A Brief Discussion of the Comparative Biology of *Apis mellifera* Our European Honey bee

Apis = bee

mellifera = honey carrying

There are roughly 20,000 known species of bees in the world!
There are 400 native bee species in Wisconsin
Our honey bees are not natives

Ground Rules

1. **I have borrowed information from several sources without acknowledging the source**
2. **I will only present for 45 minutes**
3. **I have way too many slides for so little time (over 50)**
4. **I can't present anything in its entirety, hopefully enough to spark your interest**
5. **I may skip some slides to discuss essential details when I'm running out time.**
6. **I am discussing the honey bee as a single organism, not the superorganism hive**
   (That requires another discussion at some other time)
7. **I am willing to take questions at any time, especially if I'm not making sense**
   (but may not have the answers)
   As a popular WPR radio game show declared,
   "The questions are well researched…… the answers are not"

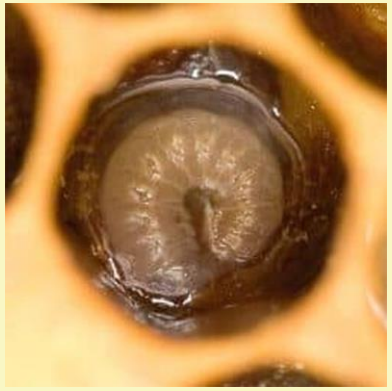
Honey bee or Honeybee? Scientific or Informal?

- Entomologists use two words if a common name accurately describes the order to which a particular insect belongs.
- For example, all true flies belong to the order Diptera
  - **True fly** names will be spelled using two words— **house fly, horse fly, fruit fly, etc.**
  - However, despite their names, **dragonflies and butterflies are NOT true flies**— so they are spelled as one word.
- **Honey bees** and **bumble bees** are **true bees** in the order Hymenoptera
  - Entomologists spell them as two words
  - But dictionaries and newspapers spell them as one
- I may have used both versions in this discussion

Discussion of Comparative Anatomy

Honey Bee Queen --- Honey Queen

Honey bees ---Humans



3 days
bee larva
16days

41 days
human embryo
18-25 years

Scientific Definitions:

Biology- the study of living organisms, divided into many specialized fields that cover their morphology, physiology, pathology, ecology, paleontology, genetics, anatomy, behavior, origin, and distribution.

Morphology- the study of the structure of the body in connection with its development and function through human anatomy, embryology, and histology.

Anatomy- is the identification and description of the body structures of living things.

Gross anatomy- the study of those body structures large enough to be examined without the help of magnifying devices.

Histology- studies the microscopic structure of cells, tissues, and organs in relation to their function.

Comparative anatomy- compares similar body structures in different species of animals in order to understand the adaptive changes they have undergone in the course of evolution.

Physiology- the study of the chemistry and physics of basic body functions, from how molecules behave in cells to how systems of organs work together.

Pathology- the study of disease with special reference to the nature, the causes, and development of abnormal conditions, as well as the structural and functional changes that result from the disease process.

Ecology- the branch of physiology that deals with mutual relations of living organisms and their environment, or the relations of organisms to each other.

Paleontology- the branch of science concerned with fossils of animals and plants.

Genetics- the study of heredity, the transmission of characteristics from parent to offspring

Metabolism- all the chemical processes going on continuously inside the organism that allow life and normal functioning .These processes include those that break down nutrients from food, and those that build and repair the body.

Useful Scientific Definitions:

Biology- the study of living things which includes:

Anatomy- what things look like

Gross Anatomy- parts large enough to be seen without magnification

Microscopic Anatomy or Histology- studies of cells and smaller units

Comparative Anatomy- compares similar body structures in different organisms

Morphology- how things are put together

Physiology- how things work

Pathology- how things become diseased

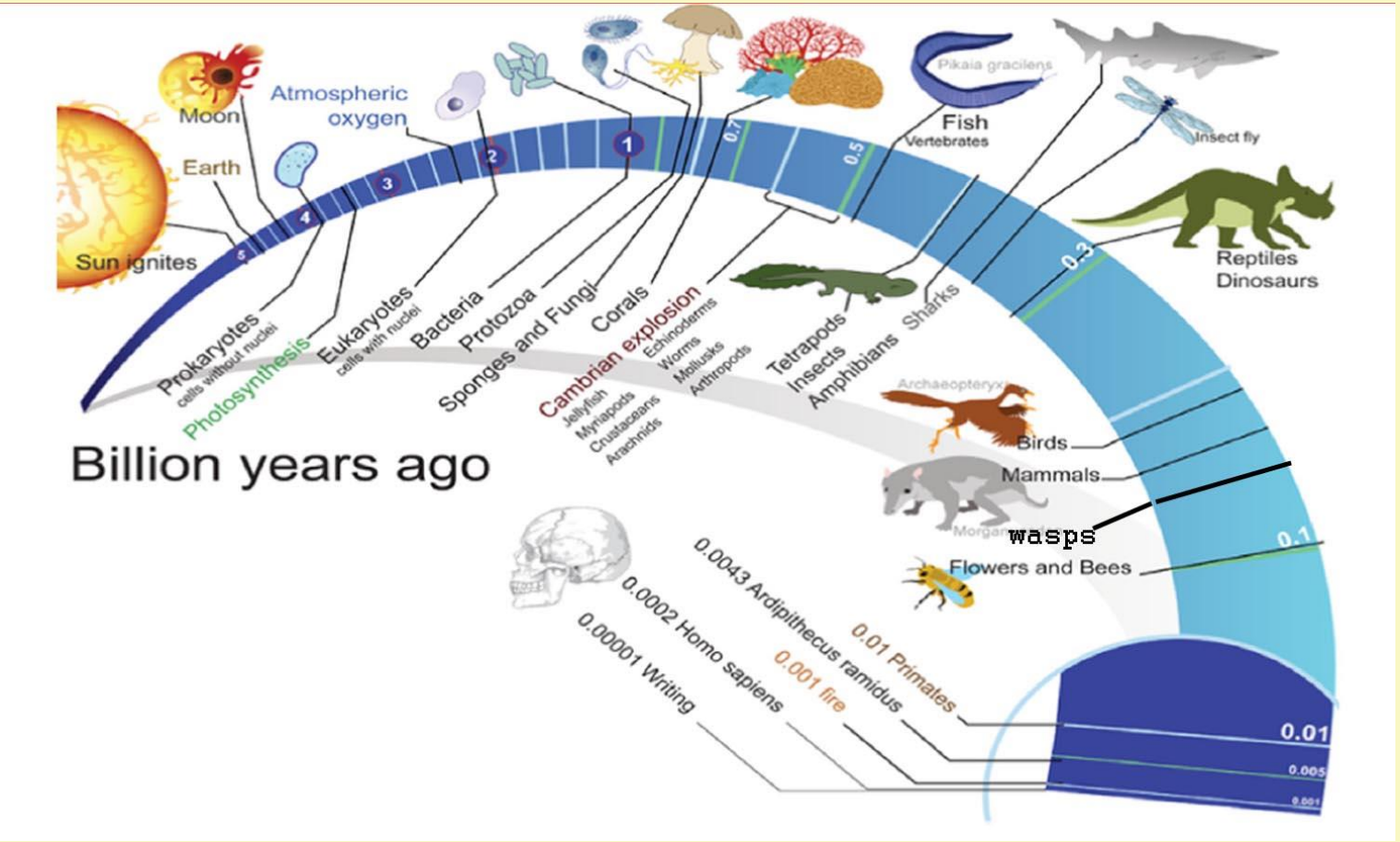
Ecology- relationships of organisms and their environment

Genetics- how characteristics are passed from parent to offspring

Metabolism- the chemical reactions that keep things alive

Paleontology- fossils

A Brief History of the Universe



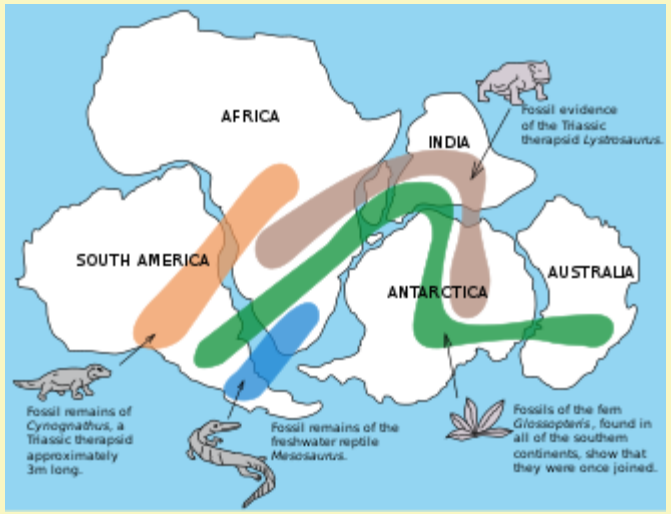
- **Wasps originated** during the Jurassic period about **150 million years ago** (mya) having evolved from a common Hymenoptera ancestor including bees and ants.
- **Bees** evolved from hunting wasps that **decided to become vegetarians** and acquired a taste for nectar.
- Bees probably evolved about the same time as flowering plants in the Cretaceous period,146 to 74 mya
- Homo sapiens evolved about 300,000 years ago. We are new on the block!

Honey bees existed over **100 million years before** there is any evidence of **human** activities.

A Brief Geology Lesson- Six Supercontinents

Geologists have theories of how our present continents have developed starting 3.5 billion years ago (bya)

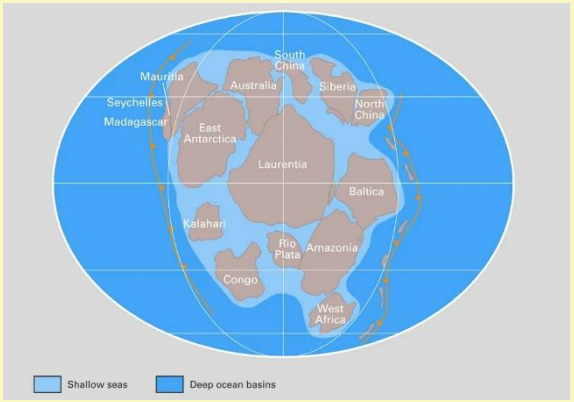
1. Ur (3 bya) half the size of current Australia, included parts of India, Madagascar and Australia
2. Kenorland (2.7-2.6 bya) located at the Equator, most of US, Canada, Greenland, Scandinavia, western Australia and southern Africa.
   - After 100 million years it broke up
   - Earth spent millions of years below freezing temperatures **1st Snowball Earth**
3. Columbia (2.1-1.8 bya) was about a third of today's land mass
4. Rodinia (1.3-1 bya) was big, located south of the Equator, breakup resulted in **another Snowball Earth** but also **shallow seas** eventually **allowed life to develop**
5. Pannotia (650-560 mya) resulted from Rodinia turning itself inside out due to the movement of the exterior oceans
6. Gondwana (550-175 mya)
7. Pangaea (320-195 mya)



A Brief Geology Lesson

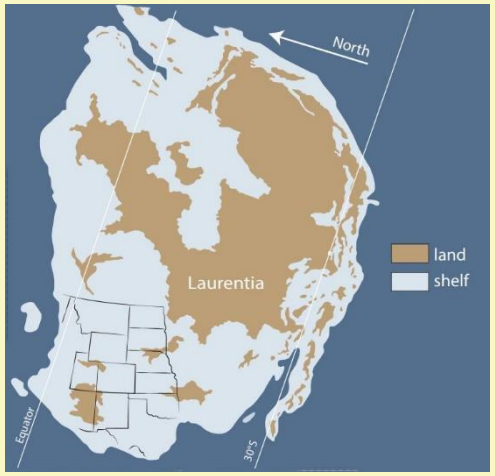
Kenorland

Columbia



Rodinia

Pannotia



Laurentia

Pangaea

Supercontinents not drawn to scale

Why Did I Lead You Down This Rabbit Hole?

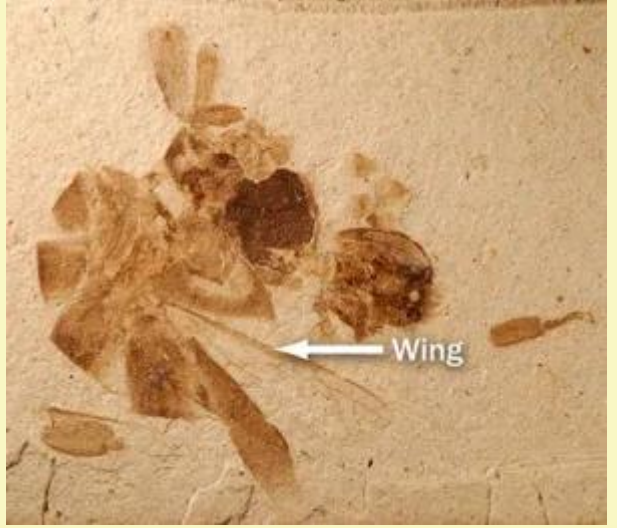
- **325mya- Winged insect fossils** are abundant from the time that Pangaea formed
  - The oldest fossils are of dragonfly and grasshopper-like insects
- **240 mya- Wasp-like insects** are found
- **200 mya-** Gondwana broke away from Pangaea
- **175 mya-** The part of the Pangaes that became **North America broke away**
- **95-115 mya- Bees origin** in western Gondwana, the supercontinent that at that included **today's continents of Africa and South America**

- 100 mya- The earliest bee fossil with pollen is trapped in amber
- The first Apis bee fossil from 34 mya was found in Europe
- A single 14 mya fossil record from Nevada is the only documented New World Apis species, the Apis nearctica.

European Apis

New World Apis

How many Bees are there?



There are seven families of bees with 20,000 known species

1. Melittida
2. **Apidae**
3. Megachilidae
4. Andrenida
5. Halictidae
6. Stenotritada
7. Colletidae

Apidae

- The largest family of bees with **6,000 known species** today
- Includes the **honey bee** and **300 different types of bumble bee**
- originally to be found only in the Old World, namely **Asia, Africa and Europe**
- Suggests that the **genus appeared much later than the other types**
- Four species: Apis florea, the Little Honey bee; Apis dorsata, the Giant Honey bee; Apis cerana, the Eastern Honey bee; and Apis mellifera, the Western Honey bee.

Scientific Names of the Subspecies of Honey Bees

Domain: Eukaryota
Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hymenoptera
Family: Apidae
Genus: Apis
Species: A. mellifera
Subspecies: (31)

Apis mellifera adansonii
Apis mellifera capensis
Apis mellifera intermissa
Apis mellifera jemenitica
Apis mellifera lamarckii, (Egyptian honey bee)
Apis mellifera litorea
Apis mellifera monticola,
Apis mellifera sahariensis,
Apis mellifera scutellata,
Apis mellifera simensis
Apis mellifera unicolor
Apis mellifera anatoliaca, (Anatolian honey bee)
Apis mellifera caucasia, (Caucasian honey bee)
Apis mellifera meda,
Apis mellifera mellifera, (European dark bee)
Apis mellifera pomonella,
Apis mellifera remipes,
Apis mellifera ruttneri
Apis mellifera sinisxinyuan
Apis mellifera syriaca,
Apis mellifera adami
Apis mellifera artemisia (Russian honey bee)
Apis mellifera carnica, (Carniolan honey bee)
Apis mellifera cecropia,
Apis mellifera cypria,
Apis mellifera iberiensis,
Apis mellifera ligustica, (Italian honey bee)
Apis mellifera macedonica,
Apis mellifera siciliana
Apis mellifera sossimai
Apis mellifera taurica

Subspecies of interest

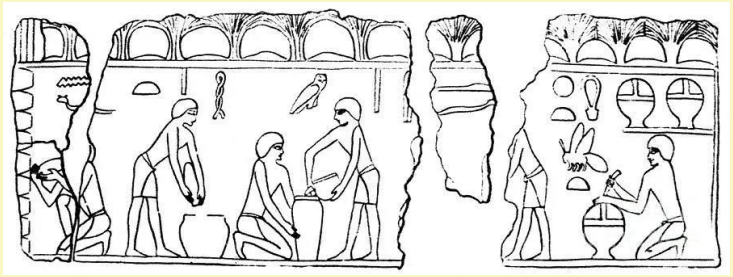
Apis mellifera lamarckii, (the Egyptian honey bee) found in Nile Valley of Egypt and Sudan, domesticated before 2600BC. This genetic subtype can also be identified in honey bees from California.
Apis mellifera scutellata, Due to a mishap, some East African lowland virgin queens mated with local European honey bee drones and produced what is now known as the Africanized honey bee in South and North America. The struggle for survival of honey bees in Sub-Saharan Africa is a reason that this subspecies is proactive in defending the hive and more likely to abandon existing hives and abscond to a more secure location. They direct more energies to defensive behaviors and less to honey storage.
Apis mellifera mellifera, (European dark bee) originating in central Asia and migrating throughout northern Europe after the last ice age, it has the largest geographic range of all European honey bees. It was domesticated in Europe and imported into Britain during Roman times and Ireland during Christian times. Hives were later exported to North America in the colonial era in 1622 where they were referred to as the English Fly by the Native American Indians. In 2014-2017 a European survey of 621 colonies, which included the various subspecies kept by beekeepers found that the A. m. mellifera was the most aggressive, had the highest swarming tendency and the lowest hygienic behavior
Apis mellifera carnica, (Carniolan honey bee), 2014-2017 the European survey found that the A. m. carnica was the most docile, had the lowest swarming tendency and the highest hygienic behavior
Apis mellifera ligustica, (Italian honey bee) originating from the Italian mainland, it is a commonly kept subspecies for commercial beekeeping in much of the world.
Apis mellifera artemisia is the Russian steppe honey bee, first identified in 1999 near Kyiv, Ukraine. Its name is derived from Artemis the Greek goddess for whom the honey bee was a symbol and whose temple at Ephesus was listed as one of the Seven Wonders of the world.

Honey Bees in Human History

8000-6000 BC

Evidence of honey and beeswax has been found in articles from the stone age
A cave drawing in Spain demonstrating collection of honey from a hive on a cliff face

3100-30 BC



Egyptians have the first records of actually keeping honey bees. They used honey as a sweetener, as a gift to their gods and even as an ingredient in embalming fluid.

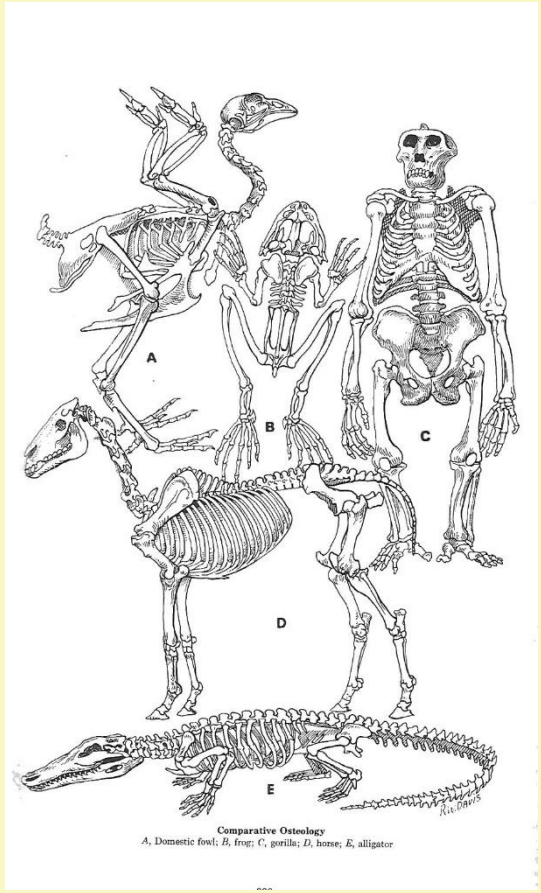
2000-30 BC

The Greeks viewed honey as not only an important food, but also as a healing medicine and linked with knowledge and power. The bee was the emblem used on coins in the Greek city of Ephesus, the symbol of the Greek goddess Artemis and the emblem of Eros/Cupid

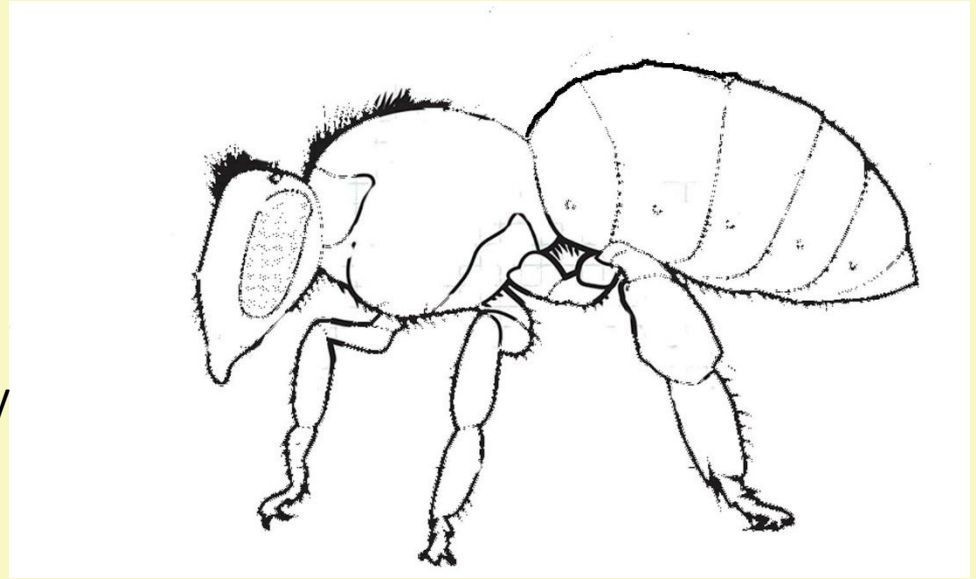
Honey Bee Myths and Legends

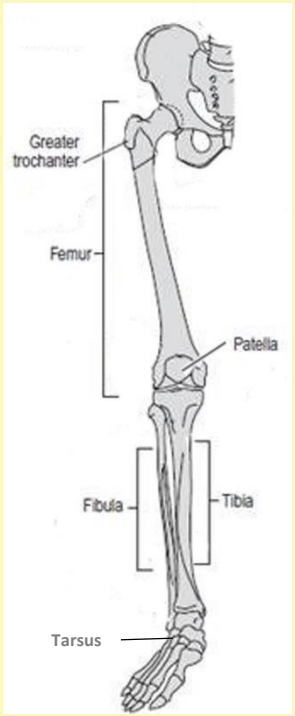
- Greek mythology associate bees with life and death. They believed openings in rock faces and caves where bees built hives were entrances to the Underworld. One myth is that Zeus promised any favor they pleased to whoever provided the most interesting dish for his wedding to Hera. All creation participated. When Zeus tasted the contents of a small jar filled with a sticky sweet goo, t was something he had never tasted before; sweet and perfumed with a flavor that drove the senses wild. When Hera tasted the sweet-smelling goo, the scent of the loveliest meadows and mountain herbs danced along her taste buds. Melissa, the creator of the delightful treat, told the gods it was called honey. The gods agreed they had found their winner. Melissa explained how difficult it was to collect nectar deep from within the flowers and that only a tiny amount could be sucked up at any one time. She complained that the flowers were such long distances from each other that she spent most of her time buzzing from one to the other before returning home to deposit the nectar. Melissa then expressed her disapproval that other animals were stealing it and that she had had enough of her precious honey being robbed. Her favor was for a weapon would be fatal to anyone she chose to use it against. Zeus was furious this little insect had asked for such a thing. He declared that her honey would be for everyone, that she would be a queen of a colony of workers that would aid her in gathering honey, and that she and the workers were granted a fatal sting. However, this sting would be fatal to her or her workers if they ever used it. (adapted from “Mythos” by Stephen Fry)
- Celts believed honey bees traveled between worlds, bringing back with them messages from the gods. They also believed they bees could carry messages to the dead. In the western isles of Scotland, bees were said to embody the ancient knowledge of the druids. Highlanders thought that a person’s soul took the form of a bee during sleep or while in a trance. A popular Celtic tradition says that bees should be treated like members of the family. Whenever a significant event took place, like a birth or death, a family needed to report these occurrences back to the bees. Superstition held that to protect against further deaths, the message of someone’s passing needed to be delivered before their funeral. The messenger also had to tie a black ribbon around a piece of wood and place it in the hole at the top of the hive. Some traditions considered bees as being the spirits of those to be born or those of the dead.
- An English tradition requires bees to be informed of any major changes in the family such as a birth, marriage or death and that hives be wrapped in black for mourning when the beekeeper or family members die.

Comparative anatomy

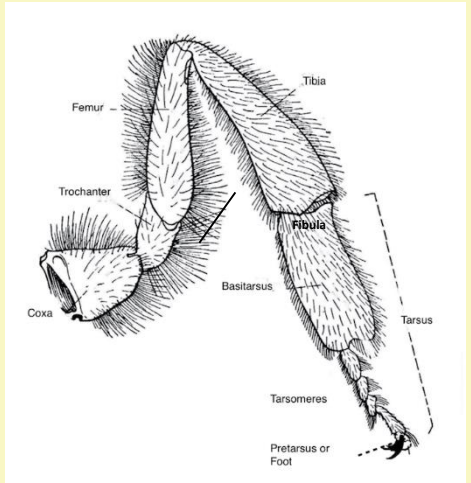


Vertebrates possess an endoskeleton with a **backbone** or spinal column, including mammals, birds, reptiles, amphibians, and fishes.
Invertebrates have an exoskeleton, a **rigid exterior covering** found on many animals including honey bees.





However, terminology is shared between the two:
Trochanter, Femur, Tibia, Fibula, Tarsus



Do Honey Bees Have a “Thin Candy Shell”?

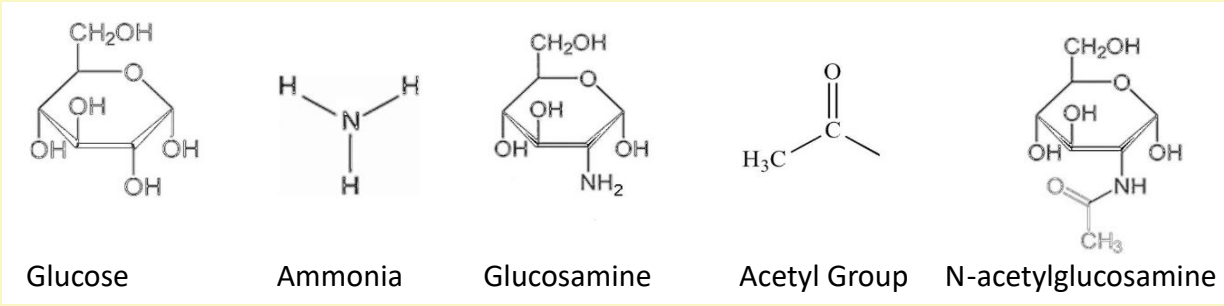
The Exoskeleton

The **main component** of exoskeleton is **chitin** a **polymer of glucose**

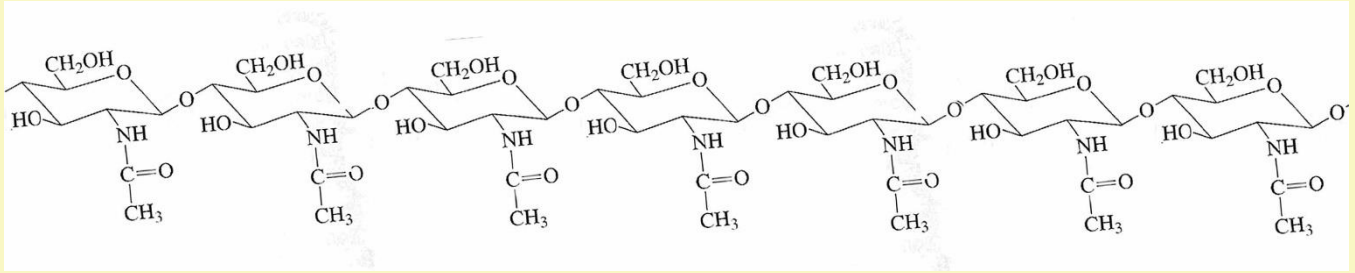
- It is brittle but **tough** and **elastic**
- It is secreted by a layer of skin cells
- It **prevents the adult bees from growing**
- (Larvae shed their skins periodically)
- It has **antimicrobial** and **antifungal** properties

Layers of **wax** over the chitin **protect bees from desiccation** (losing water)

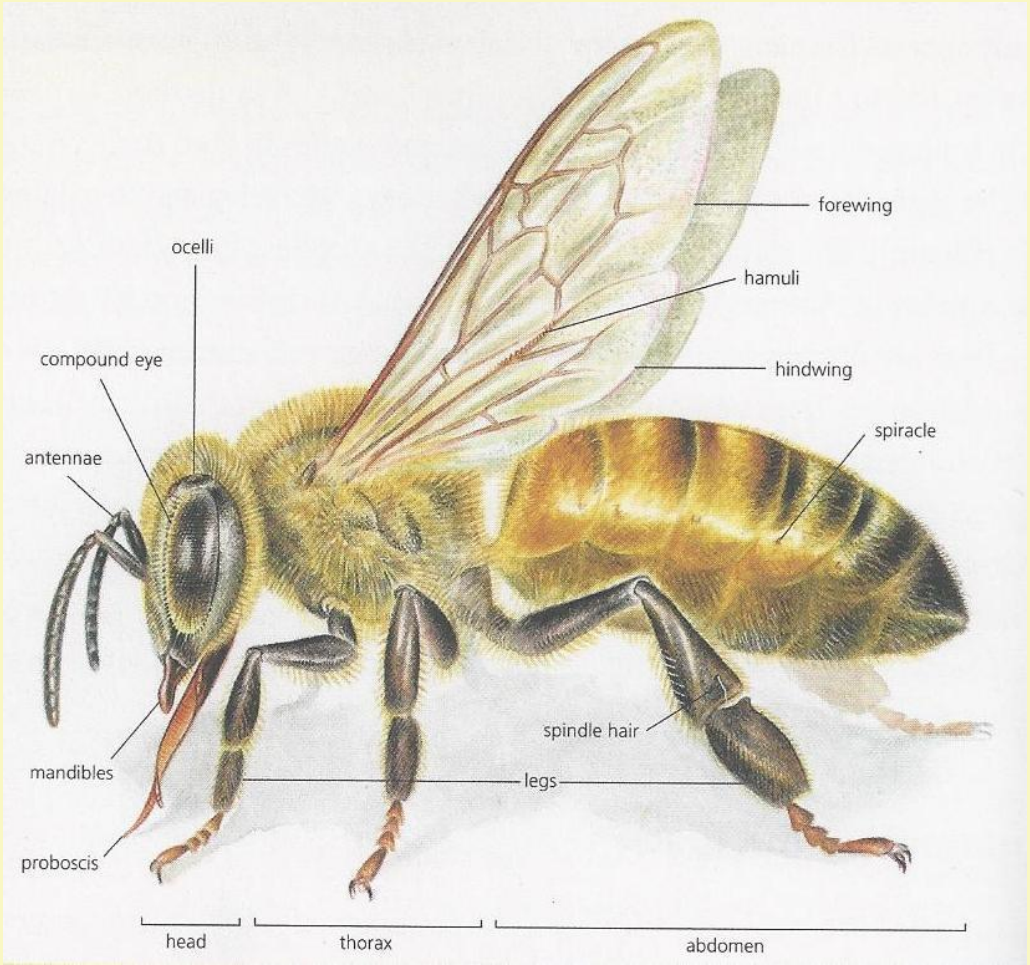
Although the honey bee exoskeleton is formed from glucose, they aren't just candy coated so they won't dissolve when they get wet!



Chitin is formed in long strings of N-acetylglucosamine and is closely related to cellulose which has similar chains of many hundred to thousands of glucose molecules



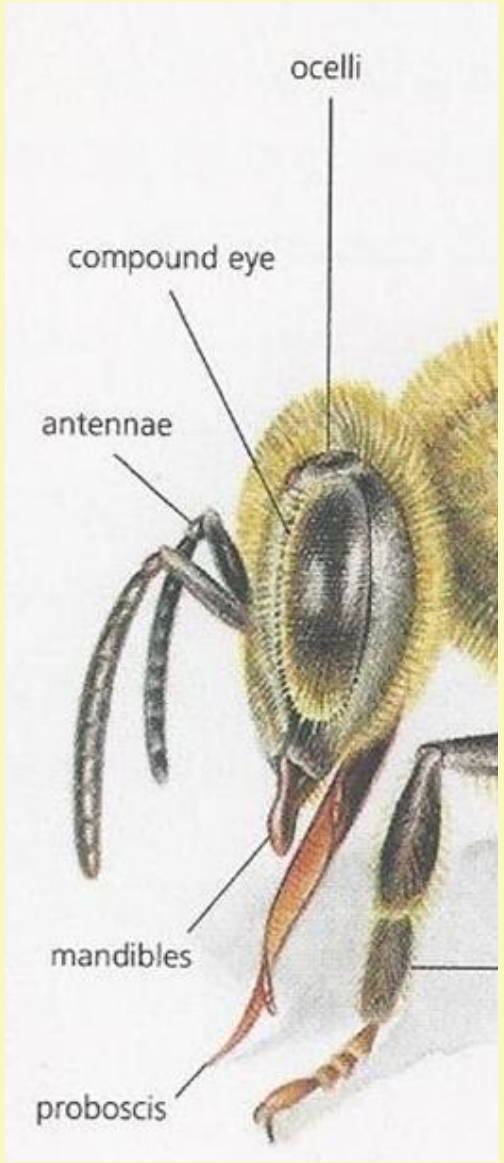
Surface Anatomy of the Honey Bee



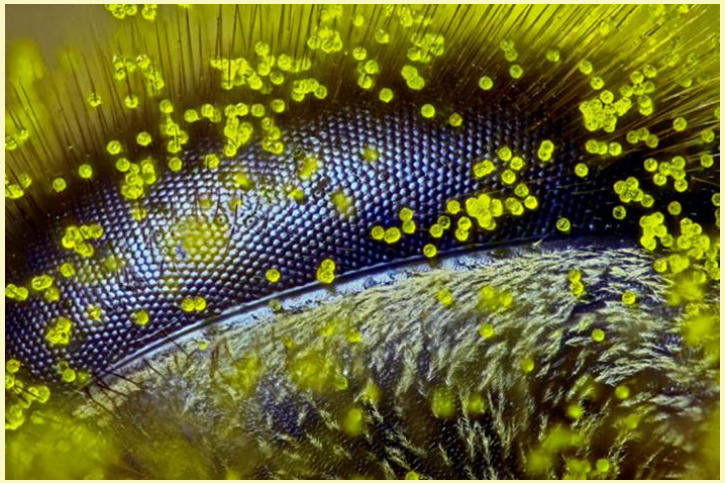
Honey bees have 3 million hairs covering their bodies!
The hairs become electrically charged while in flight and attracts pollen
The hairs are very sensitive to changes in vibrations
Sensory neurons of the hair transpose sun-compass based information to gravity-based information in the dark hive
Antennal joint hair provide information on dance direction and distance stimuli generated by abdomen waggling and wing vibration

Structures of the Head

- **Antennae** have 12 segments with receptors for senses of smell, taste, feel, and interpretation of temperature, humidity, and sound waves
  - Yes, honey **bees do "experience" sound!**
  - **Chemoreceptors** interpret the chemical **pheromone communications** of the queen and other bees
- **Mandibles** are used to chew their way out of their cell and manipulating wax
- **Proboscis** is like a straw used to suck up nectar and water and to transfer it to a house bee (a process called tropholaxis).
  - Honey bees are unique as most insects don't have both a mandible and proboscis
- **Ocelli** are three simple eyes that assist bees with sun orientation and probably sets daily biological rhythms.
- **Compound eyes** have several thousand lenses that send a mosaic-like picture to the brain



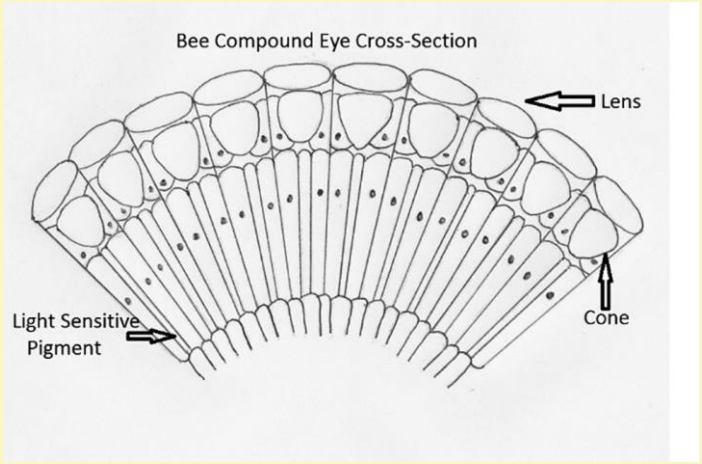
Honey Bee Vision



Honey bee eye covered with dandelion pollen

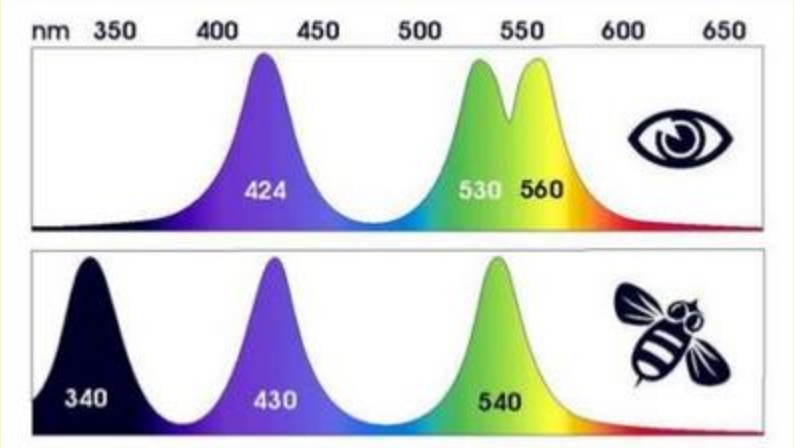
An approximation of what a bee sees at 5, 10 and 15 cm (top right and bottom pictures)

A **compound eye** is made up of **thousands of tiny lenses** called facets
Each facet takes in one small part of the insect's vision
The bee's brain then converts these signals into a mosaic-like picture made of each image
Queens have only 4,000 facets while worker bees have 6,900 facets in each eye, and drones have 8,600 facets (better vision for finding a virgin queen)
Every facet is connected to a tiny tube, ommatidium, contains a lens, a cone of visual cells and pigment cells that help separate it from its neighbor cells



Honey bee Vision

Electromagnetic wavelength



Humans have 3 distinct color-sensing cones—for **red, green, and blue light**. By combining these cells' signals, the brain can distinguish thousands of different colors.

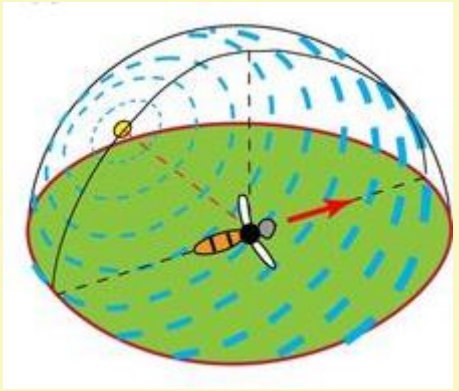
Honey bees also have **trichromatic vison** but they **can't see red; instead they see ultraviolet light**

A bee is able to see color, because each of the tiny lens tubes contains eight cells that respond to light. Four of these cells respond to yellow-green light, two respond to blue light, and one responds to ultraviolet light.

Humans have a total of 6 million red, green and blue receptors, bees have only 50,000

Some animals have 4, 5, or 6 color receptors and can see "colors" we can't even imagine

Honey Bee Vision Super Power #1 Polarized Light Vision



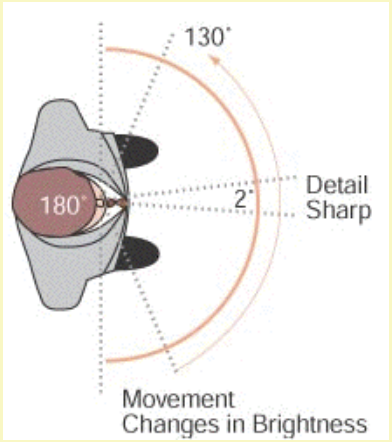
- Bees can detect polarized light even on cloudy days
- Polarized light moves in one direction and is caused when air molecules from the atmosphere scatter the photons to create a “super highway” of light
- A bee scans the polarization patterns in the sky and uses this as a navigating system even when the sun isn’t shining
- Bees find their way back home using the polarized light in the sky and communicate the direction to the colony
- Deprived of ultraviolet light, bees lose interest in foraging and will remain in the hive until they are forced out by food shortage and starvation

Honey Bee Vision Super Power #2 Ultraviolet Light Vision

Honey bees see UV light

- Penetrates cloud cover
- Nectar rich areas of flowers often reflect UV light
  - Sunflowers, primroses and pansies have nectar guides that can only be seen in ultra-violet light
- Some flower petals appear to change color depending on the viewing angle (iridescence) and is often in the UV spectrum

Honey Bee Vision Super Power #3 Fast Color Recognition

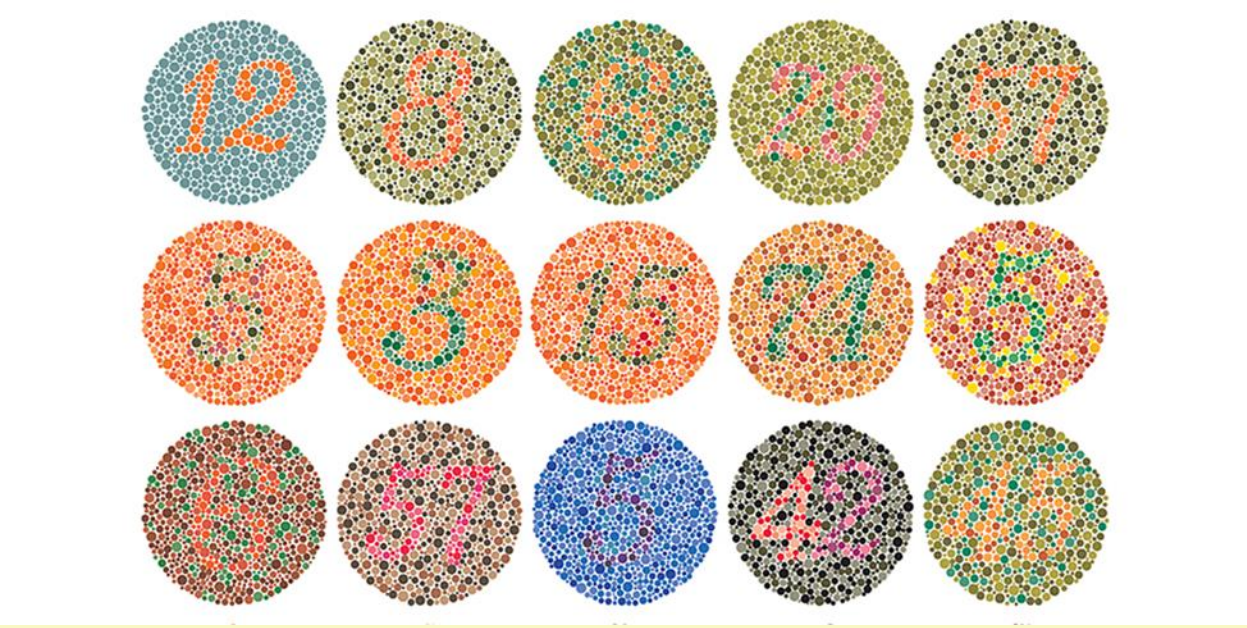


Bee color vision is the fastest known in the animal kingdom

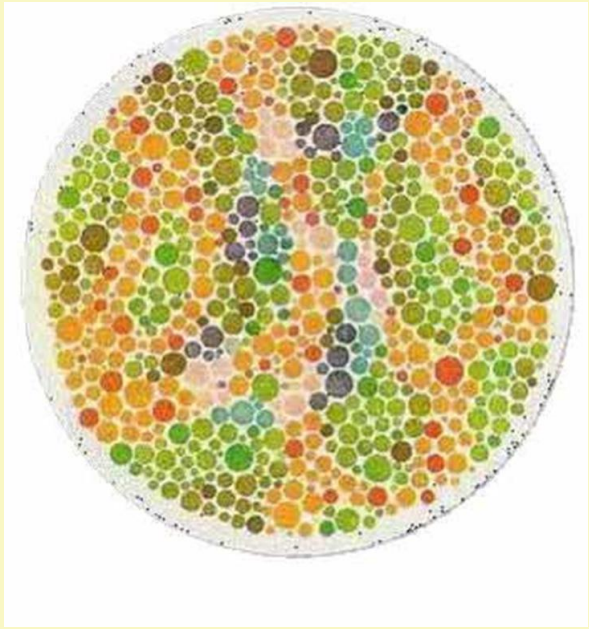
- Wider field of vision… 280 degrees compared to our 180 degrees
- **Five times faster than human vision**
- Traveling at 15 mph they can still distinguish one flower in a group from another
- This high “flicker” threshold means they **respond better to moving objects** than stationary ones
  - **Flying helps bees see better**
  - **Slow movement** when working in the hive **is less alarming** to the bees
  - Bees are **less likely to notice someone standing** in their path to the hive and run into them
  - Bees gradually slow their approach to landings by observing the change in their visual fields

But what do honey bees actually see?

Color Blindness Test



Normal color vision



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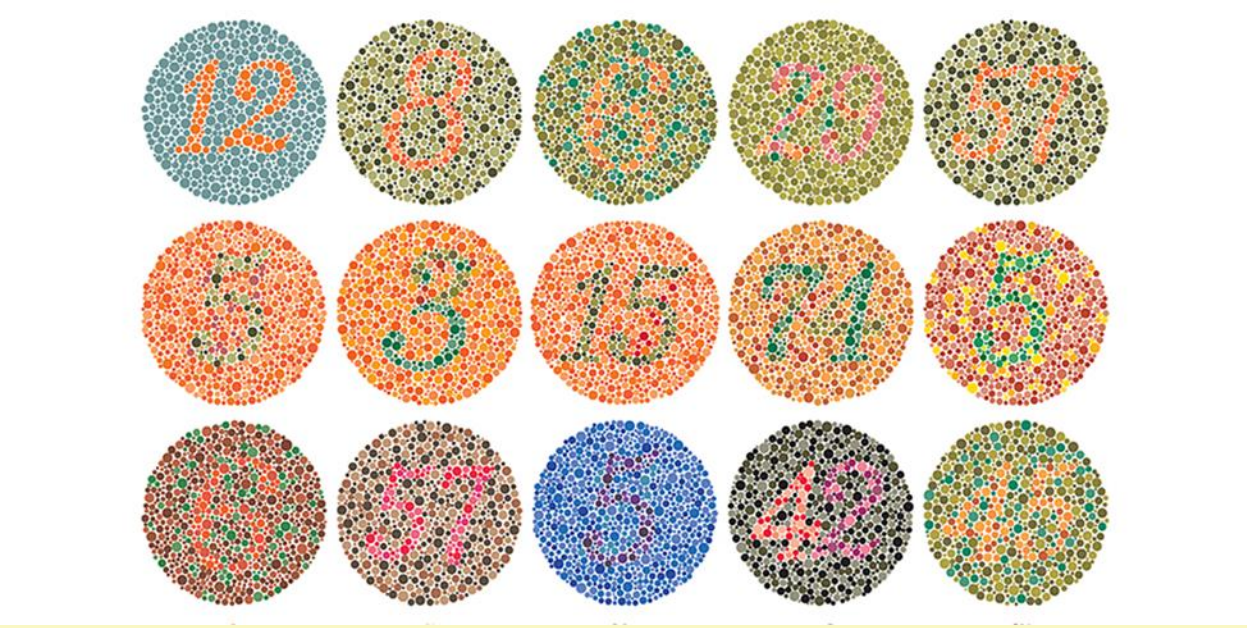
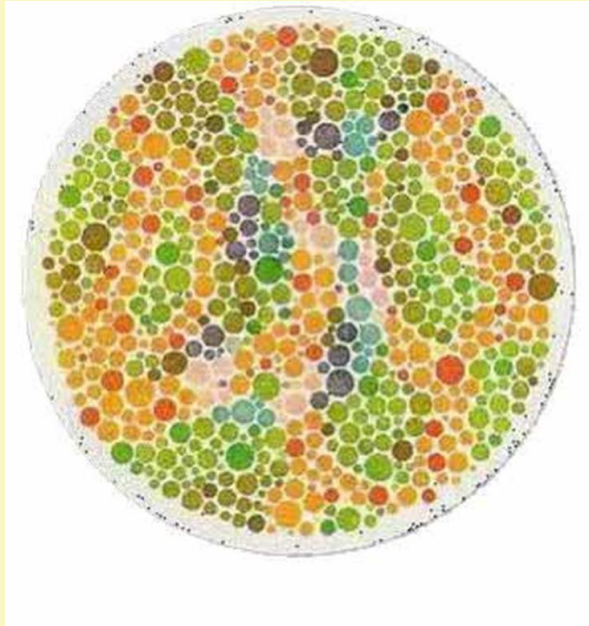
Answers:

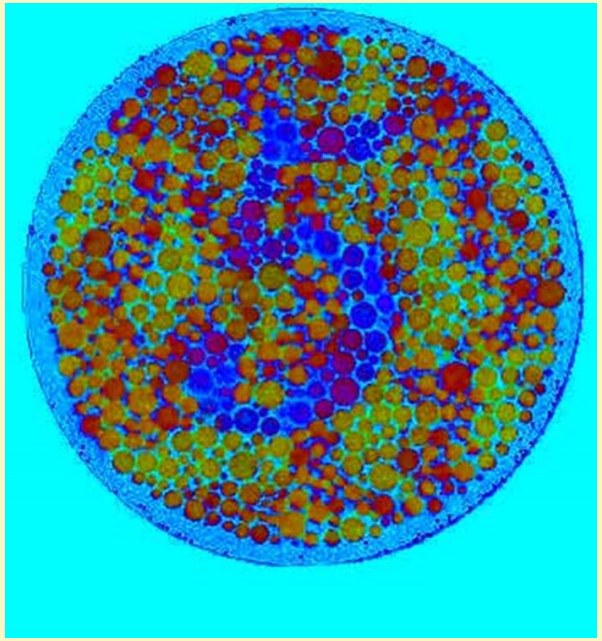
12	8	6	9	57
5	3	15	74	5
6	57	5	42	45

Color Blindness Test

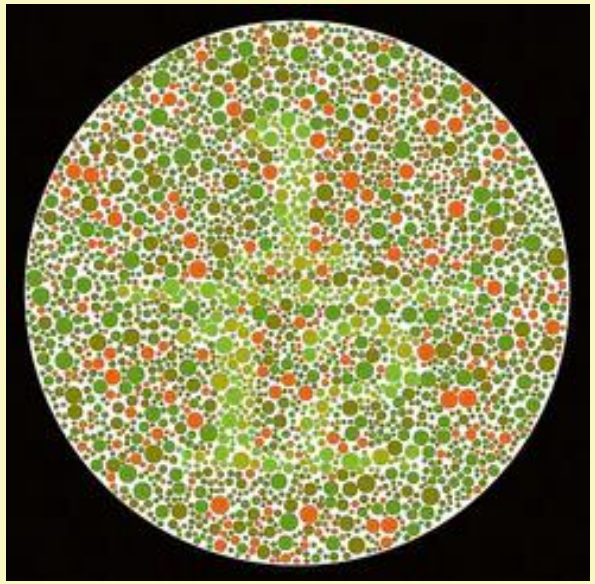


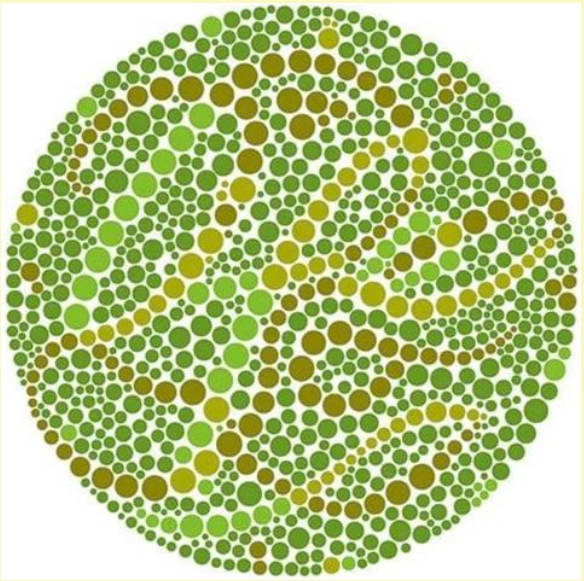
Normal

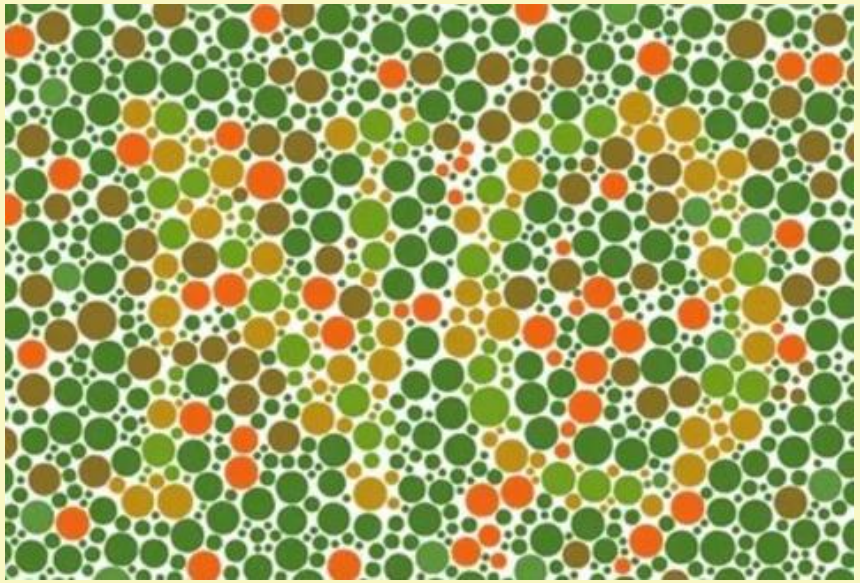




Can anyone read these color plates?



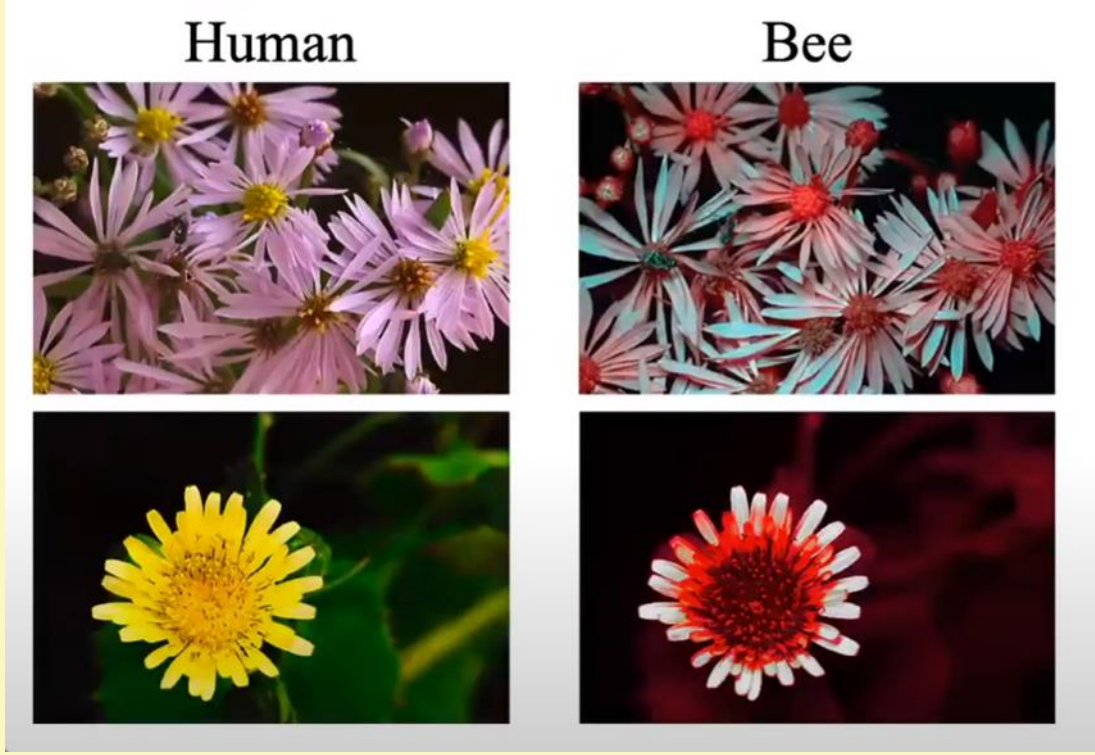


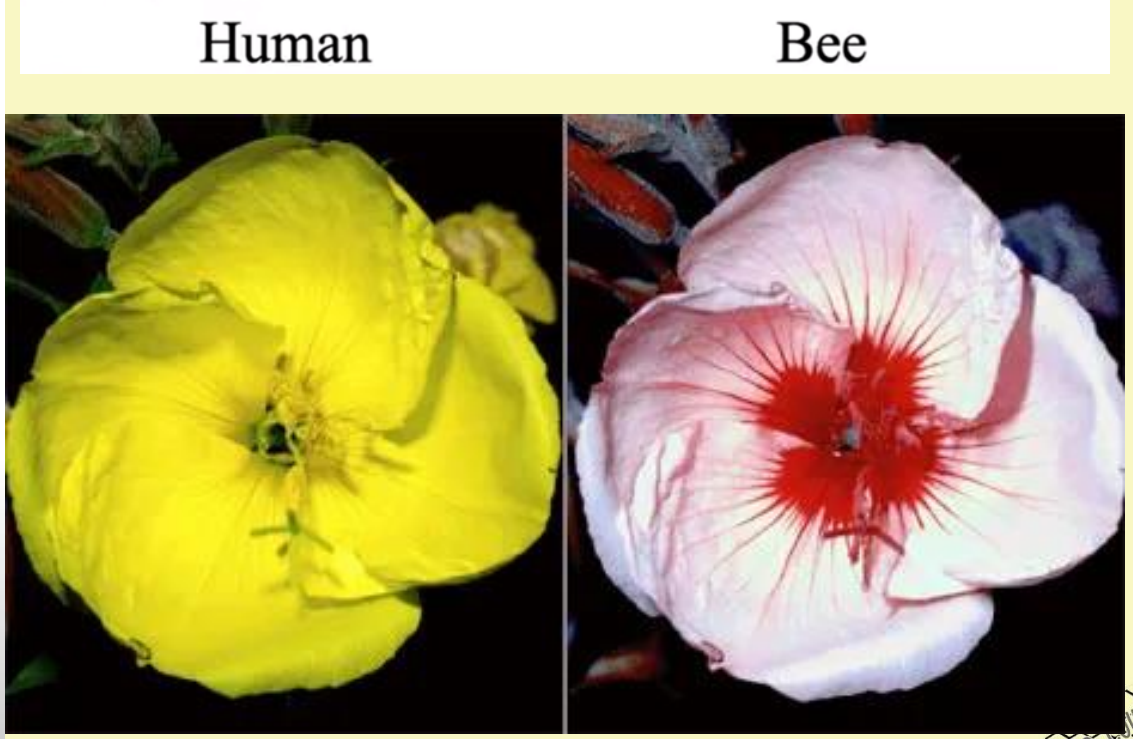


Deuteranomaly & Protanopia
Subnormal green/ red blindness

1: 5
2: 1/12
3: Life
4: NO

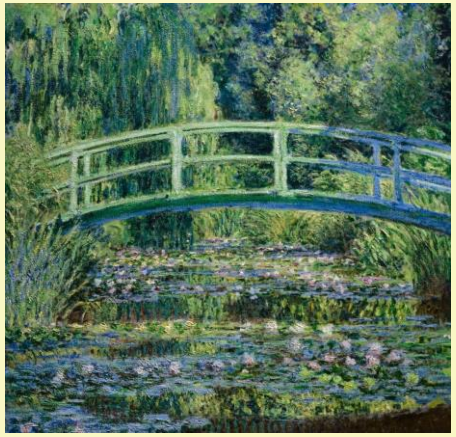
Honey Bees don’t see the colors in plants that we do





Bees see reddish wavelengths, such as **yellow** and **orange**. They can also see **blue-green, blue, violet**, and **“bee’s purple”**, a combination of **yellow and ultraviolet light**. Bees will head to the UV-absorbing area of a flower first. Just because a flower is ugly to us, doesn’t mean that it’s ugly to a bee. Recent studies have shown that weeds are more successful than other plants because they’re more attractive to the pollinators.

Can Humans See Ultra-Violet Colors?



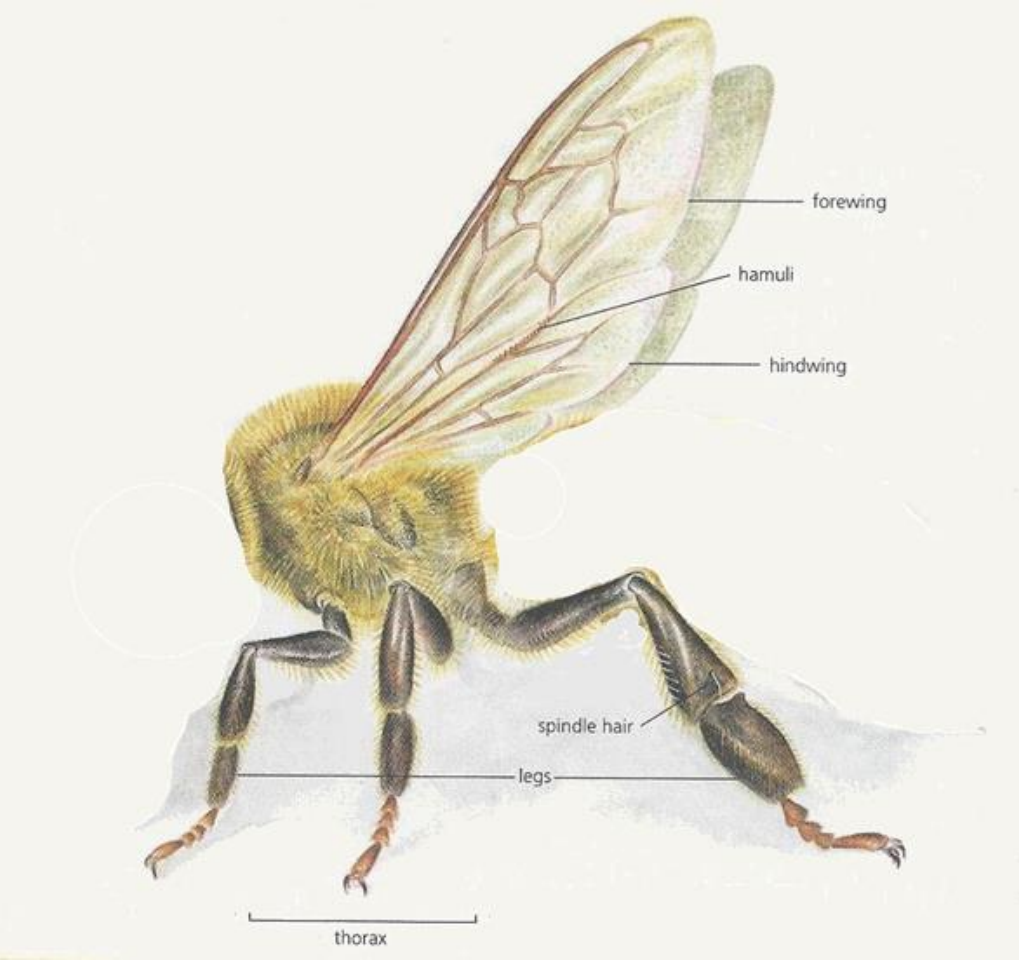
1898

1922

1926

The lens in our eyes filter out ultra-violet light, but some people who have the lens removed can perceive a near UV whitish-violet color
The French impressionist painter Claude Monet had this condition after cataract surgery. Before the surgery, his cataracts were so bad that his color range was limited to red and orange. After the surgery his paintings included deep purple and blue hues.

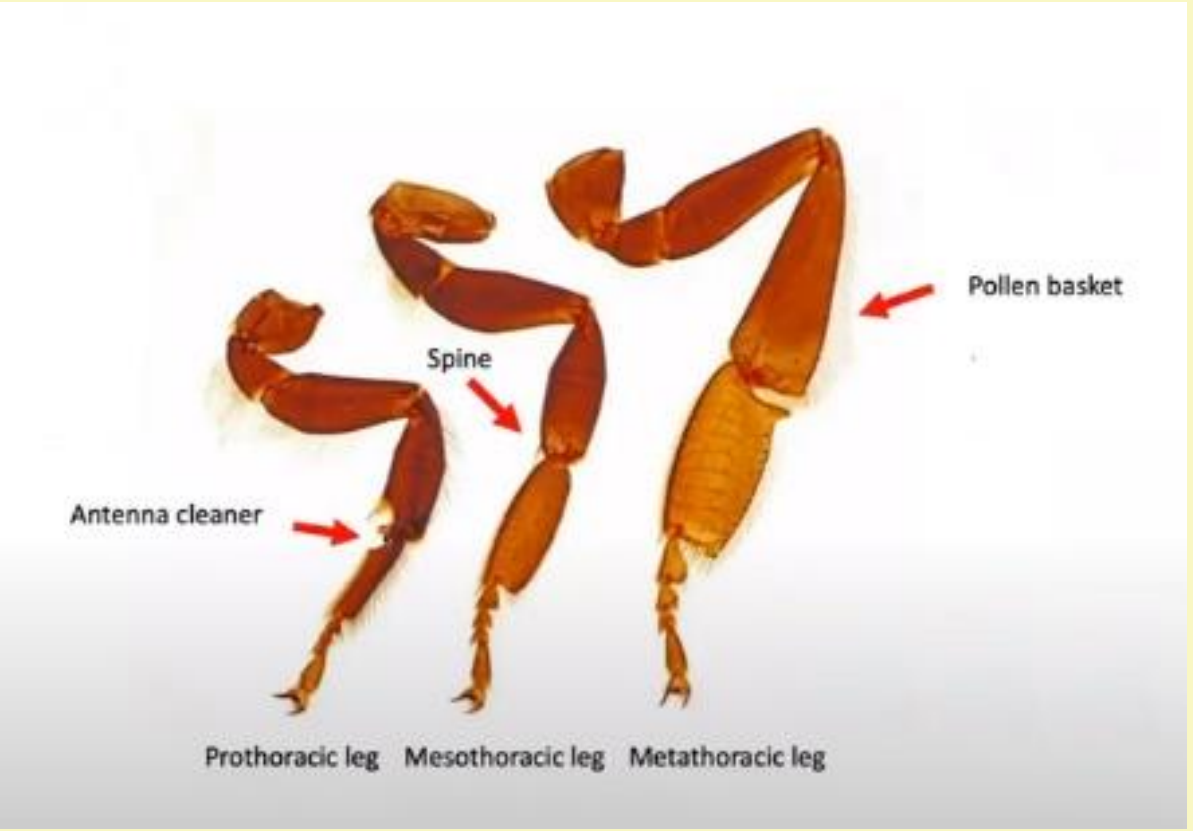
Surface Anatomy of the Honey Bee- the Thorax

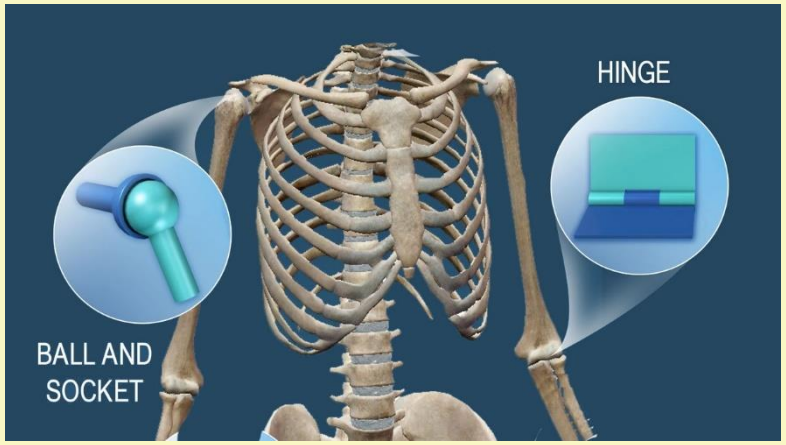


The **thorax** is the center of **locomotion**

- where the muscles are contained
- where all of the movement originates
- Three segments make up the thorax
  - Promeso is where the front leg is located
  - Mesothoracic is the middle leg location
  - Metatoracic is the rear portion
- The wings are attached to the meso and metathoracic regions

Surface Anatomy of the Honey Bee- the Thorax

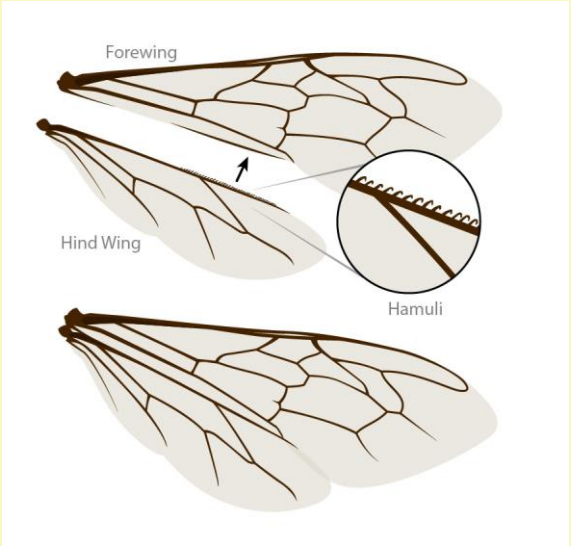




All bee leg joints are ball joints meaning they can rotate like our shoulders

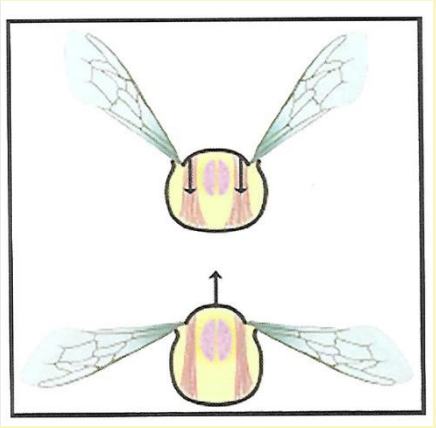
- Prothoracic front leg has a notch that is shaped to clean the antennae
- Mesothoracic middle leg has a spine used to spear secreted wax from the lower abdomen and moves it forward to the mandible
- Metathoracic rear leg has the pollen basket
  - Bees manipulate their legs to fill the basket
  - **Bees** have a **positive electrical charge**, **pollen** has a **negative charge** so pollen sticks on the bee's hairs

Surface Anatomy of the Honey Bee- the Thorax



Wings

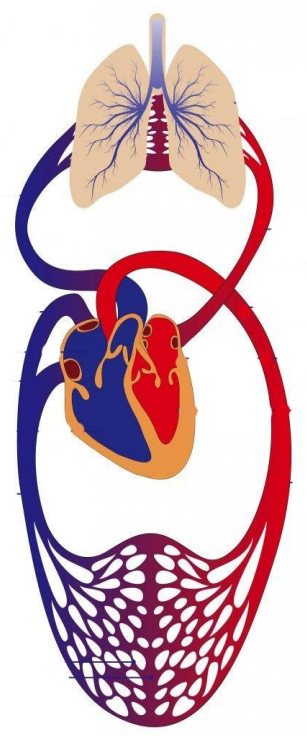
- Four wings
  - Forewing and the hindwing
- **Hamuli**
  - a row of **tiny hooks** on the hindwing that connect to the forewing for flight
  - When joined the wings are very powerful
- **Flight muscles**
  - Do not attach directly to the wings
  - **Located within the thorax**
  - Two pairs
    - Top to bottom
    - Front to back
- **Wing muscles**
  - Small
  - **Fold wings** over abdomen

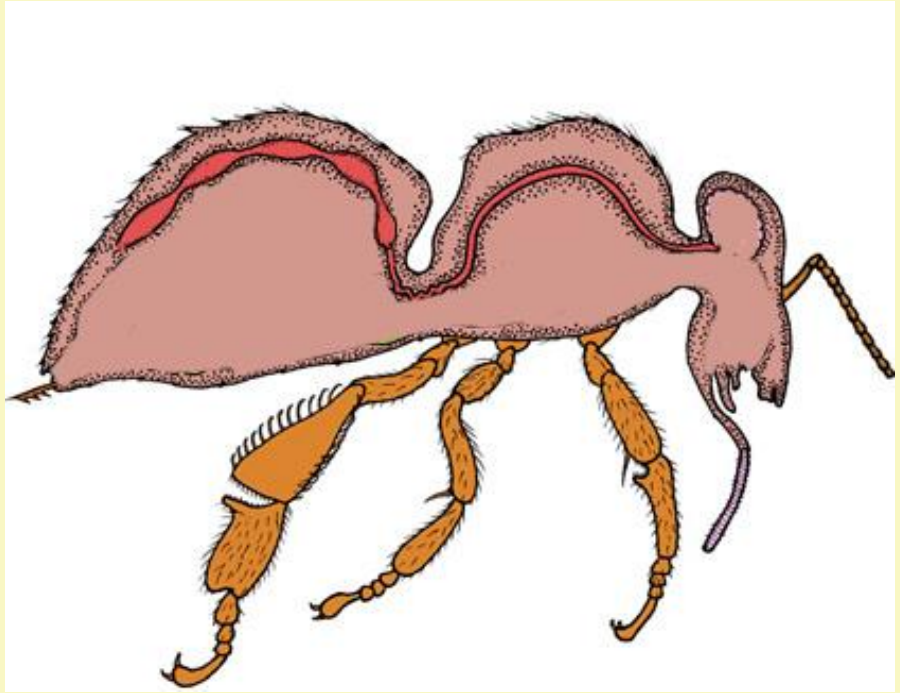


Honey bees beat their wings 240 times per second!

A bee can raise its thoracic temperature 30ºF while it is flying. If it is flying in 55º weather, it will barely be able to keep its wing muscles up to their **minimum operating temperature (85ºF)**—hence bees don't fly much at temperatures below 55 degrees. And if they do, they often don't return.

Circulatory System





Humans

- Closed circulatory system
- Blood stays in the heart, arteries and veins

Honey bees

- Open circulatory system
  - Five-chambered heart
    - Series of muscular chambers open on both ends
    - When relaxed, blood enters from the abdominal cavity
    - Contracts forces blood forward to the head
  - Aorta
    - Carries blood, hemolymph, forward to the head
  - Once in the head the blood is free within the body cavity
  - It sloshes around percolating backward aided by breathing and abdominal movements
  - Sucked back into the heart to complete the circuit

Human Blood and Lymph vs. Honey Bee Hemolymph

Human blood

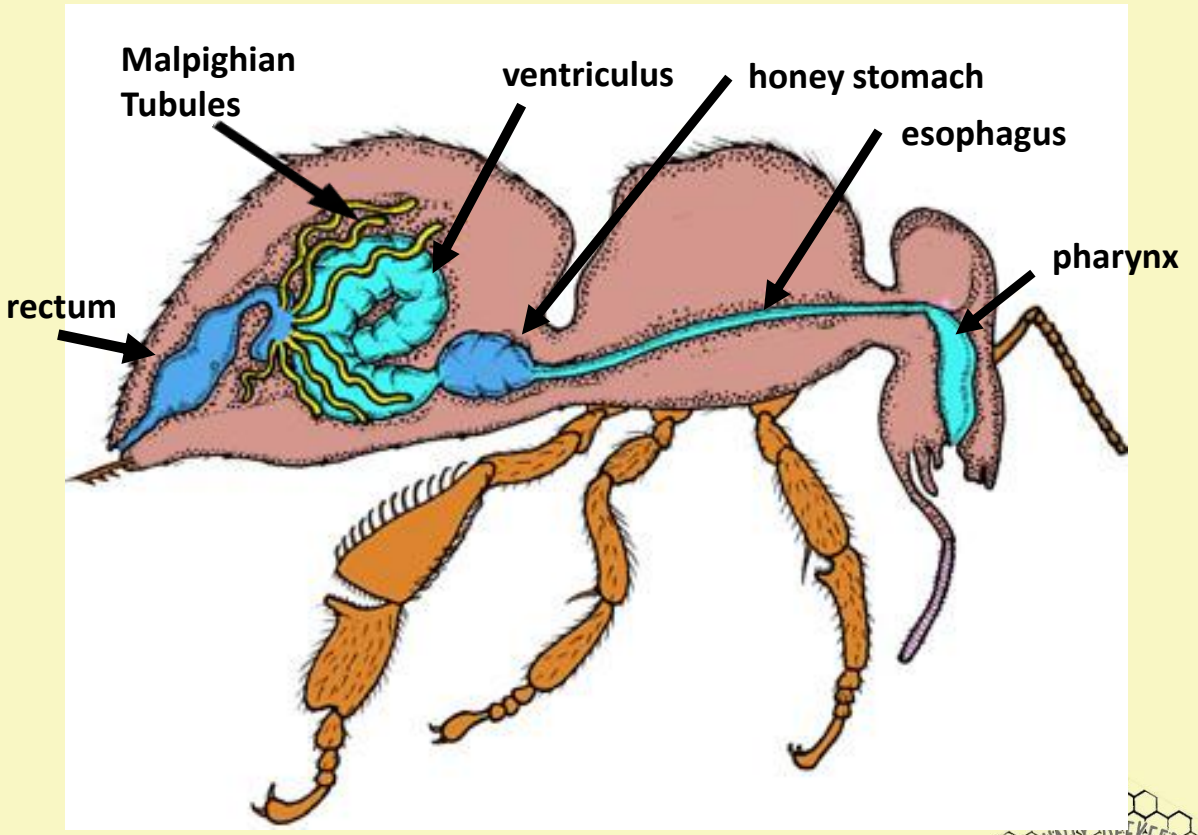
- Red blood cells, white blood cells and platelets
- Liquid called plasma
- Carries nourishment, electrolytes, hormones, vitamins, antibodies, heat, and oxygen
- Removes waste matter and carbon dioxide
- **Lymph**
  - Fluid that leaks out of circulatory system
  - Carries
    - Lymphocytes, white blood cells created in areas such as lymph nodes, tonsils, spleen
    - Macrophages, cells that engulf damaged cells and infectious agents.

Hemolymph

- no oxygen-carrying red blood cells
  - not red in color
  - does not need to circulate rapidly
- Hemocytes engulf foreign substances
- Plasma carries
  - Nutrients, carbohydrates, lipids, amino acids
  - Hormones, immune components, antimicrobials
- Removes cellular wastes
- The nutrients enter the blood absorbed from the digestive tract

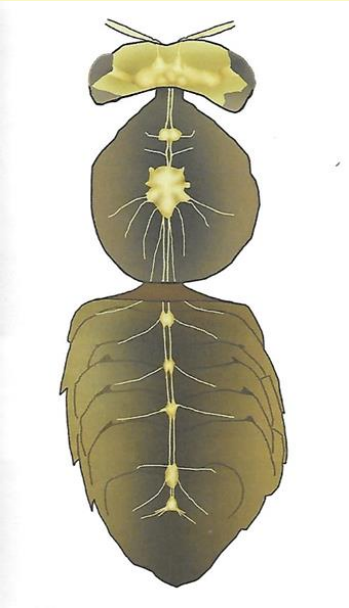
Digestive System

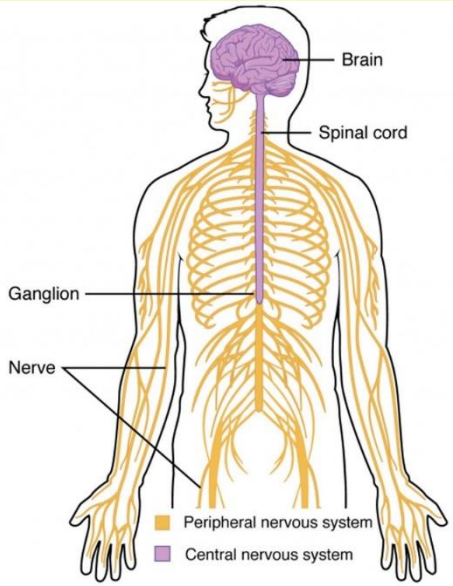
- **Pharynx**
  - Muscles pull food in from mouth
- **Esophagus**
  - Transports food and nectar through thorax
- **Honey stomach**
  - Storage and transporting nectar only
    - Can expand to half of abdomen foraging
  - No digestion
  - Tooth-like structures filter pollen from nectar
  - Closed by a valve when the bee eats
- **Ventriculus**
  - Stomach where digestion occurs
- **Rectum**
  - Reclaims reusable products and reabsorbs water
- **Malpighian tubules**
  - Connected to the stomach
  - Take waste matter from the blood
  - Pass waste to the rectum



Malpighian tubules function is similar to our kidneys

Human vs Honey bee Nervous System





Honey bee brain

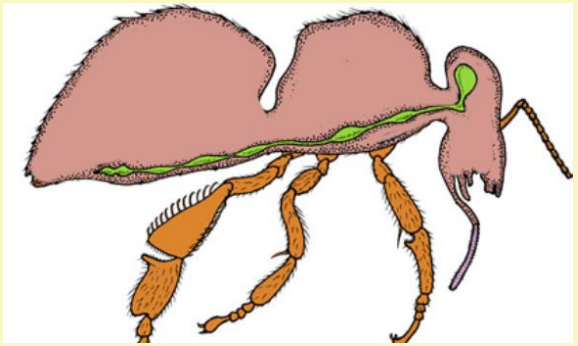
- Two optic and antennal lobes
  - Coordinates functions such as memory and foraging flights
  - Nerve centers for taste and touch
- Seven ganglia in the thorax and abdomen
  - Regulate the organs of the respective body segment
  - Sends information to other ganglia and the brain to unify behavior of the whole individual.

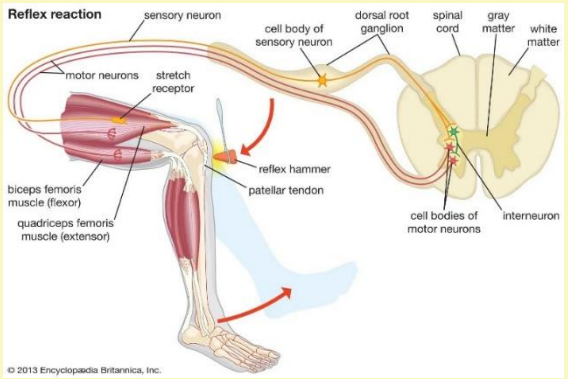
Human brain

- **Cerebrum** is divided into two hemispheres with six lobes
- Each area has unique function (movement, speech, vision, hearing, taste, emotions, memory, etc.)

Human ganglia

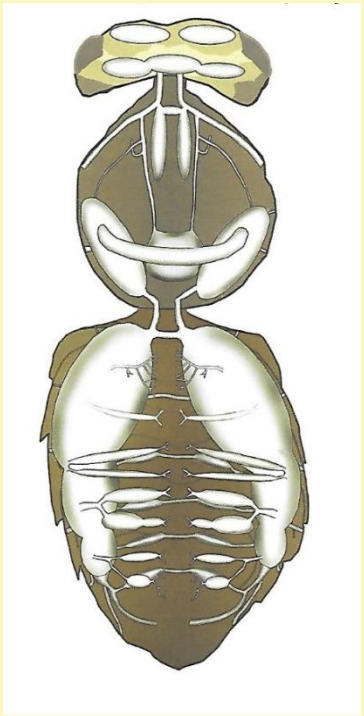
- throughout the nervous system
- switching centers to coordinate automatic body functions (blood pressure, breathing, digestion, reflexes, etc.)





The honey bee's last ganglion coordinates the behavior of stinging.
A headless bee can still walk and sting, although not as well as with a brain!

Honey Bee Breathing



SPIRACLES

- Ten pairs of external respiratory openings
  - 3 pairs on the thorax
  - 7 pairs on the abdomen.
- Branch to every organ in the bee's body
- Valves control the flow of air

TRACHEA

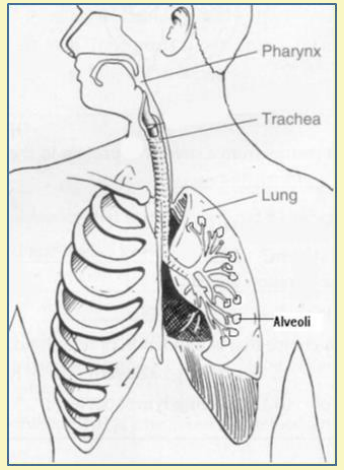
- Connect the spiracles to air sacs

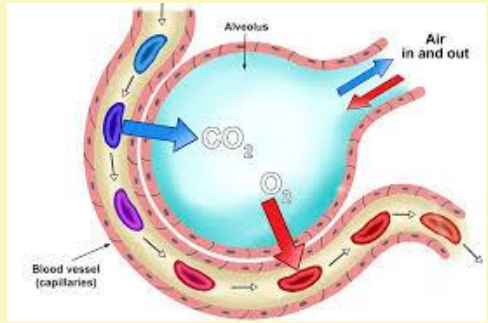
AIR SACS

- Store air
- Few in number but have a large volume
- The abdomen contracts and expands as needed to move air within the system

TRACHEOLES

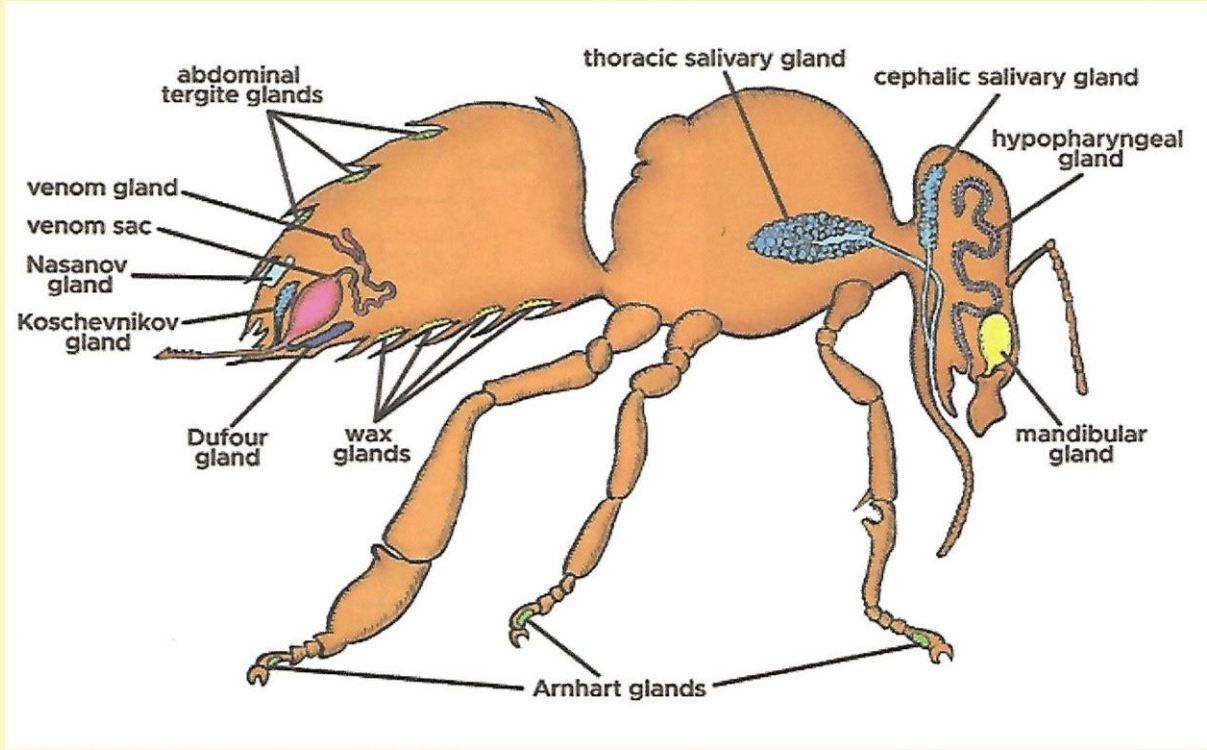
- Smaller tubes emerging from the air sacs to the tissues
- Oxygen from the tubes diffuses into the tissues and carbon dioxide diffuses out
- Unlike humans, bees have no red blood cells to carry the oxygen to the tissues

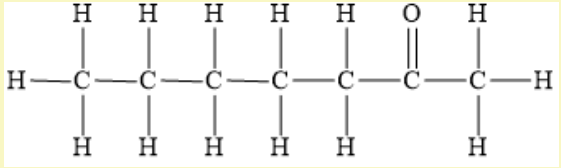




Gland Activity

- **Hypopharyngeal**
  - Royal jelly- sugar, protein and vitamins
  - Only develop in workers and after they ingest pollen
  - Secretion only lasts a few days
- **Salivary**
  - Watery saliva to dilute food
  - Sucrase, lipase & amylase sugars, fat, and starches
- **Mandibular**
  - Queen bees
    - Queen substance pheromone
      - Multiple chemicals affecting several behaviors
      - “Social glue of colony” responsible for colony cohesiveness.
  - Workers
    - Aids wax molding
    - Secretes 2-heptanone
      - Banana alarm scent
      - Anesthetic to paralyze intruders



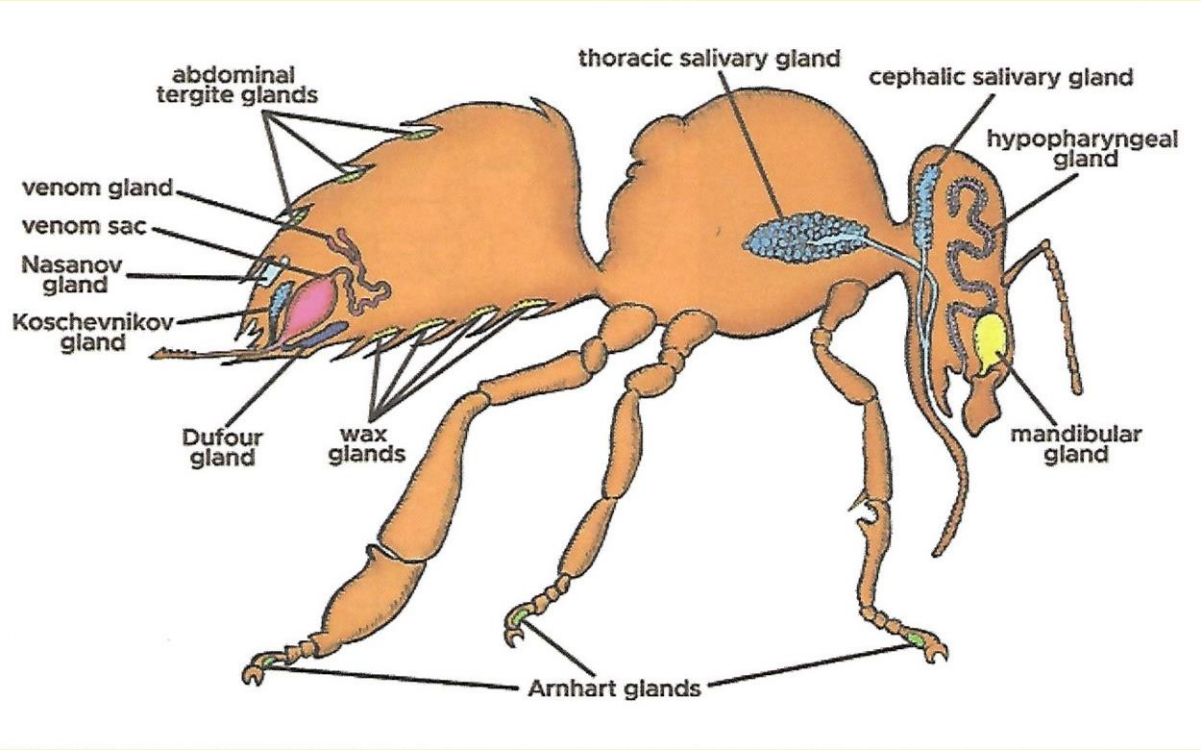


Gland Activity

- **Tergite**
  - Queens pheromone
    - Induces workers to attend her
    - Inhibits development of worker bee ovaries.
- **Nasonov**
  - Worker bee pheromone
    - Attracts workers to food
    - Help lost bees locate home

- The secretions of the Mandibular, Tergite and Nasonov glands keep a swarm cohesive

- **Wax**
  - Produce scales of wax
  - 12 to 16 day old workers
- **Stinger** (4 glands)
  - **Venom (Acid)**
  - **Dufour's**
  - **Koschevnikov**



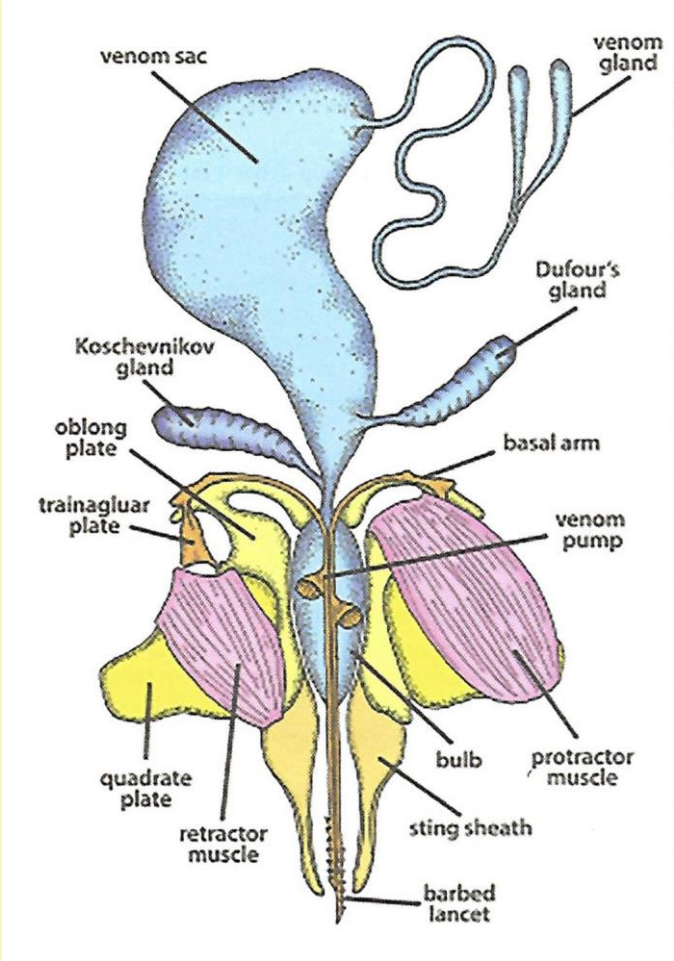
Gland Activity

Sting Structure

- **Dufour** and **Koschevnikov**
  - Produce isopentyl acetate, another banana-like odor
  - Released with the sting.
- **Venom**
  - produce a mixture of enzymes and proteins that cause local inflammation and act as anti-coagulants.

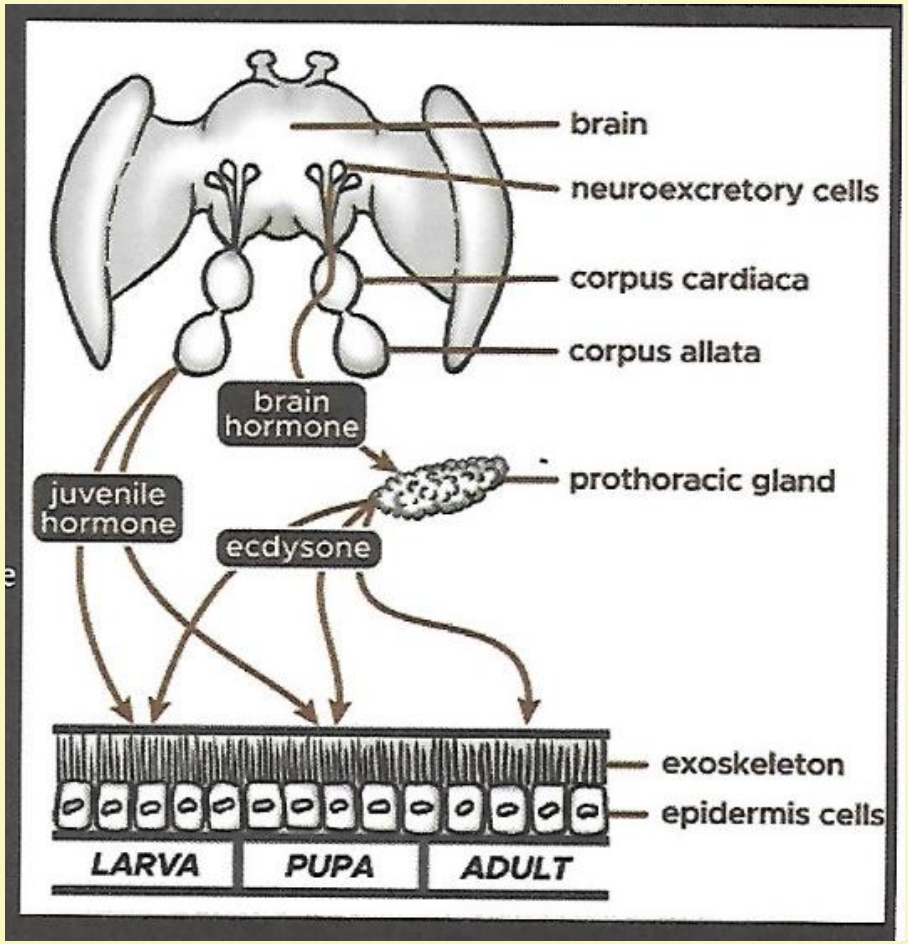
Pharmacologically important substances in bee venom include melittin, apamin, hyaluronidase, phospholipase and histamine. Melittin has antiviral, antibacterial, antifungal and antiparasitic activities. It is also a powerful anti-cancer substance

Other chemicals in bee venom have potential for treatment of multiple sclerosis, Alzheimer's disease, Parkinson's disease and chemotherapy induced neuropathies.

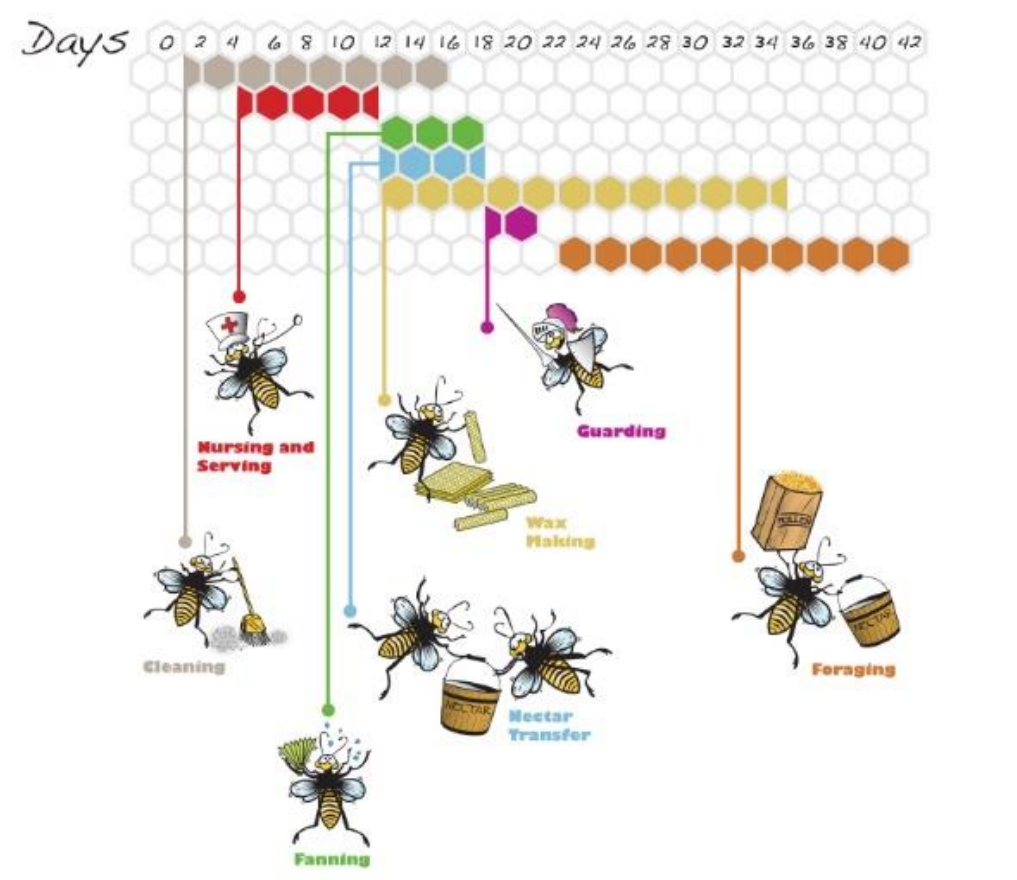


Gland Activity

- The Brain regulates growth and development of glands
- **Neurosecretory cells**
  - Respond to internal and external stimuli
  - Release brain hormone to small glands
- **Corpus cardia**
  - Releases brain hormone to hemolymph
- **Prothoracic gland**
  - Receives brain hormone from hemolymph
  - Produce molting hormone (Ecdysone)
- **Corpus allata**
  - Secretes Juvenile hormone into hemolymph
    - In larva juvenile hormone suppresses expression of adult characteristics until final molt
    - In adults it regulates worker duties



Increasing Levels of Juvenile Hormone Effect Changes in Worker Bee Behaviors



Juvenile hormone is low during the first 2–3 weeks of adult life when performing tasks in the hive such as brood care ("nursing") and is high in foragers

- Newly emerged workers are negatively phototactic-they avoid light.
- **House Bees**
  - Clean the hive and brood cells and remove dead and diseased bees
  - Feed on pollen causing their hypopharyngeal glands to mature and produce royal jelly
- Young **Nurse Bees**
  - Feed larvae royal jelly the gland only secretes the royal jelly a few days
- Older Nurse Bees
  - Feed the older larvae other secretions along with honey and pollen

At 12 Days

- **Nectar Transferors**
  - Receive foraging bees' nectar from their honey stomachs and store it
  - Blow bubbles in nectar secreting sucrose beginning honey conversion
- **Fanning Bees**
  - Reduce moisture in the nectar with their air movement
- **Wax Makers** and begin to build comb and cap cells.

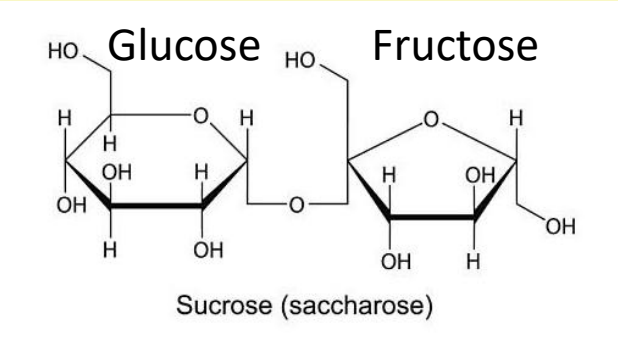
At 18 Days

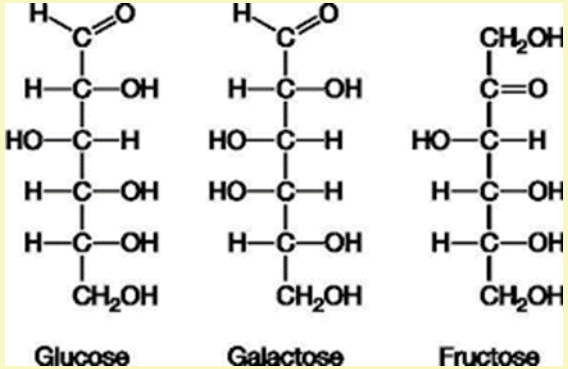
- **Workers**
  - Become positively phototactic, attracted to light
  - Begin **Guarding** and explore outside the hive

At 21 Days

  - Stinger function is matured
  - The "armed" worker moves on to **Foraging.**

Sugar metabolism in honeybee





Sucrose

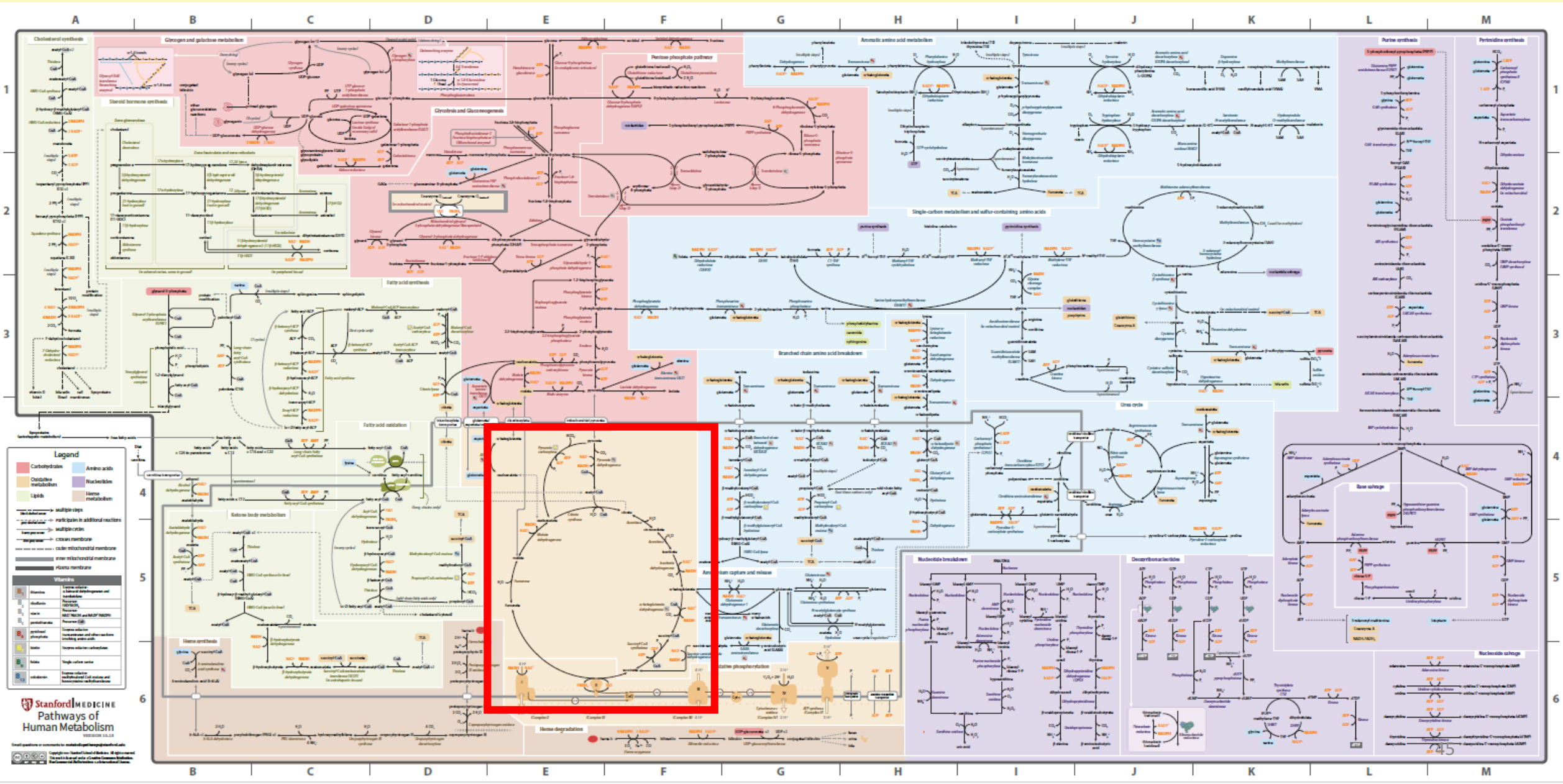
- Table sugar
- Disaccharide (two sugars) of fructose and glucose
- Split by enzymes sucrose and invertase

Fructose and glucose

- Same chemical formula ($C_6H_{12}O_6$)
- Two different sugars
- Atoms are arranged differently
- Difference makes **fructose taste sweeter**
- (Honey is also slightly sweeter than table sugar, because honey contains more fructose)
- Fructose undergoes more chemical reactions than glucose, so it is available to the body as quickly
- Too much fructose can cause liver disease in humans

Nectar is mainly a watery solution of the sugars **fructose, glucose, and sucrose** but also contains traces of proteins, salts, acids, and essential oils.

Metabolism-The biochemical reactions continuously occurring in our bodies

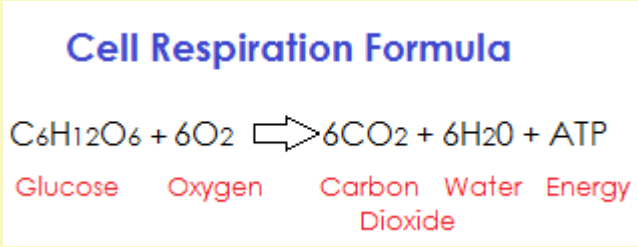


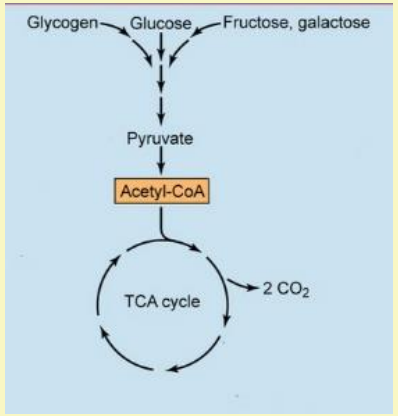
Sugar metabolism in honeybee

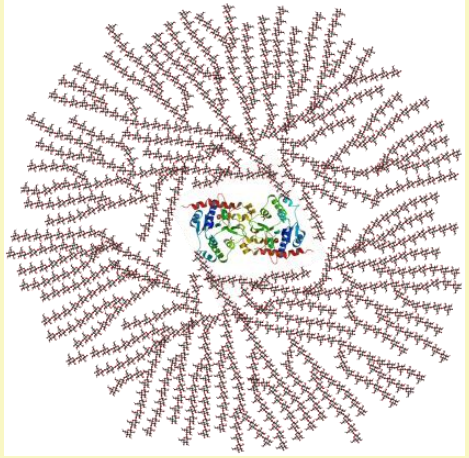
- Sucrose is broken into Glucose and Fructose starting with salivary gland secretion and in the ventriculus (stomach)

- **Energy Production**
  - Glucose and Fructose are metabolized (chemically changed into pyruvate)
  - Their products enter the citric acid (Krebs, tricarboxylic acid) cycle producing carbon dioxide, water and energy in the form of ATP

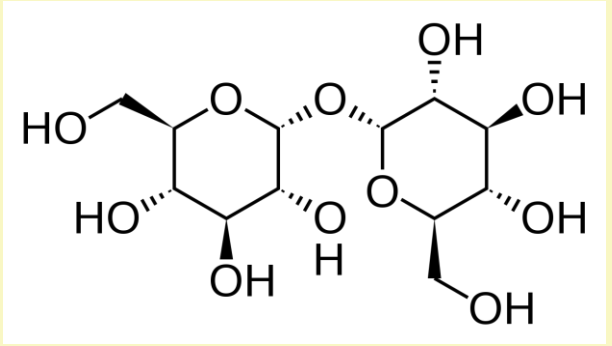
  Other products
  - Gluconic acid makes honey acidic
  - Hydrogen peroxide (H2O2) helps protect honey
  - Two molecules are combined to make trehalose which circulates in the hemolymph for nutrition
  - Several thousand glucose molecules can be combined to form glycogen, a storage mechanism allowing for quick release of glucose when needed
  - Some is converted into fat







Glycogen



Trehalose

Pollen

- Bees use pollen to meet their protein needs
- A single colony consumes 37 to 75 pounds of pollen a year
- Ingested protein is broken down into its compliment of amino acids (22 amino acids)
- Ten essential amino acids to the growth of the honey bee (bees can't create them from other amino acids
  - arginine, histidine, leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine
- The largest need is for **leucine, isoleucine and valine**
- Bees need amino acids and minerals for development of muscles, glands and other tissues
- Adult bees begin pollen consumption within two hours of emergence and quickly increase pollen intake to reach a maximum five days after emergence
- Pollen consumption is negligible in bees older than ten days of age
- Young nurse bees serve as the nutritional center of the colony, consuming the pollen and producing royal jelly. It is not known how they pass on the nutritional needs to the foragers.

Pollen also supplies the vitamin and mineral needs.

Nine amino acids—histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine—are not synthesized by mammals and are therefore dietary essential or indispensable nutrients. **Dandelion pollen has low levels of valine, leucine, isoleucine and arginine**. Other pollen sources such as apple blossoms balance the dandelion's deficit.

Plants with **high quality pollen** include **clover, oilseed rape (canola), pear, poplar, aspen, cottonwood, and lupine**

Fat Body

Forager vs. winter bee

- The equivalent of our liver in functions
- The white, creamy insides of larvae is the fat body
- Adults- fat bodies are found throughout the honey bee body but especially in the abdomen
- Summer bees have few fat bodies, winter bees have large numbers of fat bodies ("fat bee" but doesn't look any different)

Function	**If Compromised**
• Controls changes from egg to pupea	Bee growth and lifespan are reduced
• Energy metabolism	Flight and environmental challenges require higher energy levels
• Stores and mobilizes energy (glycogen)	Foraging bees can't convert energy stores, fail to return to hive
• Pesticide detoxification	Lower levels of pesticides become lethal
• Produces anti-microbial peptides	Immune function reduced, more susceptible to viral infection

• Regulates temperature
  • Insulating layer
  • Produces hot/cold hormonal control
	Failure to recognize threat and activate flight muscles to regulate heat. Possible cause of winter colony loss

• Protein and fat synthesis	Adults bees unable to provide adequate protein for young bees and queens Less bees are able to forage and produce honey
• Vitellogenin production	Rapid aging, less stores required to last through winter

Vitellogenin

Egg development

- egg-yolk precursor **protein** used to deliver nutrients to developing eggs

Immunological functions

- binds to and **eliminates pathogenic** bacterial and fungal cells
- **protects host cells** from oxidative stress (**aging**) by binding to and neutralizing dangerous chemicals
- binds to damaged host cells and protects them from further injury
- transports the zinc required to maintain immune cell (hemocytes)

- Workers and queens develop from the same genome, but queen lifespan is ≈10-fold longer
- Queen longevity is achieved without the typical tradeoff between longevity and reproduction
  - Queens lay up to 2,000 eggs per day and live for 1–3 years
  - Workers have limited egg laying and live for 3–6 weeks
  - In workers, the Juvenile Hormone level is low during the first 2–3 weeks of adult life and is high in foragers. Vitellogenin levels follow an opposite pattern in queens, both Juvenile Hormone and Vitellogenin levels are elevated in emerging virgin queens, but Juvenile Hormone drops and stays low while Vitellogenin remains high

Varroa destructor- Enemy #1

Varroa mites may be found on adult honey bees

To **feed on the fat body**, the Varroa mite pierces through the abdominal plates of the adult bee exoskeleton

Young mites and male mites feed and live only on the larvae and pupae

Fat body tissue is spread throughout immature bees, Varroa are able to access it from anywhere on the body

The mite **injects an enzyme that destroys** the structure of **the organ**, allowing for easier consumption

This **causes severe damage** to the bee and larvae **without** necessarily leading to immediate **death**

Varroa can transmit multiple viruses that damage that bees

Adult female Varroa mites lay their eggs within the brood cells, first laying an unfertilized egg, a male, then fertilized female eggs every 25-30 hours. The process of egg to adult mite takes six to seven days

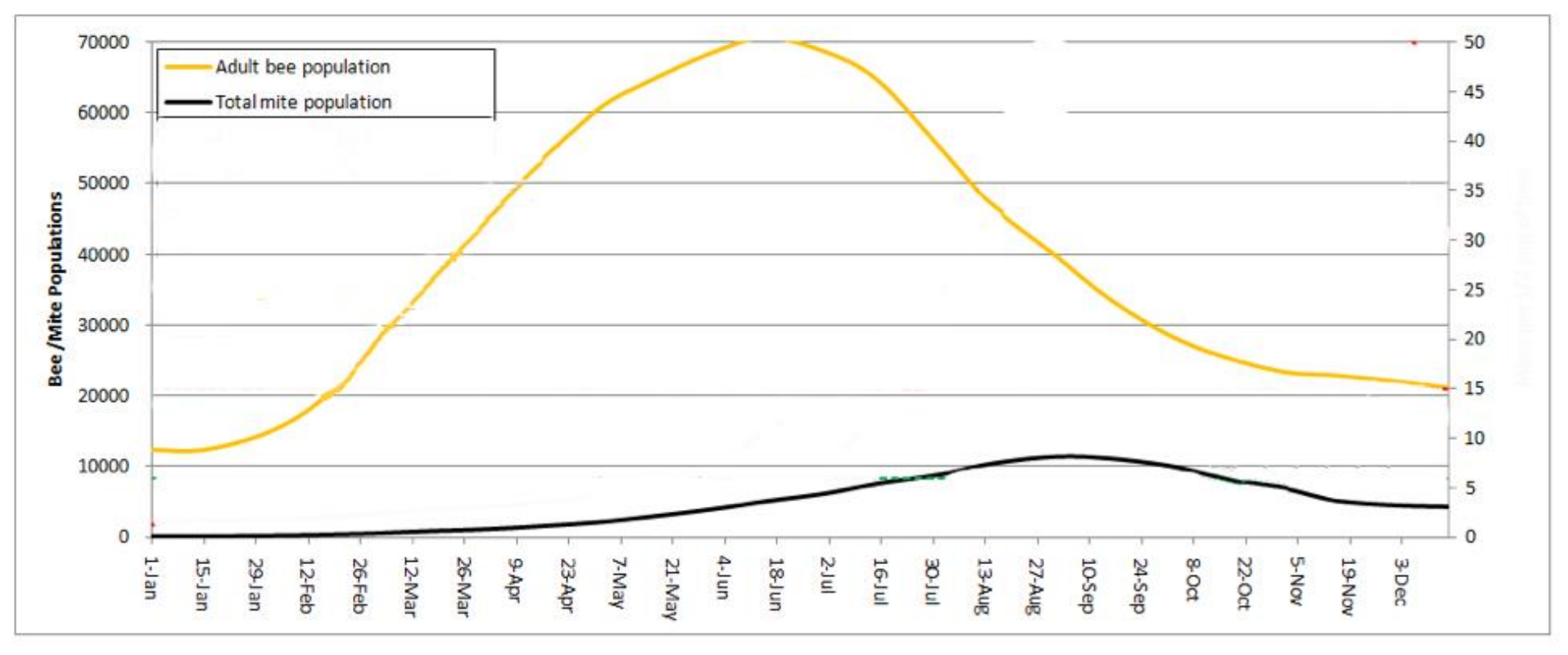
Once the bee breaks open the beeswax cap and crawls out, adult female mites emerge from the cell

The male mites die shortly after mating; they never leave the brood cells, Undeveloped female mites also die

The adult female can live for three months Varroa can reproduce in several cells

Female mite enters cell just before it is capped and sits under the larva for70 hours before laying the first egg. She then lays 5-6 additional eggs every 24-30 hours. As a queen cell is capped for less than 8 days, no new mites are created. Worker cells are capped for 11 days and could produce 2 mites and drones for 14 days, 4 mites. An average of 3.4 mites develop in lab studies but variations occur on which workers phoretic mites use for nutrition.

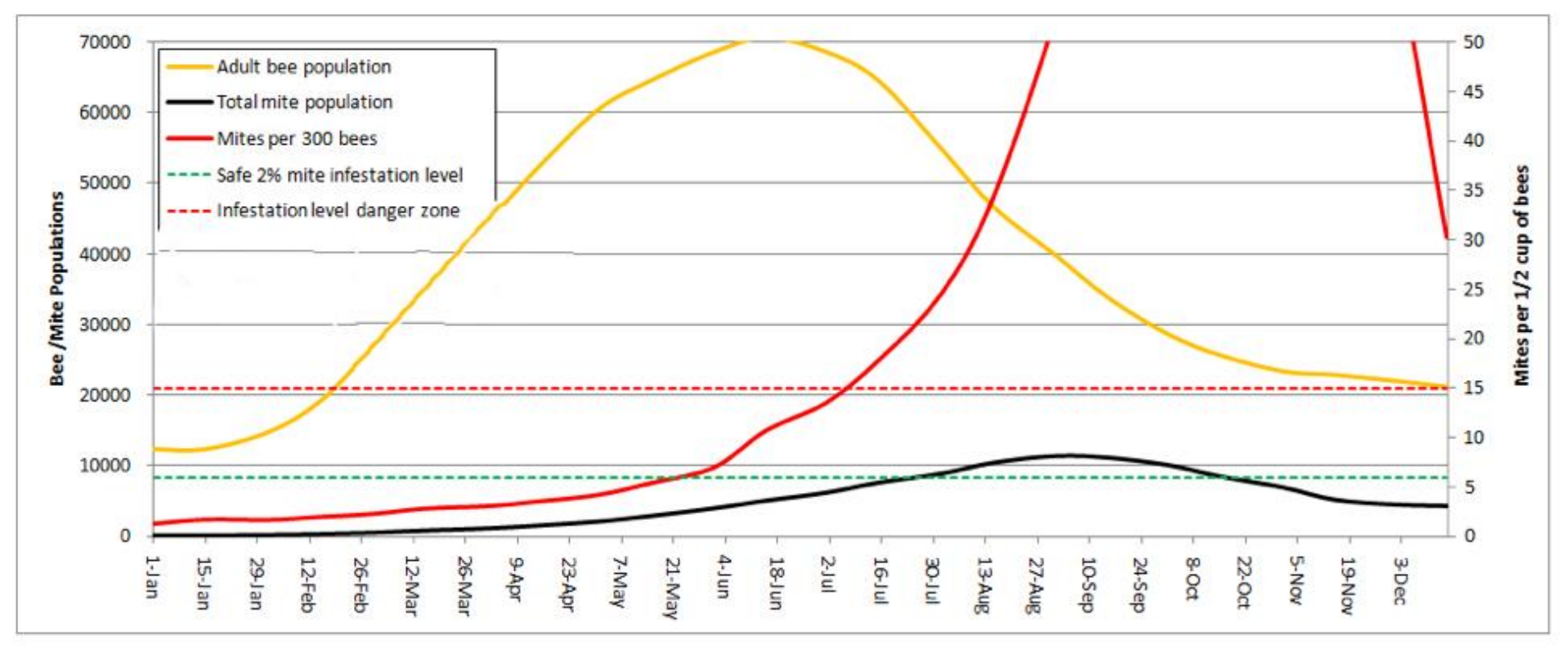
Honey Bee and Varroa Mite Population Growth



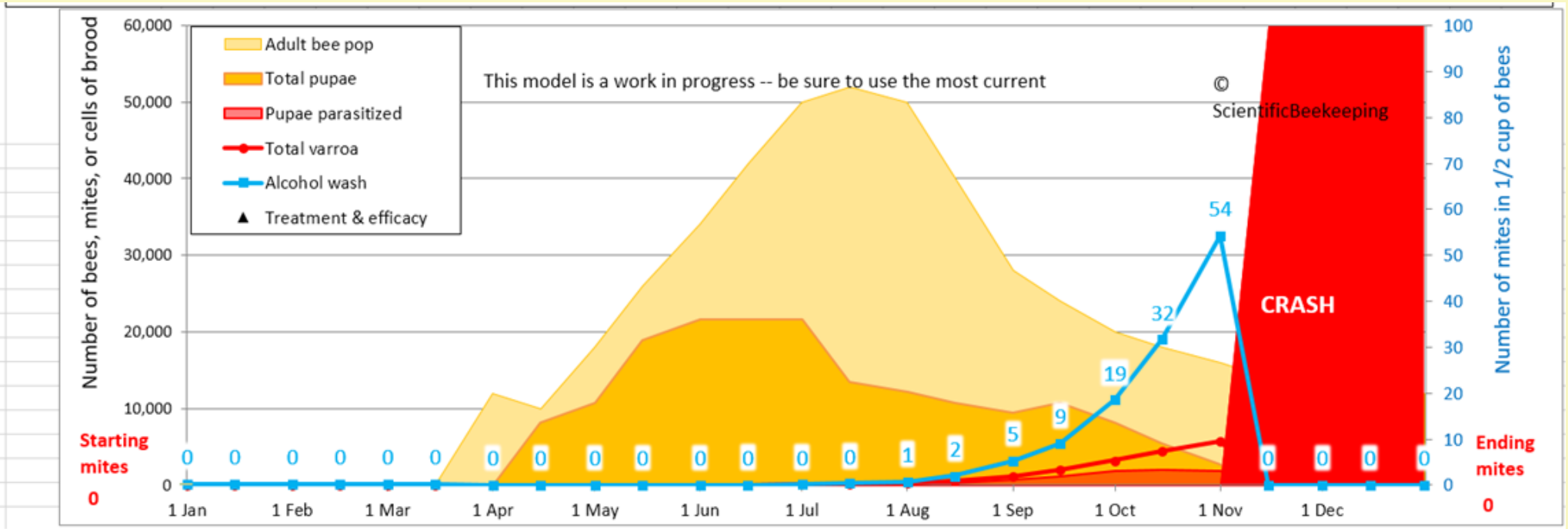
r value = the change in total population over 15 days e.g 100 bees growing to 140 140/100= 1.4
During brood production the rate of both bee and mite population growth are about the same r=1.4
However, in mid-summer the bee population decreases at a rate of r=0.8, but the mite population doesn't die at the same rate, r=.96

Randy Oliver used a reproductive rate of 1.4 for mites instead of 3.4… no sure why.

Varroa Mite Count per 100 Bees Becomes Exponential



During the spring and early summer 2/3rds of the mites are in the brood. As the number of bees decreases, the number of mites per bee rises quickly.
(If the hive swarms, half of the bees leave but take only 1/6th of the mites!)



Mite reductions→																										
Colony type*	p	P: Package bee colony (3 lb), installed on drawn comb and fed well																								Type "x" above for Southern Hemisphere
Mite population	1						1	2	2	4	6	30	76	158	290	594	1,182	2,000	3,210	4,384	5,675					
Mite immigration**	4	0	0	0	0	0	0	0	0	0	20	30	45	75	200	400	500	400	200	100	30			2000	Total	
% mites in brood	%	0%	0%	0%	0%	0%	0%	77%	71%	75%	72%	68%	64%	57%	56%	57%	60%	65%	63%	59%	51%	#VALUE!	#VALUE!	#VALUE!	#VALUE!	

Randy Oliver's model showing the demise of a package of well fed bees due to untreated mites.
Note that the mite count showed only 1 mite in August, but demise of the hive in November.
If a hive determines it is overrun by mites it may abscond to another apiary and spreading the Varroa problem

Summary

- Beekeeping requires knowledge and anticipation of the bees' needs
- Honey bee have unique anatomical parts and functions
- Honey bees have adapted in many ways to harvest nectar and pollen to produce honey
  - Special vision, honey stomach, pollen basket
  - Biological process of turning sugars into honey
- Honey bees communicate through pheromones and other chemical scents
- Hormonal changes effect the succession of worker bee tasks
- Honey bees require good nectar and protein sources
  - Not all flowers provide the nutrients that are needed
- Healthy fat bodies are required for optimum bee health
  - Varroa mites feed on fat bodies
  - Life expectancy of worker bees is decreased by damage to fat bodies
- Integrated pest Management for treatment of Varroa mites is necessary for every hive

- Several graphs and pictures were taken from "Honey Bee Biology and Beekeeping, third edition, Dewey M Caron and Lawrence John Connor. Others from various sites on the internet including Randy Olivers site, Scientific Beekeeping . https://scientificbeekeeping.com/

Tripod vs Tetrapod gait

Honey bees as do most insects walk with a tripod gait meaning the front and back leg on one side move forward with the middle leg on the other, alternating from side to side and swaying the body from side to side. But that only produces straight forward motion. To make a turn the nervous system of the bee changes the gait to a tetrapod pattern. The opposite pairs become synchronous with alternating the front and middle, middle and rear, and front and rear legs working together. This requires coordination of the ganglia controlling leg movement.