The Animal Kingdom

Animals are the largest most diverse kingdom of life on earth

all life on earth can be categorized into 5 major kinds

→ 5 kingdoms

although more recent information has now expanded that to 6 to 9 major kingdoms; for our purposes we'll consider 5 here

over 2 million individual species have been identified so far in all kingdoms

known species in each kingdom:

	# of species
Bacteria	10,000
Protista	65,000
Fungi	100,000
Plants	300,000
Animals	1,700,000

Animals cleary dominate

→ over 3/4ths of all know species belong in animal kingdom

Estimates of the **total number of living animal species**, known & unknown, are difficult to make

yet all indications are that there are many more species yet to be discovered:

→ each year ~ 13,000 new species are described

→ some of the most diverse areas on earth are just beginning to be investigated

eg. vertebrates

birds: 3 new bird species/yr described

fish: estimate only 40% of those in South America have been described

eg. invertebrates

insects: ~700 new species of insects are described each year

eg. of 19 trees in one Panama study 1200 species of beetles were collected and 80% of them were new species

eg. marine invertebrates of the deep ocean

only 1.5% of the deep ocean have been investigated

on an area the size of a parking lot off New England coast

→ 800 different species of inverts found

recently discovered whole new kind of community of 100's of new species of organisms

marine biologists estimate there may be up to 10M invertebrate species in the deep ocean alone

→ there are probably ~25 x's more animal species that have not yet been named than those that have been named

Also, all animals alive today comprise <10% of all animals that have ever lived

perhaps 500 Million species of animals have lived on this earth in the last billion years

Even in terms of total numbers of **individuals**, animals are second only to bacteria

eg. estimate 10,000 Trillion ants on planet

→ all the earth's ants weigh ~ same as all earth's human population

eg. there are more animals on earth than stars in our galaxy

What exactly is an Animal?

1. ALL animals are **multicellular**

the **CELL** is the basic unit of life

→ ALL living things are composed of cells

an organism can consist of one or more cells:

unicellular = solitary cell

eg. bacteria, some protists

multicellular = always consist of many cells

different cells have become specialized for different functions

cells are interdependent on each other

→cells **never** found alone

eg. most fungi, all plants, all animals

animals show the best development of multicellularity of all kingdoms

2. ALL animals are **heterotrophs**

a few marine species carry chloroplasts in their skin cells and can do photosynthesis

→ but these chloroplasts are taken from the algae they eat

a newly discovered species of sea slug actually contains some of the genes for photosynthesis in its own genome

→ but still needs to steal chloroplasts to do photosynthesis

all life requires a set of **nutrients**

→ chemicals that are essential to keep the organism alive

these nutrients may be used as **building blocks** or as an **energy source**

nutrients are used as **building blocks** to make cells, tissues, skeletons, blood, etc

organisms also need an **energy source** to "power" everything that an organism does

the **direct** source of a cell's energy is the breakdown of **organic** molecules (mainly sugar)

→ ie. they use **chemical energy**

energy is stored in "chemical bonds"

when you break bonds you release energy

organic molecules have lots of bonds and store lots of energy

organisms have developed two basic ways to get these energy molecules:

Heterotrophs

=organisms that must **eat** organic molecules and then break them down for energy

eg. us and other animals

Autotrophs

= organisms that extract energy from sunlight or some other source to make organic molecules

then they can break them down as needed for energy

ie. they don't need organic molecules in their diet

eg. plants, algae and some bacteria

3. all but 3 newly discovered animals produce energy primarily by **aerobic respiration**

sugars and organic molecules can be broken down for energy with or without O_2 gas.

producing energy without the use of O_2 is called **anaerobic respiration** and is common in bacteria and some fungi

aerobic respiration extracts much more energy from organic food

eg. anaerobic respiration of sugar → 2 units of energy

aerobic respiration of sugar → 36-38 units of energy (19x's more)

some animals can use **anaerobic respiration** temporarily or in specific tissues such as muscle tissue but primarily rely in aerobic respiration for most energy

recently, 3 new species of loriciferans have been found to completely lack mitochondria and get all their energy from anaerobic respiration

4. most animals store extra energy as **fats or oils**

most efficient way to store energy for active animals

eg. twice as efficient as storing extra energy as starch as plants do

5. most animals are **motile** and much more active than members of any other kingdom

Animal Records: Locomotion

Swimming

fastest fish
barracuda → **27 mph**

fastest mammal
seal → **25mph** (40kph)

Running

fastest land mammal
Cheetah, *Acinonyx jubatus*→ **60mph** (96kph) in spurts
speeds up to 90 mph have been claimed, not verified

slowest land mammal
3 toed sloth, *Bradypus tridactylus* → **6-8 ft/min** (0.088mph)

Flying

Fastest bird (horizontal flight):
racing pigeons and dunlin sandpipers →**110mph**
fastest diving flight: peregrin falcon 82mph
(unverified to over 200mph)
(but horizontal flight 30-60mph)

Fastest mammal flight:
mexican free tailed bat → **48mph**
(others suspected to be faster)

Fastest Insect:
Dragonflies, some flies & moths →**25-30 mph**
black cutworm moth →70mph (rides cold fronts)

6. most animals have **true tissues**

groups of interdependent **cells** specialized for a particular function

epithelial	→ covers body
***muscular**	→ used for movement
***nervous**	→ coordination and control
connective	→ storage, transport, protection, etc

7. most with **organs** and complex **organ systems**

groups of interdependent **tissues** specialized for a particular function

plants have simple organs; roots, stems, leaves

animals have organs grouped into complex interacting organ systems

8. most animals have a **head** with distinct sense organs and some kind of brain

9. most animals have outgrowths, processes or appendages for sensory functions, collecting food &/or for movement

eg mouthparts
antennae
tentacles
fins
legs
wings

10. most reproduce both **sexually and asexually**

asexual: exact copies, clones

easier, quicker, don't need a mate

sexual: unique combination of traits

produces variation which allows adaptation and evolution

involves specialized sex cells:
sperm and **egg**

reproduction at **organismal level:**

asexual:

eg **budding**
fragmentation
regeneration

sexual:

eg **monoecious**
dioecious
protandry

11. most animals show **complex development**, with extended embryonic phase, often with free living larval stages

all organisms (even bacteria) pass through a characteristic **life cycle**

changes in size and shape

eg. Frog: embryo→ larva→adult
eg. Human: embryo→fetus→juvenile→adult
eg. Butterfly: embryo→caterpillar(larva)→pupa→adult
eg. Fly: embryo→maggot(larva)→pupa→adult
eg. Clam: embryo→larva(glochidium)→adult

some involve alternation of two completely different body forms; one that reproduces asexually, one sexually

the immature forms may be self sufficient or

completely dependent on mother for nourishment and protection

eg. embryos, larvae, nymphs, etc

the life cycle often involves **metamorphosis** of one free living form into another

in some animals the embryonic or immature stage is a dormant or resistant stage

12. in animals **behavior** plays a major role in how they interact with their environment and with each other

behaviors play a major roll in food gathering, social interactions, mating and care of young

one of the more distinctive animal behaviors is **migrations**

animals in many groups migrate; arthropods, fish, birds and mammals are the best known

13. Probably some of the most unique chemicals produced by animals are a huge variety of **venoms**

venomous creatures are found throughout the animal kingdom

estimated 100,000 venomous animals from corals and sponges to spiders, scorpions, snakes, etc

each carries its own unique coctail of toxins, mostly, various kinds of proteins

14. all living organisms constantly **adapt** to their environment in many ways through physiological, anatomical or behavioral changes

some adaptations can be in the form of changes in growth and physiology

eg. fur color of the same species may vary across habitats adapting to temperature or amount of sunlight

eg. same species of bird may have harder stronger beak in one habitat than another depending on type of food available

some adaptations involve behavioral changes and learning

eg. tool use among animals

15. adaptations also occur across generations as the most useful traits are selected for and passed on while harmful traits are eliminated

→ =**evolution by natural selection**

eg. same species in different ecosystems

eg. reproductive displays

eg. niches and evolution → marsupials in australia

Animal Records

A. Largest Animal

=longest

longest animal in existence is a nemertean
= 60 M (180') long

"Lions Mane" jellyfish → ~150' long.

= tallest living animal

giraffe, *Giraffa camelopardalis* → 19' (5.8 m)

=most massive

a. blue whale, *Balaenoptera musculus*, would be bigger in every other dimension (weight, girth, displacement)

eg. Mature blue whales typically measure anywhere from 75 feet (23 m) to 100 feet (30.5 m) from head to tail

and can weigh as much as 150 tons (136 metric tons).

The largest blue whale on record is a 110' female that weighed 195 tons (177 tonnes).

b. largest of all reptiles: *Seismosaurus hallorum* ("Earth-shaking lizard")

120+ feet long (37 m); 30-80 tons

→ largest animal ever to have walked on land

b. the sauropod dinosaur, *Argentinosaurus*, weighed

about 90 tons (82 tonnes).

→That's little more than half the size of an adult blue whale.

It makes a lot of sense that the world's largest animal would be a sea creature.

Land animals have to support their own weight, whereas sea creatures get some help from the water.

c. The largest land animals today are male Savannah Elephants, up to 11' tall with one known example weighing around 7.25 tons(6.7 tonnes)

d. Largest land mammal ever was *Baluchitherium*

B. Smallest Animal

some unusual invertebrates are microscopic being made up of <100 cells

C. Longest Lived Animal

Confirmed: The ocean quahog (Arctica islandica), a type of clam, lived in the deep water off iceland before being dragged onto a ship, age was confirmed by growth rings on shell

Invertebrates (unconfirmed estimates):

eg. biochemical and nuclear evidence indicates that some sea urchins may live up to 200 years

eg. some crinoids may live for 1000's of years

eg. some sea anemones are essentially immortal, can live 1000's of years

Cold Blooded Vertebrates:

eg. Chilean sea bass is claimed to live over 100 yrs

eg. Orange roughy up to 150 years

eg. A Madagascar radiated tortoise (*Geochelone radiata*) → ~188-192 years

presented to the Tongan royal family by the British explorer Captain Cook in either 1773 or 1777, died in 1965, lived to the age of at least 188 years old! The animal was called Tui Malila.

eg. A Giant Galapagos Tortoise Harriet, collected in 1835, lived in captivity until she died in 2006 at about 177 years old.

Warm Blooded Vertebrates

eg. some Macaw birds may live up to 100 years

eg. unconfirmed report of a bowhead whale living to be 245 yrs old; dated from stone and metal harpoon points found in the whales & chemical testing

eg. primates are generally the longest lived as a group and man is the longest lived of the primates: 122 years (Jeanne Louise Calment, 1875 - 1997).

(mammals with shortest lifespan are tiny shrews: maybe 1 to 1.5 years.

→The faster you live, though, the shorter you live)

Animal Cells

animal cells are "eukaryotic" cells

much larger, much more complex,

most genetic material is contained in prominent **nucleus**

lots of internal and surface structures including **organelles**

animal cells **lack cell walls**

the thin flexible cell membrane forms the outer boundary of each cell

not rigid, but flexible

also acts as a gateway for things moving into and out of the cell

organelles and other internal structures provide a division of labor and allow the cells to work much more efficiently

eg. **mitochondria** → energy factories

eg. **vacuoles** → storage containers

eg. **ribosomes** → energy factories

eg. **lysosomes** → cellular digestion

animals are generally much more **active**, have a much **higher metabolism** than the members of other kingdoms

they therefore require much more energy than species in any other kingdom

almost all this energy is the product of **aerobic respiration** inside **mitochondria**

→animal cells have many more mitochondria than those of other organisms

animal cells make much more use of **proteins** for structure, movement, nerve impulses and metabolism

→many more **ribosomes** (protein factories)

Animal Tissues

single celled organisms like protozoa are "jacks of all trades"

move
feed
produce energy
respond to stimuli
reproduce
etc

in multicellular organisms such as animals the large size and complexity dictates that individual cells **specialize**

rather than performing all tasks each group of cells becomes specialized to do one or a few tasks very well (much more efficiently):

eg. muscle cells → contraction & movement
eg. bone cells → support
eg. blood → circulation

while they become more efficient at one or a few specific jobs, they lose their independence and can no longer exist on their own

tissues are groups of similar cells performing similar functions

includes cells and any secretions (=**matrix**) they produce

There are 4 basic animal tissues:

1. **epithelial**
2. **connective**
3. **muscular**
4. **nervous**

1. Epithelial Tissues

this is the most primitive animal tissue

→presumably the first true animal tissue to evolve.

It forms the **outer coverings** of animals

lines the inner and outer surfaces of all organs.

consists of cells fitted tightly together

Functions of Epithelial Tissues:

1. **protection**

   from microbes, physical injury, water loss, etc

2. **absorption**

   of food, water etc in the intestine

3. **transport**

   sometimes have cilia (tiny hairlike processes)

that move things along a tube

eg. oviducts → move egg toward uterus

eg. respiratory tract → move dust and bacteria out of lungs

4. **filtration**

in kidneys

5. **gas exchange**

lungs

6. **secretion**

eg. form glands that secrete various substances

eg. mucous, sweat, digestive juices

2. Connective Tissues

the most widespread and abundant type of tissue in animals

the most diverse in structure and function

most connective tissues are heavily vascularized

connective tissues have an abundance of **matrix**

→the noncellular matrix often comprise the majority of the tissue volume

the nature of the matrix and the fibers it contains identifies the specific kind of connective tissue

fibers composed mainly of **collagen**

a uniquely "animal" protein

(esp. skin, tendons, ligaments, cartilage)

Functions of Connective Tissue:

1. **Glue**

eg. areolar tissue

2. **Support & movement**

eg. bone & cartilage

3. **Nutrient Storage**

eg. bone, adipose

4. **Temperature Homeostasis**

eg. fat for heat production and cold insulation

5. **Transport**

eg. blood, lymph

3. Muscle Tissues

elongated cells, spindle shaped, up to 1 ft long

= **muscle fibers**

highly contractile and elastic cells

all cells contract to some degree, but muscle cells are much stronger and contract much more efficiently

eg. our calf muscles can support 1 ton

muscle cells generally stop dividing at birth

(# fixed at birth)

but each cell can expand greatly in volume

Functions of Muscle Tissue:

1. **movement**

both **voluntary** movements such as swimming or running

and internal **involuntary** movements of various organs such as the pumping heart, and peristalsis of the digestive organs.

2. **posture**

3. **heat generation**

used for **movement**

4. Nervous Tissues

nerve cells are also elongated into long fibers

typically large cell body with one or more long fibers extending from it

grouped together to form extensive interconnected network of "wires" that extend throughout the body

nerve cells are able to conduct impulses to send signals throughout the animal body

Functions of Nervous Tissue

1. to sense internal and external environmental changes,

2. coordination and control of muscles and glands.

Stem Cells

Most adults retain some kinds of "embryonic cells" called **stem cells**

can later differentiate into replacement cells and tissues.

Animal (Including Human) Organ Systems

The **greater specialization** of cells and tissues increases the efficiency by which animals can carry out life's basic processes and allows for almost limitless opportunities for evolutionary variations and adaptations to numerous kinds of habitats and environmental conditions.

to understand and appreciate the complexity of different kinds of animals we'll focus on the most familiar (and most complex) animal → US

1. <u>Skin</u> (integumentary system)

outer covering of the animal

(plants also have outer covering, epidermis, but it's much simpler in structure and function)

→in some animals (usually relatively small ones) is a simple covering that allows food, gasses and waste products to easily diffuse in and out of the animal

→ in terrestrial animals it may serve as a waterproofing layer to keep animal from drying out

→ skin often contains various sense organs

→ in some skin is hardened to offer support

→in some animals the skin color is important in behaviors:
- communication
- camoflage
- reproductive behaviors
- etc

many animals can quickly change the color of their skin
→ **chromatophores**

2. <u>Skeletal System</u>

especially terrestrial animals

(in land plants support was also an important consideration → cellulose & lignin)

3 main kinds of support system in animals:

exoskeleton

on the outside → especially good protection (eg. clams, snails, insects)
secreted by the skin
grows at edges (clams & snails)
or must be shed periodically for growth (insects and other arthropods)

endoskeleton

internal → grows with the body
eg. vertebrates including us

hydrostatic skeleton
muscles of body wall control fluid pressure
eg. most worms, jellyfish, octopus

eg. human skeleton(endoskeleton)

is made of over 200 bones

grows continuously throughout life
→ very active tissue
→ recycled every ~7 years

subdivided in **axial** (skull, vertebrae, rib cage) & **appendicular** skeleton (arms & legs)

functions in

1. **support**
   strong and relatively light; 10% body weight
2. **movement**
   framework on which muscles act
   →act as levers and pivots
3. **protection**
   some of our most delicate organs are well protected by being encased in bone

   eg. brain, lungs, heart, reproductive system

3. <u>Muscular System</u>

unique to animals:

→ animals are much more active than any other kingdom

General Functions of muscles:

1. **movement**

most animals are **motile**

→ walk, run, crawl, swim, fly, climb, etc

a few animals are **sessile**

but even these have internal muscles that circulate blood, move food through digestive tract, etc

some muscle are **voluntary**

some are **involuntary**

2. **Heat Production**

important for warm blooded animals like us
→ muscle generate lots of heat

warm blooded vs coldblooded

all animals alive today except birds and mammals are "cold blooded"

bird & mammals are warm blooded
→ much more active
→ require much more food to maintain heat production

4. **Digestive System**

like fungi, and many protists and bacteria, animals are **heterotrophs** → take in organic food

animal food needs are much more complex

digestive system functions to break down the food so that it can be absorbed and used by the body

most animals digest the food *after* it is eaten, not before as in fungi or some plants

but a few (eg. spiders) predigest their food

lots of specialization in structures depending on how an animal gets its food & what kind of food it prefers

eg. predator, herbivore, parasite, filter feeder, fluid feeder

in some animals the digestive system is a simple sac, opened at one end

→ food is eaten, digested and the wastes are "spit out" the mouth

eg. corals, jellyfish, flatworms

in most animals the organs of digestive system form essentially a long continuous tube that is open at both ends

→ **alimentary canal** (GI tract)

mouth→pharynx→esophagus→stomach→ small intestine→large intestine→anus

near the beginning of the system food is **physically** and **chemically digested**

eg. typically the mouth is armed with the appropriate tools to rip and tear the food into smaller pieces

eg. the stomach and beginning of the small intestine produces enzymes and other chemicals to break large proteins and starches into smaller molecules

the rest of the system is used to **absorb** the nutrients released by digestion and to get rid of undigestible wastes

eg. most absorption occurs in the small intestine

a few things (water, alcohol) can be absorbed by the stomach; and the large intestine can absorb additional water and nutrients released by bacterial action

our small intestine is greatly modified for absorption **surface area** is greatly increased for more efficient absorption of nutrients:

1" diameter x 10' long

→ if smooth tube= 0.33 m^2 **(3 sq ft)**

but: interior is folded
also has fingerlike projections = **villi & microvilli**

→**Total Area =** 200m^2 **(1800 sq ft)**

in us, once the nutrients are absorbed they go to the **liver** for processing and storage

5. **The Respiratory System**

like plants, all animals require O_2 to produce energy and release $C0_2$ as a waste product

oxygen gas is needed as a nutrient;

carbon dioxide gas is a waste product of **respiration** (energy production)

since animals are more active than plants they require more efficient ways to get oxygen

(plants just used simple pores: **stomata** or **lenticels**, or **pneumatophores**)

Respiratory system functions as this gas exchange system in animals

in very small animals there is no specific "organ"
→ breath through their skin

air breathing animals have different

requirements than those that extract oxygen from water

aquatic animals

Gasses diffuse much slower in water than in air

water contains 20 times less oxygen than air
→ aquatic organisms must have more efficient respiratory systems

high surface area provided by **gills, book gills, etc**

numerous flaps or feather-like structures exposed on the sides of the animal

must keep water moving across gills
→gills in constant motion
→water is constantly pumped over gills

air breathers:

easier to extract O_2 from air

air contains 20 times more air than water

but air dries respiratory surface

→respiratory organs must be protected and kept moist

lungs, trachea, book lungs, etc

often the respiratory system is closely associated with some kind of circulatory system to more effectively collect and distribute the oxygen

eg. Human lungs

some of the most efficient

→ lots of area for gas exchange

contain millions of microscopic alveoli surrounded by capillaries

total surface area ~ $70M^2$(=760 ft^2~20'x38')

6. Circulatory System

the circulatory system is the major connection between external and internal environment

→everything going in or out of body must go through the circulatory system to get to where its going

in small organisms gas exchange and food and wastes enter and leave by simple diffusion

in large, multicellular organisms some kind of circulatory system is needed to move things around

typically, the circulatory system consists of

"**plumbing**"
=blood vessels: arteries, capillaries, veins

"**pumps**"
= heart

can be "**open**" or "**closed**" system:

open system (eg. insects)
fluid sloshes around in body cavity
pumping heart keeps fluid in motion

closed system (vertebrates; us)

blood flows in **closed system** of vessels

over 60,000 miles of vessels (mainly capillaries)

arteries → capillaries → veins

7. The Endocrine System

virtually all multicellular organisms use chemicals to coordinate activities and communicate

in animals, chemicals (= **hormones**) are used to help control long term activities such as growth, development, reproductive cycles, etc

virtually all organs produce various hormones but in some organs hormone production is their main job

eg. thyroid gland, pituitary gland, pancreas, etc

8. Nervous System

animals are much more active than members of the other two multicellular kingdoms

animals move much more quickly, must respond to things much quicker
chemicals may take minutes or hours to produce a response

animals need a system to control quick reactions: movements, emergencies, etc

→ only members of the animal kingdom have an additional systems of control

all major animal groups except sponges have some kind of nervous system

cells of the nervous system are highly specialized for receiving stimuli and conducting impulses to various parts of the body

made up mainly of **neurons**
long thin fiber like cells up to 4 ft long

very high metabolic rate (highest of any cells in body)
require glucose, can't use alternate fuels

require lots of O_2 – only aerobic metabolism
can't survive more than a few minutes without O_2

many of an animals coordination is hard wired into circuits that produce predictable responses to stimuli

reflex = a rapid, automatic, predictable motor response to a stimulus
unlearned
unplanned
involuntary
→ "hard wired" into our neural anatomy

Kinds of Nervous Systems

animal nervous systems range from very simple to increasingly complex:

eg. Nerve net:

no brain

simple coordination of swimming or feeding movements

eg. jellyfish & corals

eg. Ganglia and nerve cords

very minimal "central processing"

nerve cords can be paired; dorsal, ventral, lateral, etc

eg. flatworms, segmented worms, arthropods

eg. True brain and spinal cord

in vertebrates only

nervous system is organized into 2 major subdivisions:

CNS: brain and spinal cord
PNS: cranial nerves and spinal nerves

9. <u>The Senses</u>

monitor and allow organism to respond to its environment

senses provide direct contact between animal and its surroundings

no animal is completely aware of its environment
→ only selectively aware

eg. those that live in caves depend more on smell and sound

eg. those that live on surface of land rely heavily on sight

eg. those that live in water use smell, currents and vibrations

sensory receptors are **transducers**

information presents itself in different energy forms

→ receptors convert one form of energy into nerve impulses that the brain can interpret

our body has millions of **sensory receptors**
→ some we are consciously aware of
→ most are internal, and help maintain body at an unconscious level

kinds of transducers:

photoreceptor	- light
chemoreceptor	- chemicals
mechanoreceptor	- bending, pressure, touch
thermoreceptor	- temperature
osmoreceptor	– salt/water conc
nocioceptor ("to injure")	– pain

10. <u>Excretory System</u> (Urinary System)

excretory wastes = metabolic wastes

→ chemicals & toxins produced by cells during metabolism

all organisms must get rid of excess materials and wastes
fungi, protists, bacteria → diffusion;

plants →stomata, converted to "secondary plant products" for defense or support or stored in woody tissue)

having greater metabolism, animals generate more wastes

→ need more effective way to get rid of wastes

main job of excretory system is to collect and eliminate toxic wastes

may also help to stabilize salt and water balance in body

12. Reproductive System

most animals reproduce both **asexually** and **sexually**

→ most vertebrates reproduce only sexually

animals typically go through more complex stages of development

sometimes spending years in immature forms

some animals go through an **alternation of generations**

contains **ovaries** and **testes** for sexual reproduction

sometimes contains organ for development of young

only major human system that doesn't work continuously

→ only activated at puberty

Animal Behavior

behavior is an important tool for animal survival

social, mating, territorial behaviors etc

all behavior has a genetic basis
→ follows Darwinian evolution to some degree
predictable
programmed
adaptive (reproductive advantage)

simple behaviors are either:

Instinctive	or	Learned
taxes		imprinting
reflexes		habituation
fixed action patterns		conditioning
mimicry, camoflage		social:
		courtship
		reproductive
		family
		group

The most basic theory of behavior:
stimulus → response

may or not be aware of the stimulus

stimulus may be internal or external
→ perceived by sensory organ or cell

response is controlled or modified by nervous or

endocrine system

The simplest behaviors are movements of some kind

Tropisms → involve response to a single stimulus by a stationary organism

inherited, rigid behavior

cannot be controlled or modified

Taxes → response to single stimulus by motile organism

Reflexes →simple unlearned, unmodifiable response in organisms with well developed nervous systems including CNS & PNS

involves a complete functional circuit of nervous system:
from receptor to effector

eg. blinking as a reflex arc
eg. touching hot skillet

but what is learned vs. innate
eg. Newborns don't blink when object is brought close to their eyes
→ learned
→ maturation of pathways for reflex

eg. right or left thumb on top when folding hands

behaviors in invertebrates are usually highly rigid, stereotyped, patterns

→almost all are genetically preprogrammed

in more complex animals (vertebrates) learning plays a larger role