

Animals – Introduction

(general)

Animals are the largest most diverse kingdom of life on earth

- about 3/4ths of all know living species belong in animal kingdom
- there are probably ~25 x's more animal species that have not yet been named than those that have been named
- 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

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

Animal Origins

animals were probably the first kingdom of truly multicellular organisms to appear on earth

Bacteria and protists set the stage for animals

the main difference is that cells of animals clump together, specialize and become dependent upon each other

animals did not evolve suddenly

→lots of experimentation

→ many of the earliest animal groups no longer exist today

earliest evidence of animal life are found over 1 billion years ago

→ **trace fossils** (burrows, etc)

but sometimes difficult to distinguish between protists and animals

only 3 of the major animal phyla alive today have a fossil record before the 530 MY (during Cambrian)

eg. 700MY Ediacaran fossils

after 530 MY, fossils of all major animal phyla are found

→virtually all major animal groups (phyla) appeared in a geologic instant (~10 M yrs)

= Cambrian Explosion

What caused the Cambrian Explosion

the convergence of several factors may have produced this dramatic increase in fossils

1. rapid melting of **snowball earth**

before this time the surface of the earth was completely frozen = "**snowball earth**"

just before Cambrian it began to thaw very quickly (possibly in less than 1000 years)

more warm shallow seas may have lead to an explosion of diversity

2. some suggest that a threshold level of O₂ induced animal evolution

evidence indicates that the level of oxygen gas in the atmosphere and surface waters may have reached some critical level needed by more active animals

3. evolution of hard teeth and skeletons

predators began showing up in the fossil record in the precambrian

only after animals began trying to eat each other prey species began to evolve larger sizes, harder coverings

shells may have been a way to recycle abundant calcium in sea water

in marine cells the [Ca⁺⁺] is 10,000 x's less than in sea water

too much is toxic

animals began to use this excess toxin for defense,

support, teeth, spines

→ transformed a pollutant into something useful

by the middle of the Cambrian age virtually every major invertebrate group was well represented

Arthropods have dominated the fossil record since the Cambrian

one of the oldest animal **species** on earth (has remained unchanged) is *Triops cancriformis*

→ 180 M yrs → requires no males

insects - have dominated earth since carboniferous (300 MY)

vs **angiosperms** – dominated land plants last 150 MY
only 18% of all species

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

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

eg. some marine clams can apparently live almost 400 years

Cold Blooded Vertebrates:

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

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)

What is an Animal?

Animals: General Characteristics

1. by far, the **largest and most diverse** kingdom
2. **eukaryote cells**
eucaryotic
heterotrophs → **no chloroplasts**
no plastids, no large vacuole
lack cell walls around cells
aerobic → require free oxygen for respiration
lots more mitochondria → lots more energy
many more ribosomes → animals are much higher in protein than most other organisms need lots of ribosomes (protein factories)
3. ALL animals are **multicellular**
→ best development of multicellularity of all kingdoms
4. most are **motile** and **more active** than members of any other kingdom

Animal Records: Locomotion

Swimming

fastest pinniped → 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 Insect:

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

Fastest horizontal flight(bird):

racing pigeons and dunlin sandpipers → 110mph
spine tailed swift, *Chaetura caudacuta*, → 106mph
(170kph)
red breasted merganser ducks → 100 mph

Fastest wingbeat of bird

hummingbird → 90b/sec

Fastest flight (mammal):

48mph → mexican free tailed bat
(others suspected to be faster)

Fastest diving flight: peregrin falcon 82mph (unverified to over 200mph); (but horizontal flight 30-60mph)

5. most animals store extra energy as
fats or oils

6. most with **true tissues**

epithelial → covers body

***muscular** → used for movement

***nervous** → coordination and control

connective → storage, transport, protection, etc

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

plants have simple organs

animals have organs grouped into complex interacting systems

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

most have some kinds of appendages for collecting food or for movement

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

sexual reproduction always involves a sperm and an egg

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

10. most rely on simple or complex behaviors for survival

Animal Cells

animal cells are simpler in structure than plant cells

→ no cell wall, no chloroplasts

many more **mitochondria**

→ animals have a much higher metabolism than organisms in any other kingdom

many more **ribosomes**

→ animal tissues particularly muscle and nervous tissues contain lots of proteins

Animal Tissues

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.

The basis of this diversity is the kinds of **tissues** found in the animal kingdom.

The basic adult animal tissues are:

1. Epithelial Tissues

this is the most primitive

→presumably the first true animal tissue to evolve.

It forms the **outer coverings** of animals
lines the inner and outer surfaces of all
body organs.

consists of cells fitted tightly together
forms layers that

create boundaries (squamous)

secretory glands (cuboidal,
columnar)

commonly ciliated
often glandular

2. Connective Tissues

are a very diverse group

includes tissues used for

support like bone and cartilage

storage like adipose tissue,

glue like areolar tissue,

transport nutrients, oxygen, wastes
and hormones throughout the
body like blood.

widely spaced cells

secrete **matrix** and **fibers** (mainly collagen)

ability to make **collagen** is unique to animal kingdom

these extracellular elements used for:

mechanical stability

storage

protection

fibers composed mainly of

collagen (esp. skin, tendons, ligaments, cartilage)

3. Muscle Tissues

used for **movement**

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

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

elongated fibers

highly contractile

usually with nervous innervation

4. Nervous Tissues

used to conduct information throughout the body

to sense internal and external environmental changes,

and or coordination and control of muscles and glands.

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

5. 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

animal anatomy & physiology is dominated by its **organs** and **organ systems**

looking at detailed structure of animals we see a:
unity of design and function

Most animals have cells that have differentiated into highly complex tissues and organs.

Whereas the most complex plants had relatively simple vegetative and reproductive organs, animals have complex tissues forming complex organs and elaborate organ systems

much of the variations and diversity of animals is due to their adaptations to a variety of habitats.

Each habitat dictates some general features in animal anatomy and physiology:

differences arise as animals **adapt** to their specific habitats

→ result of **natural selection**

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

1. **Skin** (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 is a simple covering
in others it is a complex organ system

eg. in us it is very complex structure with a variety of functions

eg. each sq inch of our skin:
15 ft blood vessels
4 yds nerves
650 sweat glands
100 oil glands
1500 sensory receptor cells
>3 million cells total

General Functions of our Skin:

1. protection from:

mechanical abrasion
chemicals
bacterial infection
UV radiation → melanin pigment
desiccation → keratin

2. temperature homeostasis

high temp → sweat glands, more blood in skin capillaries → flushing
low temp → less blood in skin capillaries → pale

3. excretion

gets rid of some metabolic wastes:

water, salts, ammonia, oils, acids

4. sensation

touch (light touch, wind, etc)

pressure

heat

cold

pain

some animals use skin for respiration

in some animals the skin color is important in behaviors:

communication

camouflage

etc

many animals can quickly change the color of their skin

→ **chromatophores**

animal skins may have additional structures:

scales

hair

claws or nails

horns or antlers

secrete shells

glands (scent, oil, sweat, poison, etc)

2. Skeletal System

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

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. **Muscular System**

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 m² (**3 sq ft**)

but: interior is folded

also has fingerlike projections = **villi & microvilli**

→ **Total Area = 200m² (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 O₂ to produce energy and release CO₂ 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 O₂ 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 ~ 70M²(=760 ft²~20'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 O₂ – only aerobic metabolism
can't survive more than a few minutes without O₂

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. The Senses

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. Excretory System (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

taxes
reflexes
fixed action patterns
mimicry, camouflage

or

Learned

imprinting
habituation
conditioning
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

Animal Symbionts

virtually all kinds of animals live in symbiosis with many other forms of life

Eukaryotic symbionts

will be discussed with selected animal groups

Prokaryotic symbionts

virtually all animals have symbiotic bacteria associated with them

eg. the human body contains 10x's more bacterial cells than human cells

many bacteria are commensal, some mutualists and a few are parasitic

A. mutualists:

eg. produce additional **digestive enzymes** that free up additional nutrients from the foods animals eat

eg. "normal flora" protect the animal from some diseases

after we take antibiotics it takes a while for the normal flora to get reestablished

eg. **bioluminescence**

mainly in marine animals

bioluminescence is used for courtship, to lure prey, camouflage and distraction to avoid prey, etc

two main genera of bacteria; *Photobacterium* & *Vibrio*

some deep water forms have light emitting organs packed full of these bacteria

some animals have shutter-like doors to turn the bioluminescence on and off

Animal Classification

Animals can be classified into 25 or 30 major groups (phyla) based on:

1. overall body form:

- sac like
- tube like
- segmented
- solid body or with body cavity

2. level of complexity of structure

cellular, tissue, organ, etc

- a. some have no true tissues or organs
- b. some have some tissues but few or no organs
- c. simple organs vs relatively complex organ systems

3. complexity of the nervous system and sense organs

eg. distinct head with sense organs, mouth, etc

4. developmental and life cycle characteristics

while animals are classified into ~35 different body plans or **phyla**

95% of all species belong to only ~8 different phyla

the most subdivision of the animal kingdom is:

invertebrates vs vertebrates

→ animals without vs with backbones

95% of all animals are **invertebrates**

only 5% of all animals are **vertebrates**

→ animals with backbones (us)

found in only one phylum: Chordates