

Roughly a 100:40:10:1 ratio



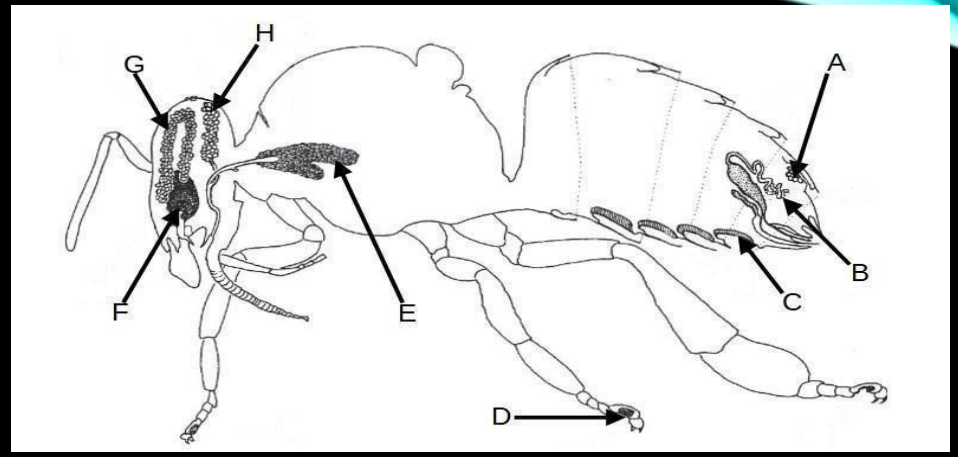
Source: Scientific beekeeping

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HOMEWORK self-paced



Describe the function of each gland in a young worker 8

Describe how G changes as the bee ages 2

Name an additional gland found in the queen honey bee1

Describe the composition of the haemolymph 10

List the functions of the haemolymph and describe each function 20

Explain how the heamolymph is circulated 15

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Next week

The brain and central nervous system

The eyes

The sensilla and the antennae

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MODULE 5 SESSION 5

The structure and function of the nervous system and sense organs

What is a nervous system?

A complex system for the command, control and coordination of the activities of an organism within itself and in relation to events in the outside world.

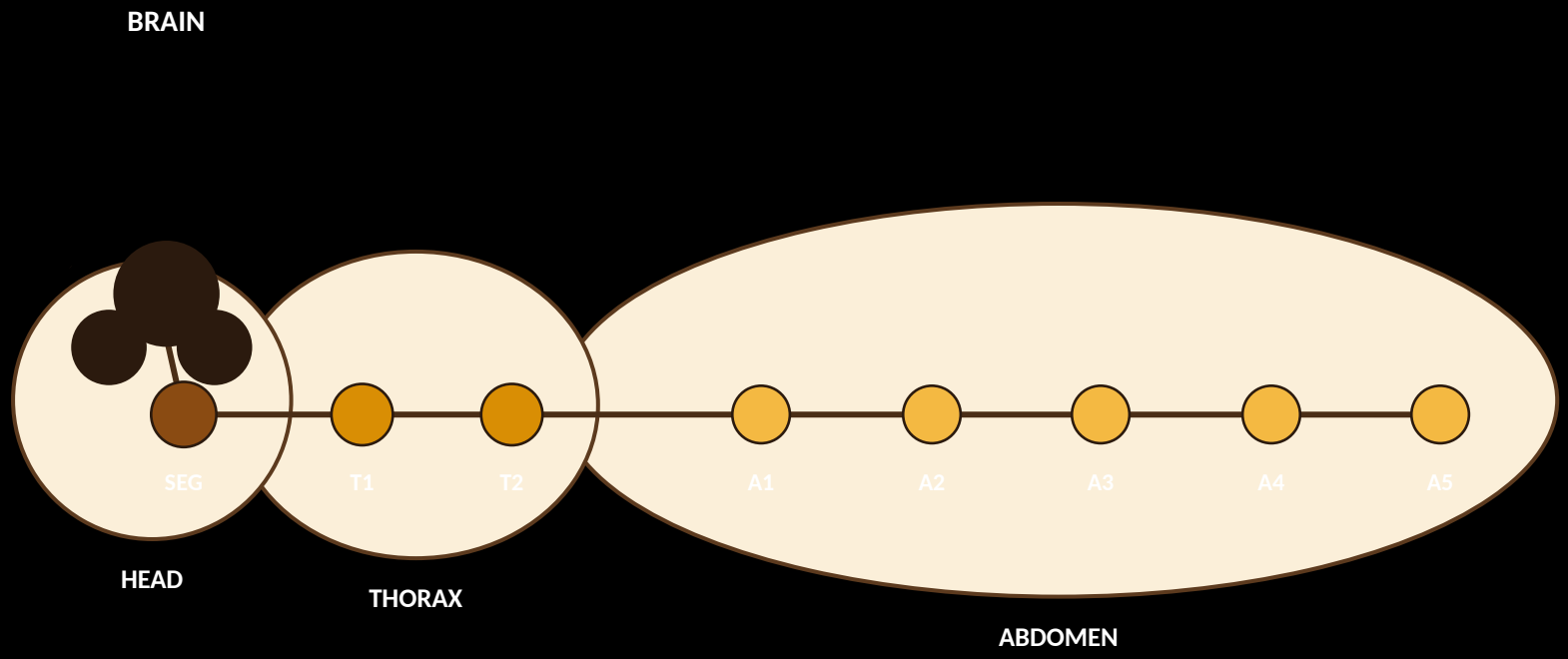
Effected by high-speed messages transmitted from part to part throughout the body of the organism via

- **Central nervous system (CNS)**
- **Nerves**
- **Sense organs**

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Central Nervous System of the Honey Bee

Schematic ventral view — brain, suboesophageal ganglion (SEG), and the ganglia of the nerve cord



KEY

Brain

Protocerebrum, deutocerebrum & tritocerebrum — vision, olfaction, learning and memory.

Suboesophageal ganglion

Controls mandibles, antennae and salivary glands; relays to the nerve cord.

Thoracic ganglia (2)

Drive the legs and the flight muscles of the wings.

Abdominal ganglia (5)

Control abdominal movement, the sting, and reproductive organs.

Ventral nerve cord

Paired connectives & commissures linking every ganglion in the chain.

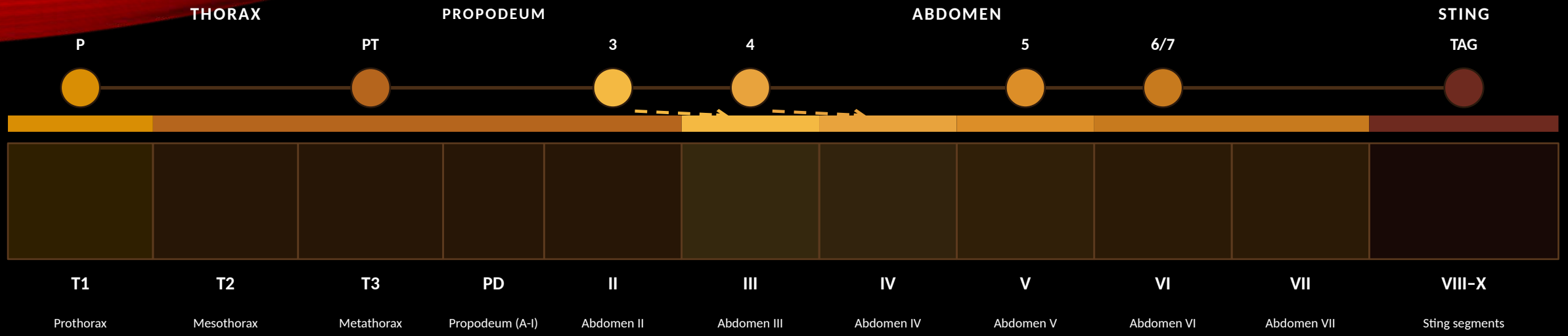
Ganglion count and layout reflect the typical adult worker bee; some segmental ganglia are fused.

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Ganglia Mapped to Exoskeleton Segments

Where each ganglion physically sits versus the segment(s) its nerves actually control



Shaded blocks show which segment each ganglion's nerves control; dots mark where the ganglion itself physically sits. Dashed arrows flag the two ganglia displaced one segment forward of the region they serve.

Prothoracic ganglion

Sits in T1 · controls only T1 (forelegs).

Pterothoracic ganglion

Sits in T3 · controls T2, T3, propodeum & A-II (mid/hind legs, both wing pairs).

Ganglion → A-III

Sits in A-II, displaced forward · controls A-III.

Ganglion → A-IV

Sits in A-III, displaced forward · controls A-IV.

Ganglion A-V

Sits in & controls A-V only — not displaced.

Ganglion A-VI/VII

Sits in A-VI · controls A-VI & A-VII together.

Terminal ganglion (TAG)

Fusion of segments VIII–XI · controls the sting, hindgut & reproductive organs.

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Segment numbering follows Snodgrass (Anatomy of the Honey Bee); the propodeum develops as abdominal segment I but fuses to the thorax.

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Thank you for your attention

Are there any questions?

