Origin and Evolution of Animals

For the first 3 Billion years of earth's history life existed only as single celled bacteria and protists

3/4ths of all geologic time was dominated by primitive, slowly evolving microbes

virtually the entire basic organization of the biological world dates from this time

→ bacteria and protists set the stage for animals:

1. **locomotion**: flagella, cilia, amoeboid motion
2. **skeletons** and **shells** for support
3. **cell to cell communication**:

   chemical messengers leading to hormones and neurotransmitters

4. **metabolism**:

   virtually all but a handful of chemical reactions that animal cells use already existed

   eg. aerobic respiration

   eg. digestion

   eg. lethal toxins for defense

   eg. hemoglobin to store O_2

5. **asexual and sexual reproduction**

the main difference in multicellular organisms is that in them cells clump together, specialize and become more dependent on each other in multicellular organisms

Multicellular Life

~1 BY ago multicellular organisms appeared and began to diversify

multicellularity was <u>not</u> a major step but a <u>natural progression</u> toward increased competitive interaction and specialization

while we tend to think of bacteria and protists as single celled organisms they more typically form groupings, films, filaments, etc

bacteria don't really function as single cells in nature but as **microbial communities**:

teams of several kinds of bacteria live together responding to and creating each others environment

→ wastes of one becomes another's food
→ complementary enzymes to share the process of digestion
→ they communicate chemically with each other
→ protect each other
→ essentially become interdependent

→ in other words they were **functionally multcellular**

a multicellular body is the only way that a living organism can achieve sizes larger than a few millimeters

→ cells can't get too large without breaking

better to make lots of small cells than a few very large cells

multicellularity evolved many separate times among eukaryotes:

seaweeds
slime molds
fungi
plants
animals

→must have been a clear advantage

<u>Advantages of Multicellular Life:</u>

1. allows individual cells to become more **specialized** for specific functions:

   all cells don't have to do everything

   eg. epithelial cells: cover, protect, support, etc
   eg. muscle cells: movements
   eg. vascular tissues: transport of nutrients and wastes and hormones

2. allow much **more variation in size & shape**

   most single cells take in food and oxygen and get rid of wastes by simple diffusion in and out of the cell

   in larger organisms there are more ways to solve these problems

   eg. getting food: herbivores, carnivores, fluid feeders, insectivores, etc

   eg. getting oxygen: gills, book gills, lungs, tracheae, etc

3. multicellular organism becomes more **resilient**

   damage doesn't kill you

   →it can often be repaired

but there are some tradeoffs:

<u>Disadvantages of Multicellular Life:</u>

1. individual cells become completely dependent on each other

   → can no longer survive on their own

2. larger organisms need MUCH MORE food and oxygen

→ lots more cells to feed

3. as size increases need more elaborate ways to supply each cell with nutrients and remove wastes

elaborate organ systems to collect and distribute nutrients and get rid of wastes

eg. vascular systems, etc

4. need method of **coordination and control** to get all parts on the "same page"

eg. hormones, nervous systems

5. need some kind of **support**, especially on land, to counteract gravity

6. **Dispersal** becomes more of an issue

eg. most bacteria and protists have worldwide distributions

relatively few large animals and plants have worldwide distributions

of the three multicellular kingdoms (fungi, plants & animals; animals appeared earliest in the fossil record

earliest **fossil** evidence of animals is 575 MY ago

but **indirect evidence** of animal life are found over 1 billion years ago

→ not true fossils, trace fossils (burrows, etc)

molecular evidence puts animal origins at ~625 MY ago

poor fossil record of animals during most of this earliest time

mostly soft bodied forms → leave few fossils

The Cambrian "Explosion"

once multicellularity originated the more complex lifeforms evolved fairly quickly

→evolution of multicellularity is correlated with an explosion of diversity in the fossil record

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

eg. sponges, corals, molluscs, arthropods, echinoderms, vertebrates, etc

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

= Cambrian Explosion

all modern animal phyla originated as marine organisms

only a relatively few animal groups successfully adapted to land

→ **no** animal phylum is completely terrestrial

earliest fossils of land animals are arthropod fauna: eurypterids, scorpions, centipedes ~440 MY (Ordovician)

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)

→ may have lead to an explosion of diversity

2. some suggest that a threshold level of O_2 induced animal evolution

before this time there was not enough oxygen in the atmosphere or surface waters to meet the much higher aerobic energy demands of animals

3. warm shallow seas may have promoted diversification

eg. much of North America was covered by a warm shallow sea rich in nutrients, rising oxygen levels

4. evolution of hard teeth and skeletons

almost all fossils BEFORE the Cambrian Explosion were soft bodied forms

→ indicated that predators had not yet evolved

only after animals began trying to eat each other

→ evolved larger sizes, harder coverings

hard bodied invertebrates (animals) are much more likely to leave fossils

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

→ Calcium tended to diffuse into the cells

in large amounts this could be toxic

animals began to use this excess toxin for defense, support, teeth, spines

→ transformed a pollutant into something useful

[Nabokov – the greatest enhancements in nature involve deception]

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

Arthropods quickly became the dominant lifeforms and have dominated the fossil record since

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

→ 180 M yrs → requires no males

History of Animal Life

The Animal Kingdom has dominated life on earth for the past 600 MY (at least in terms of 'visible' species)

we have a fairly good fossil record as evidence of life's history over this time

<u>Fossils</u>

actually, only a relatively few organisms actually leave a record of their past existence

fossils are usually preserved as molds or casts or when tissue is replaced with harder minerals

fossils of aquatic forms are much more common than fossils of terrestrial organisms

they are more likely to get buried in sediment before they are eaten or decompose

fossils are especially common when an organism produces some kind of hard part

eg. teeth, shells, bones

only occasionally do we find impressions of soft bodied forms or tissues

eg. jellyfish or impressions of skin, feathers or hair

aware of these limitations, paleontologists are adept at interpreting the past history of life on our planet

in the past 600 MY paleontologists estimate that 100's of times the number of species alive today have existed and become extinct

they also estimate that individual species only last 5-10 MY before they have adapted to such a degree as to become new species

→ the 'lifespan' of a species is usually 5-10 MY

the fossil record reveals two major trends in the past history of animals (and all life on earth):

1. the oldest species are **very different** from the species in the world today

   (even though they represent most of the same phyla)

2. the total number of species has generally increased over the history of life on earth

   → today there are more species alive at one time than at any other time in hearth's history

Classification of Animals

Animals can be classified into 34 phyla based mainly 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, organ systems

    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

    eg. nerve net, nerve cords and ganglia or brain and spinal cord
4. developmental and life cycle characteristics

Additional characteristics used to help classify animals:

1. **type of symmetry:**

assymetrical, radial symmetry, bilateral symmetry

2. **degree of tissue and organ differentiation:**

    embryonic: ectoderm, mesoderm, endoderm

    adult: epithelial, connective, muscle, nervous

3. nature of body cavity or **coelom**

    this is the actual space within the body in which most organs are found

    acoelomate

    no body cavity – most primitive

    pseudocoelom – space, but missing tissue layers

    true coelom

    additional tissue layers enclosing the coelom allow for much more elaborate developent of skin and internal organs, circulatory system and nervous sytem

4. presence or absence of **segmentation**

    (=metamerism)

    serial repetition (segmentation) of body parts is an ancient feature of animal design

5. **cephalization**

    the formation of and the development of a nervous system

    leads to sense organs and mouth at anterior end of animal

Animal Classification

Cellular level of organization:
- Porifera (sponges)
- Mesozoa
- Placozoa

Tissue level of organization:
- Cnidaria (Jellyfish & corals)
- Ctenophora (comb jellies)

Organ level of organization:

Acoelomates
- Acoelomorpha
- Platyhelminthes (flatworms)
- Nemertea (ribbonworms)

Pseudocoelomates
- Nematoda (roundworms)
- Rotifera
- Gnathostomulida (jaw worms)
- Micrognathozoa
- Gastrotricha
- Kinorhyncha
- Loricifera
- Priapulida
- Nematomorpha (horsehair worms)
- Acanthocephala (spiny-headed worms)
- Cycliophora
- Entoprocta

Eucoelomates

Protostomes
- Mollusca (clams & snails)
- Annelida (segmented worms)
- Arthropoda
- Sipuncula (peanut worms)
- Echiura (spoon worms)
- Onycophora (velvet worms)
- Tardigrada (water bears)
- Phoronida

- Brachiopoda (Lampshells)
- Ectoprocta (bryozoa)

Deuterostomes
- Echinodermata (starfish & sea urchins)
- Chaetognatha (arrow worms)
- Hemichordata
- Chordata
    - Urochordata
    - Cephalochordata
    - Vertebrata
        - Agnatha
        - Chondrichthyes
        - Osteichthyes
        - Amphibia
        - Reptilia
        - Aves
        - Mammalia

while animals are classified into 34 different body plans or phyla

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

the animal kingdom can also be considered as 2 great groups:

invertebrates vs **vertebrates**

95% of all animals are **invertebrates**

→ animals without backbones

represented by all 34 phyla

5% of all animals are **vertebrates**

→ animals with backbones

found in only one phylum: **Chordates** (including vertebrates: fish, amphibians, reptiles, birds & mammals)