MACRO - EVOLUTION

von Baer's Laws

1) General features of a large group of animals appears earlier in development than do specialized features of smaller groups
2) Less general characteristics develop from the more general ones, with the most specialized features appearing last skin first, scales, feathers, hair appear later
3) embryos of a given species become more distinct as they develop
4) early embryos of 'higher' animals are not like lower animals, but only like their embryos
5) for all vertebrate development, the 3 germ layers give rise to the same tissue types in fish, frogs, chicks, or mammals
6) all early vertebrate embryos look similar -- they diverge as they develop

ERNST Haeckel law

- The phrase "ontogeny recapitulates phylogeny" originated with Ernst Haeckel (1834-1919). It means that as an embryo of an advanced organism grows, it will pass through stages that look very much like the adult phase of less-advanced organisms. For example, at one point each human embryo has gills and resembles a tadpole. ***Although further research demonstrated that early stage embryos are not representative of our evolutionary ancestors, Haeckel's general concept that the developmental process reveals some clues about evolutionary history is certainly true.***

Patterns of Speciation

- Branching and Unbranched Evolution
- *Cladogenesis* applies to populations that become isolated from one another and subsequently diverge in different directions. This is more common
- *Anagenesis* is a pattern of descent in which species form within a single, unbranched line. – evolution of horses

Evolutionary Trees and Rates of Change

- Evolutionary tree diagrams show a simple way to show lines of descent from a common ancestor.
- The *gradual model* of speciation is represented by tree diagrams with branches at slight angles to each other to show slow change over time.
- The *punctuation model* of speciation is drawn with short, horizontal branches that represent abrupt periods of speciation followed by stable periods.

ORGANIC EVOLUTION

- The slow process of change from simple to complex is known as evolution.
- Evolution assumes that all living things are interrelated.
- According to Darwin, evolution is descent with modification.
- The term 'evolution' was coined by the British philosopher, Herbert Spencer.

ORGANIC EVOLUTION CONT`D

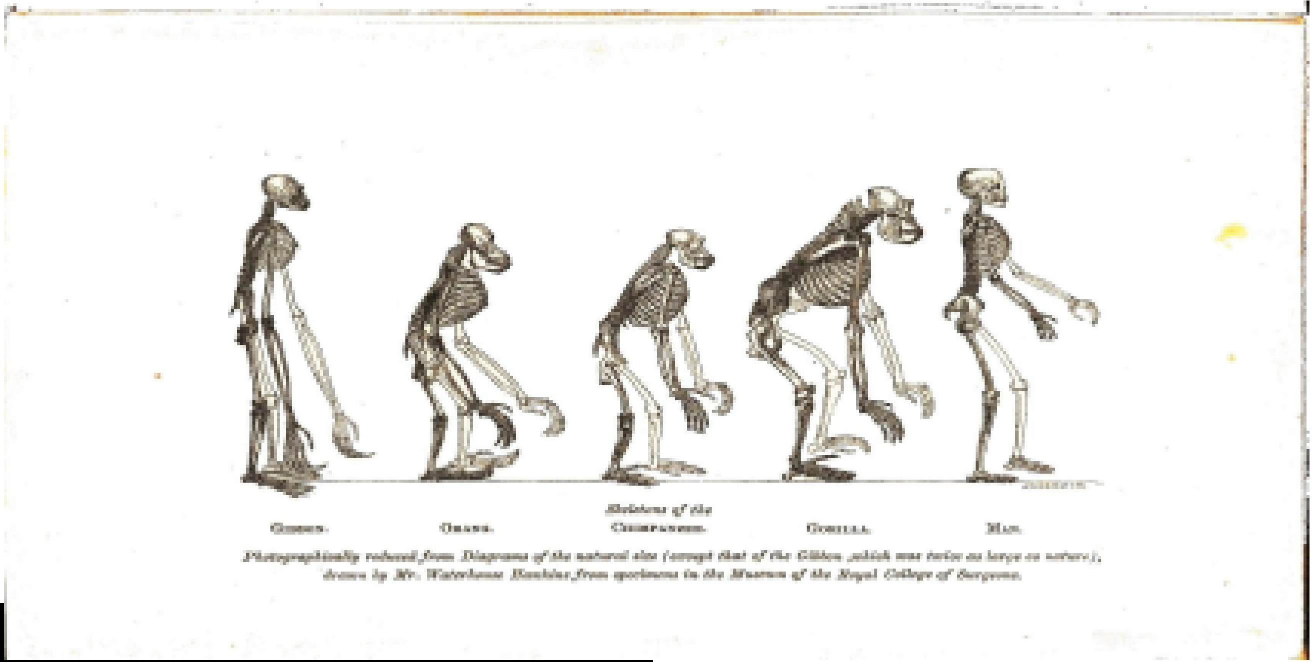
- According to Dobzhansky (1973) 'Nothing in biology makes sense except in the light of evolution'.
- Organic evolution is the change in the characteristics of a population of organisms over the course of generations, resulting in forms that are more complex from pre-existing simpler forms.

ORGANIC EVOLUTION CONT`D

- There are several evidence in favour of organic evolution.

I. Evidence from Comparative Anatomy

- Comparative anatomy is the study of the different internal organs of different animals.
- The study of different systems of organisms like digestive, circulatory, respiratory, muscular, skeletal, etc., in various animals shows similarities in their structure and functions.



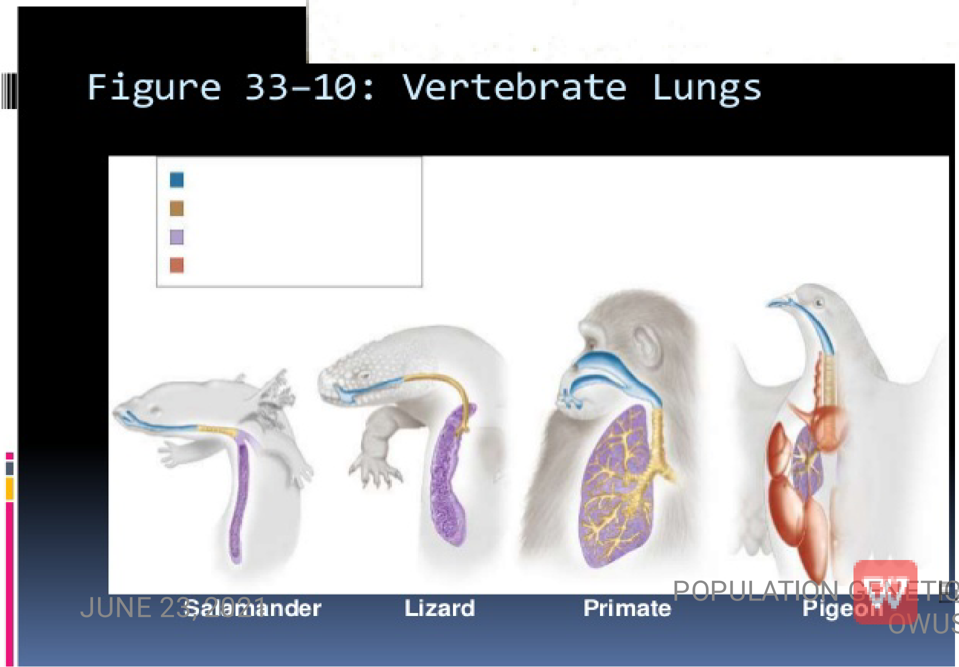


Figure 33-10: Vertebrate Lungs
Salamander
Lizard
Primate
Pigeon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I. Evidence from Comparative Anatomy cont`d

- These similarities in the structure and functions of different organs in different animals indicate that they have originated from a common ancestor.
- Evidences from comparative anatomy are as follows:

I. Evidence from Comparative Anatomy cont`d

- Homologous Organs - Organs having similar basic structure but different functions are known as homologous organs. Homologous organs of different animals provide evidence for evolution. (a) The forelimbs of frogs, birds and humans are built on the same basic design of bones, but perform different functions.

<u>Homology</u> – similarities across species
especially when similar form is modified for different function

Structural homology

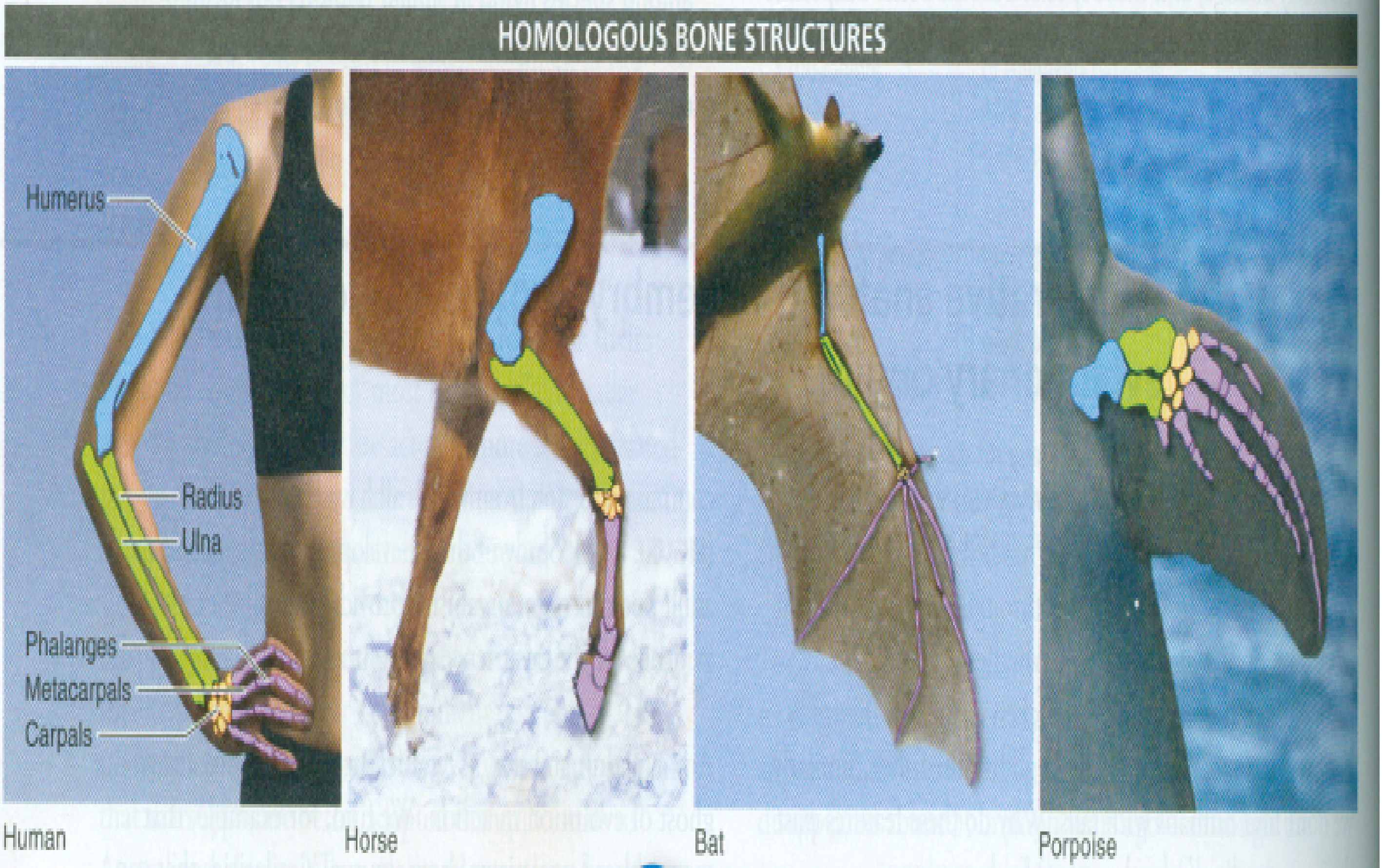


FIGURE 8-39 Evidence for evolution: comparative anatomy. Homologous bone structures among some mammals.

The similarities in the bone structure of the forelimbs of mammals demonstrate common ancestry.

- **Homologous structures**
    - Are features that often have different functions but are structurally similar because of common ancestry

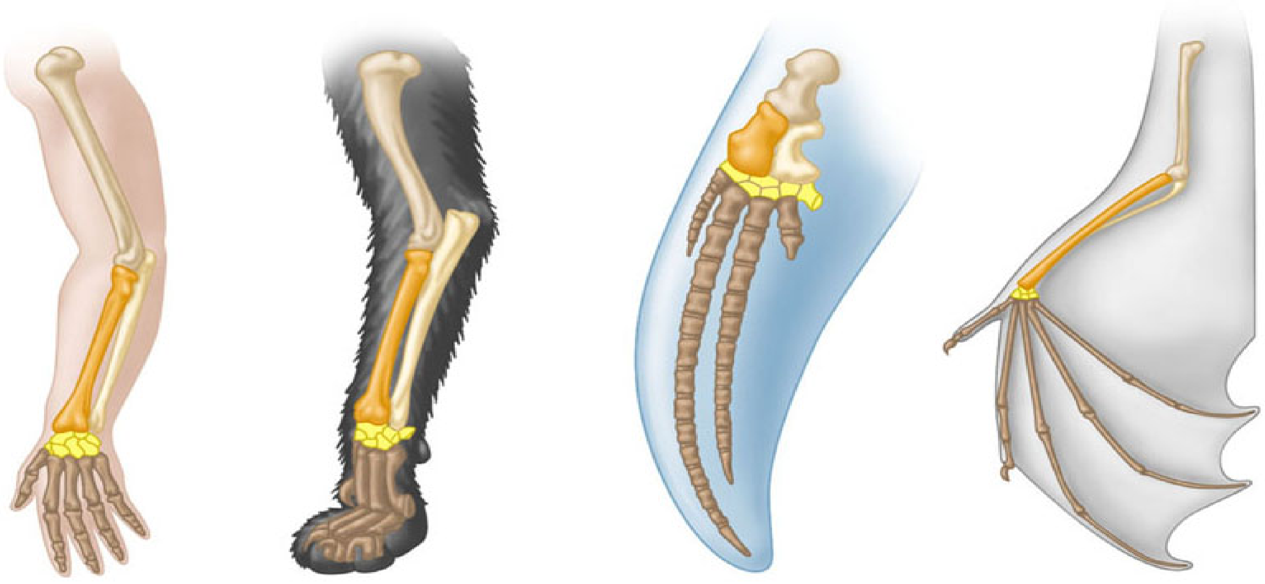


Figure 13.4A

I. Evidence from Comparative Anatomy cont`d

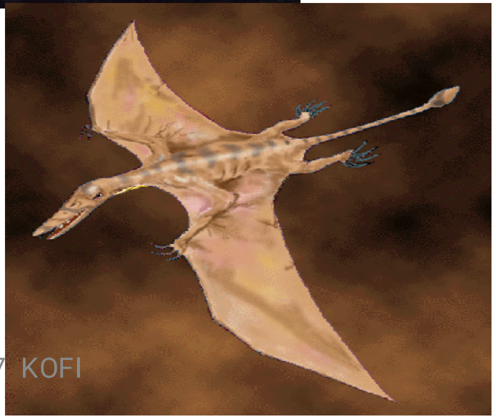
- (b) The presence of homologous forelimbs in frogs, birds and humans indicate that all these forelimbs have evolved from a common ancestor and during the course of evolution they became adapted for different functions.
- (c) Thus, it can be concluded that frogs, birds and humans have evolved from a common ancestor.

2. Analogous Organs

- Organs having a different basic structure but similar appearance and functions are known as analogous organs.

similarity in form can reveal similarity in function

The wings of insects and birds have a different structural plan, but perform the same function of flying.



2. Analogous Organs cont`d

- (b) The development of analogous organs in animals of unrelated groups to become adapted for performing the same function for their survival under hostile environmental conditions is known as convergent evolution.

3. Vestigial Organs

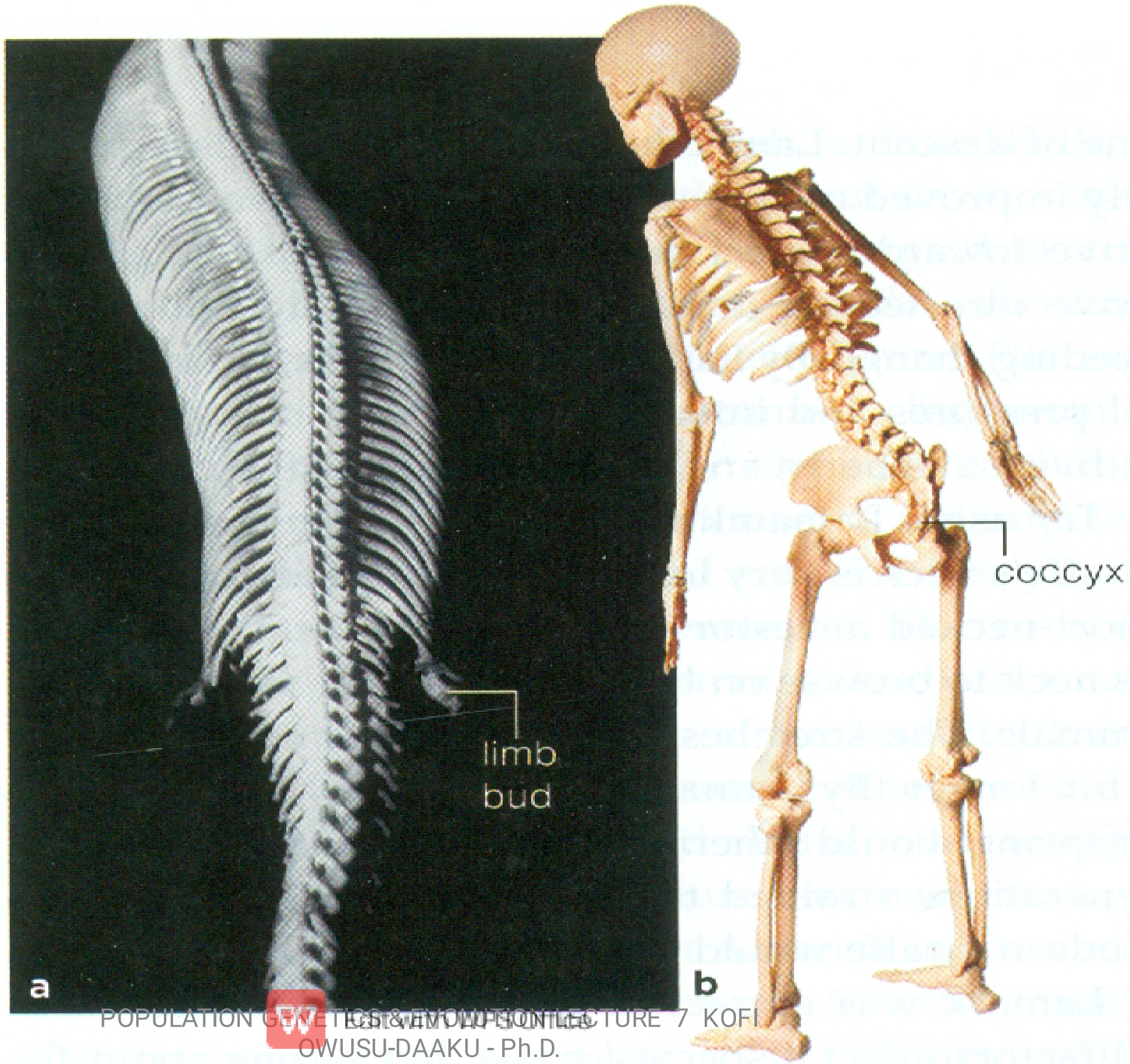
- Vestigial organs are those organs of living beings, which are functionless and useless now (but used to function in their ancestors).
- (a) Vestigial organs are believed to be well developed and functional in ancestral forms but due to changed modes of life, are gradually disappearing in living forms.

3. Vestigial Organs cont`d

- (b) The nictitating membrane is functionless in humans but is still functioning in birds and provides protection. Thus, it indicates that human beings have evolved from those ancestors that had a functioning nictitating membrane.

3. Vestigial Organs

- (c) The coccyx present at the end of vertebral column in humans is formed by the fusion of a few caudal vertebrae, indicating that the ancestors of humans were tailed.


limb
bud
coccyx
a
b

- Similarities in the anatomy and development of different groups of organisms and in the their physical appearance can reveal common evolutionary origins.

3. Vestigial Organs cont`d

- d) The vermiform appendix in the large intestine in human beings has no function but it is still functioning in herbivorous ruminant mammals and helps in the digestion of cellulose.

3. Vestigial Organs cont`d

- The presence of the vestigial form of vermiform appendix in humans suggests that human beings evolved from mammals that were herbivorous.
- During the course of evolution, when humans changed their food, i. e., became omnivorous from herbivorous, it gradually reduced in size and became functionless.

3. Vestigial Organs cont`d

- (e) Third molars are regarded as wisdom teeth in humans.
- These do not erupt in all humans, but in other primates they are well developed and fully functional, and erupt early.
- This indicates that humans have descended from some primates.

3. Vestigial Organs cont`d

(f) The presence of vestigial hind limbs in the python and boa suggests that snakes have descended from ancestors that had well-developed limbs.

II. Evidence from Connecting Links

- Connecting links are those organisms that possess characteristics of two different groups. These organisms provide continuity in the series of organisms by proving that one group has evolved from the other.
- *Peripatus* is a connecting link between Annelida and Arthropoda.

II. Evidence from Connecting Links

- Its Annelidan characters are as follows:
- (a) Worm-like body with soft cuticle and continuous muscle layers in the body wall
- (b) Unjointed legs and simple eyes
- (c) Excretory organs are nephridia

II. Evidence from Connecting Links

- Its Arthropodan characters are as follows:
- (a) Presence of antennae
- (b) Presence of tubular heart
- (c) Presence of trachea as respiratory organ
  (d) Presence of haemocoel.

II. Evidence from Connecting Links

- *Neoplina* is a connecting link between Annelida and Mollusca.
- Its Annelidan characters are as follows:
  (a) Presence of metamerism
- (b) Presence of segmentally arranged gills
  (c) Presence of nephridia
- (d) Spiral cleavage
- (e) Larva trochophore

II. Evidence from Connecting Links

- Its Molluscan characters are as follows:

(a) Presence of shell

(b) Soft and flat body

(c) Presence of mantle

(d) Presence of foot

- Some other examples of connecting links are given below.

Table 2

	Organisms	Connecting link between
(a)	Viruses	Living and nonliving
(b)	*Euglena*	Plants and animals
(c)	*Proterospongia*	Protozoa and Porifera
(d)	*Balanoglossus*	Nonchordata and Chordata
(e)	*Chimera*	Cartilaginous and bony fish
(f)	Dipnoi	Fishes and amphibians
(g)	*Archaeopteryx*	Reptiles and birds
(h)	Prototheria	Reptiles and mammals

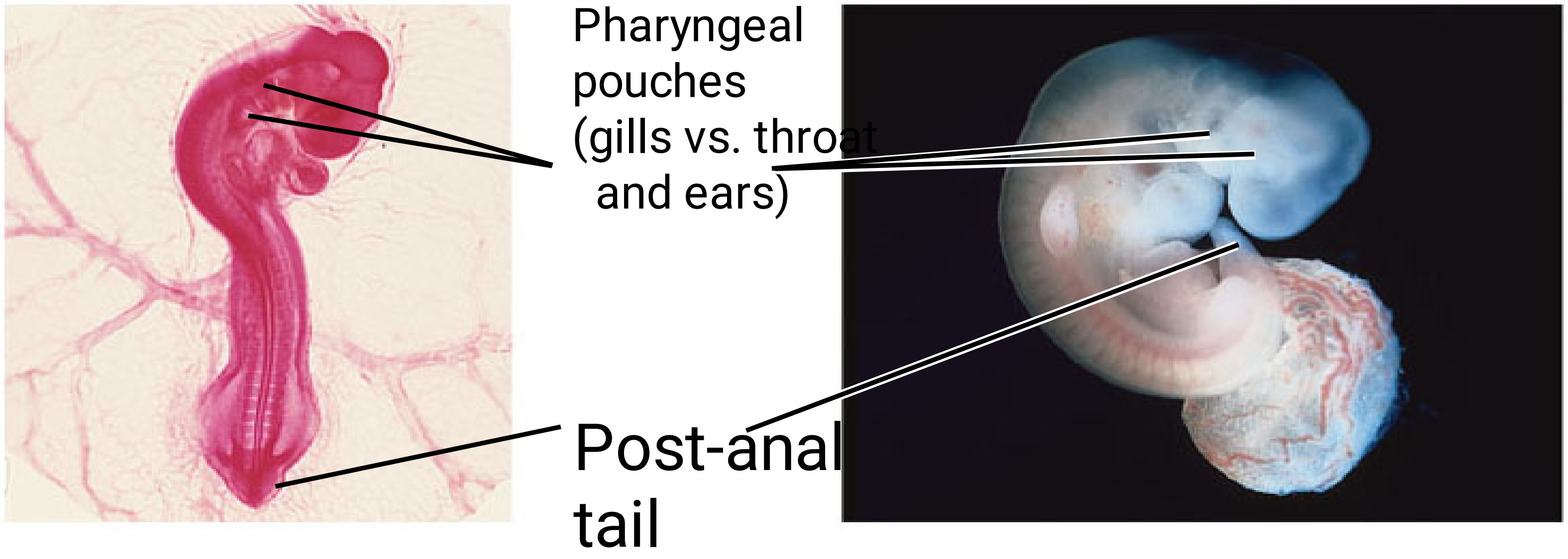
III. Evidence from Embryology

- The developing embryos of animals exhibit striking similarities in their structure.
- The embryos of vertebrates are so similar in their structure in their early stages of development that it is very difficult to differentiate one from another.

III. Evidence from Embryology cont`d

- The early embryos of vertebrates like fish, salamander, tortoise, chicks and humans look similar. It indicates that all these animals have evolved from a common ancestor.

- Many vertebrates have common embryonic structures



Chick embryo

Figure 13.4B

Human embryo

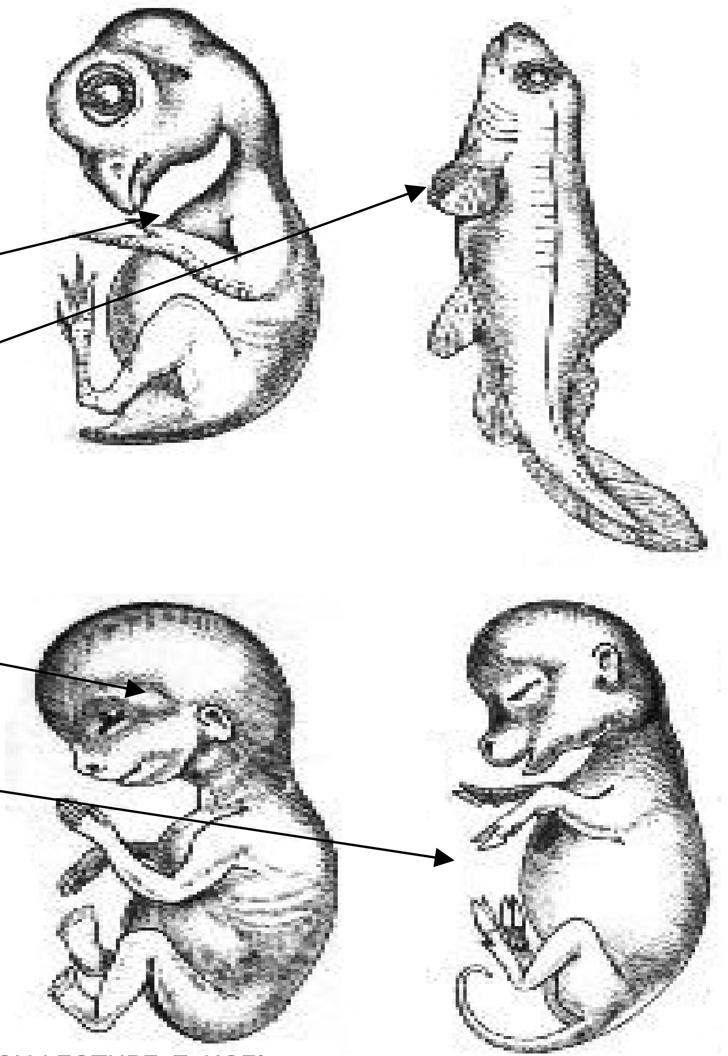
Match the embryo with the animal

chick embryo

fish embryo

human embyro

rat embryo



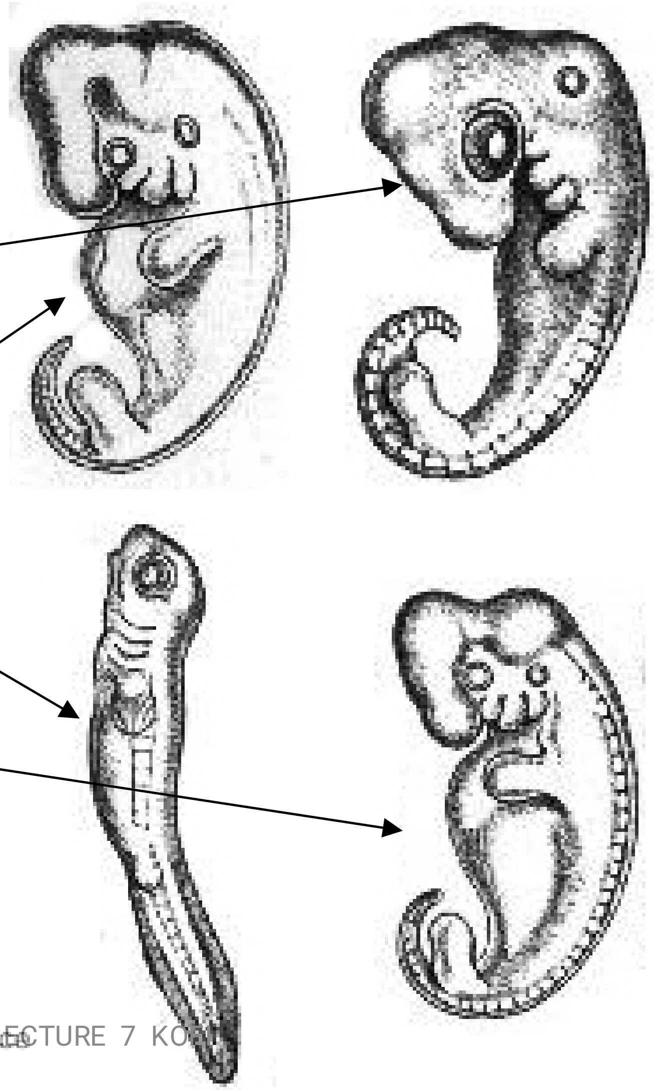
Match the embryo with the animal

chick embryo

fish embryo

human embyro

rat embryo



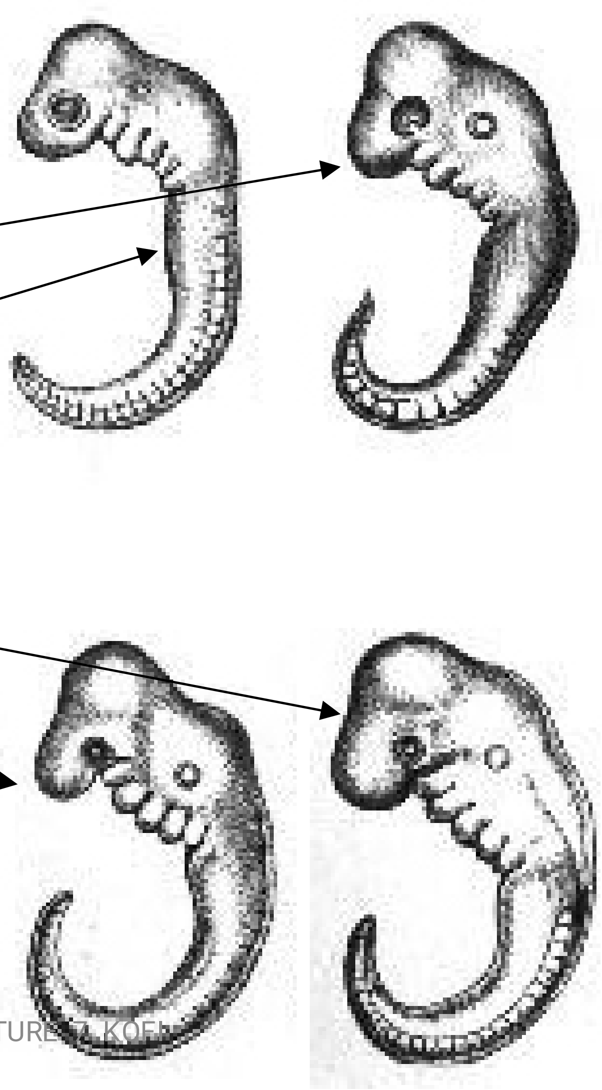
Match the embryo with the animal

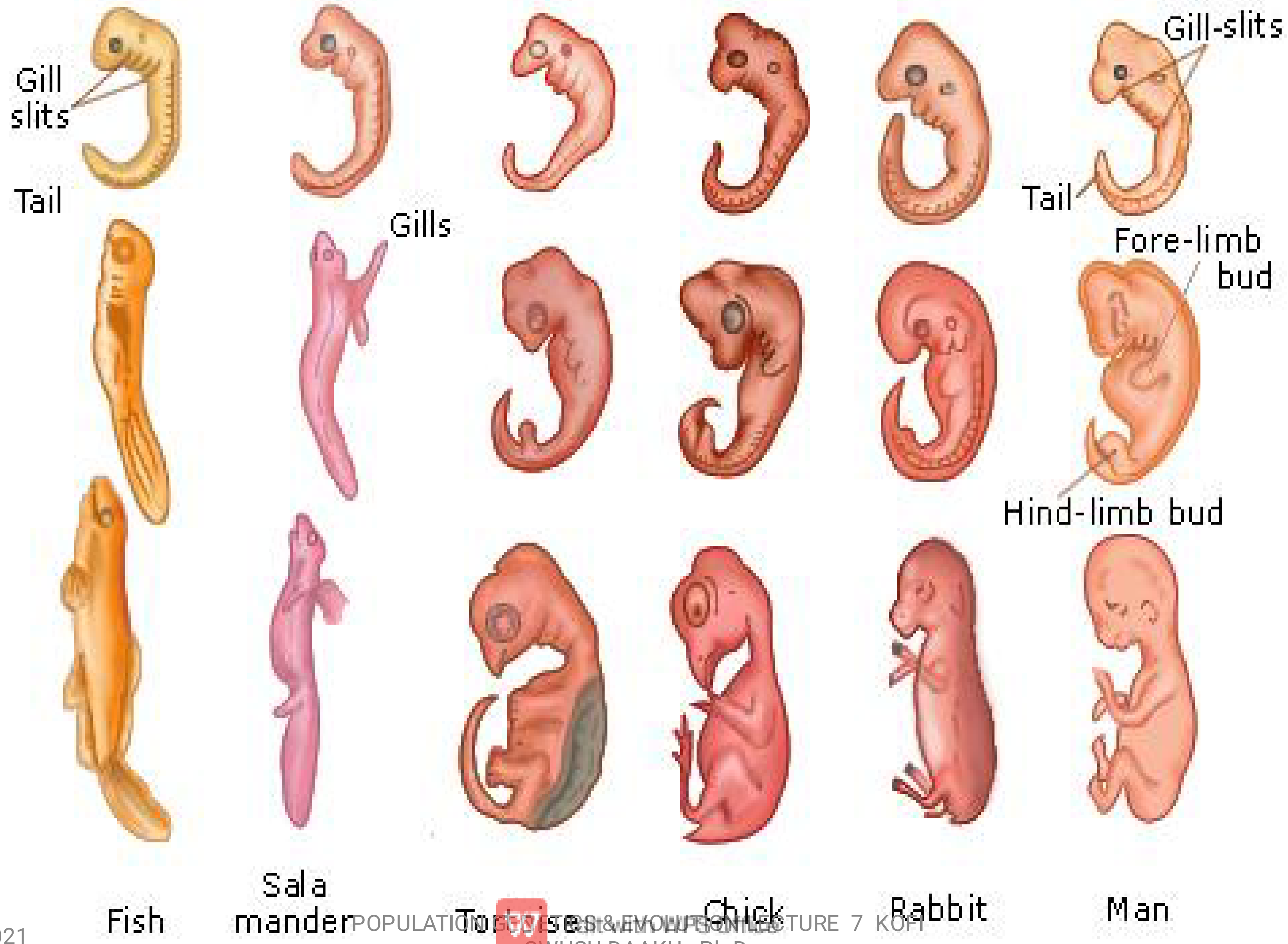
chick embryo

fish embryo

human embyro

rat embryo

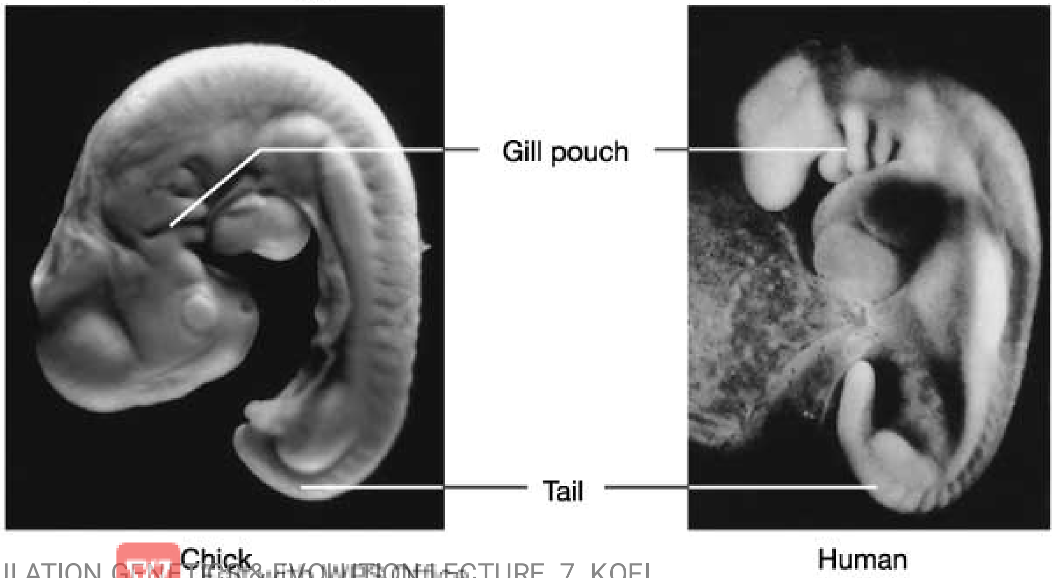



Gill
slits
Tail
Gills
Gill-slits
Tail
Fore-limb
bud
Hind-limb bud
Fish
Sala
mander
Chick
Rabbit
Man

Homology – similarities across species

especially when similar form is modified for different fun

Developmental homology



III. Evidence from Embryology cont`d

- Based on these similarities, the developmental pattern in the embryos of vertebrates, Ernst Haeckel proposed the Biogenetic Law, which states that 'ontogeny recapitulates phylogeny, i.e. , during the development of the embryo of any organism, its complete history is repeated'.
- For example, embryonic forms of human beings are similar to fishes, amphibians, reptiles and birds.

III. Evidence from Embryology cont`d

- Thus, on the basis of similarities in embryos of different vertebrates, it can be concluded that vertebrate animals have evolved from a common ancestor.

VI. Evidence from Biochemistry and Physiology

- Protoplasm is the physical basis of life and is made up of carbohydrate, protein and fat. Oxygen, hydrogen, nitrogen and carbon are its main components. The percentage of these components is found to be the same in the protoplasm of all living worlds. Thus, it suggests that all living beings have originated from a common ancestor.

- In animals, the same types of enzymes have similar reactions (e. g., trypsin acts on proteins in all animals). Thus, the occurrence of the same enzyme in different animals indicates their common origin.
- Blood protein test has revealed that humans are closer to apes (chimpanzees and gorillas) than monkeys.

VI. Evidence from Biochemistry and Physiology cont`d

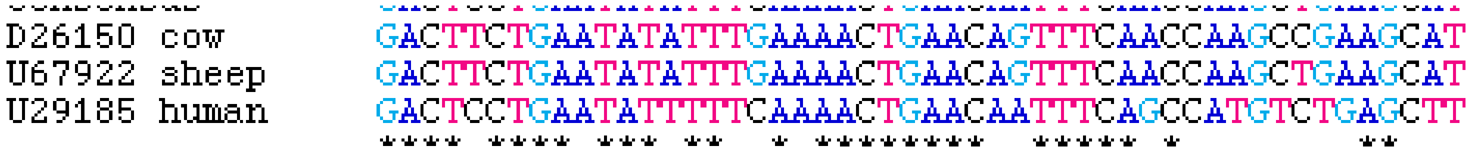
- Hormones of all vertebrates show similar a chemical nature and function.
- In the entire living world, the chromosome has the same biochemical organisation. The octamer of nucleosome has the same protein in all animals, indicating their common origin.

VI. Evidence from Biochemistry and Physiology cont`d

- All organisms utilise the same DNA triplet base and the same 20 amino acids in their proteins. Many organisms share the same introns and types of repeats. These similarities suggest descent from a common ancestor.

Homology – similarities across species especially when similar form is modified for different function

Biochemical homology



also commonality of genetic code, amino acids

TABLE 13.4 COMPARISON OF A PROTEIN IN DIFFERENT SPECIES

Species	Percent of amino acids that are identical to the amino acids in a human hemoglobin polypeptide
Human	100%
Rhesus monkey	95%
Mouse	87%
Chicken	69%
Frog	54%
Lamprey	14%

Table 13.4

- All living organisms share the same genetic code. The degree of similarity in the DNA of different species can reveal how closely related they are and amount of time that has passed since they last shared a common ancestor.

VII. Evidence from Atavism

- The sudden reappearance of an ancestral characteristic is known as atavism or reversion. The reappearance of such features in newborns is suggestive of the fact that these features were present in their remote ancestors, but lost during the course of evolution to their present-day form.

Some common examples of atavism are as follows:

- (a) Appearance of tail in the newborns of human beings.
- (b) Occurrence of cervical fistula in some human bodies, which are the remnants of gill slits found in ancestors.
- (c) Occurrence of long and pointed canine and thick body hair in human babies (Lion's boy of Russia).

VIII. Evidence from Taxonomy

- Depending on the basis of similarities and differences, animals are grouped as phyla, classes, orders, families, genus and species.
- The similarities revealed their common ancestry, while differences among them are due to different environmental conditions that operate on them.

IV. Evidence from Palaeontology

- The remains of dead plants and animals that lived in the past are called fossils and the study of fossils is called palaeontology. Fossils help to trace evolution of a particular animal as they fill the gap between two animals.
- Fossils provide evidence in favour of evolution. For example, *Archaeopteryx* is a fossil bird and is a connecting link between reptiles and birds.

IV. Evidence from Palaeontology

- It had a skeleton, beak with teeth, a tail like reptiles but wings with feathers and furcula like birds. Thus, it suggests birds too have evolved from reptiles.

V. Evidence from Geographical Distribution of Animals

- Animals are distributed throughout the entire earth, which has been divided into six different regions.
- Different regions of the world have different animals and plants. Different geographical regions, at various places, are separated or isolated from others due to geographical barriers.


BIOGEOGRAPHY: AUSTRALIAN MARSUPIALS AND THEIR PLACENTAL COUNTERPARTS
AUSTRALIAN MARSUPIALS
Sugar glider
Numbat
Tasmanian wolf
PLACENTAL COUNTERPARTS
Flying squirrel

V. Evidence from Geographical Distribution of Animals

- Due to different environmental and climatic conditions, the separated regions gave rise to different animals and plants.
- Prototheria and metatheria are found only on the Australian continent, which was separated from the Asian continent before the appearance of eutherians.

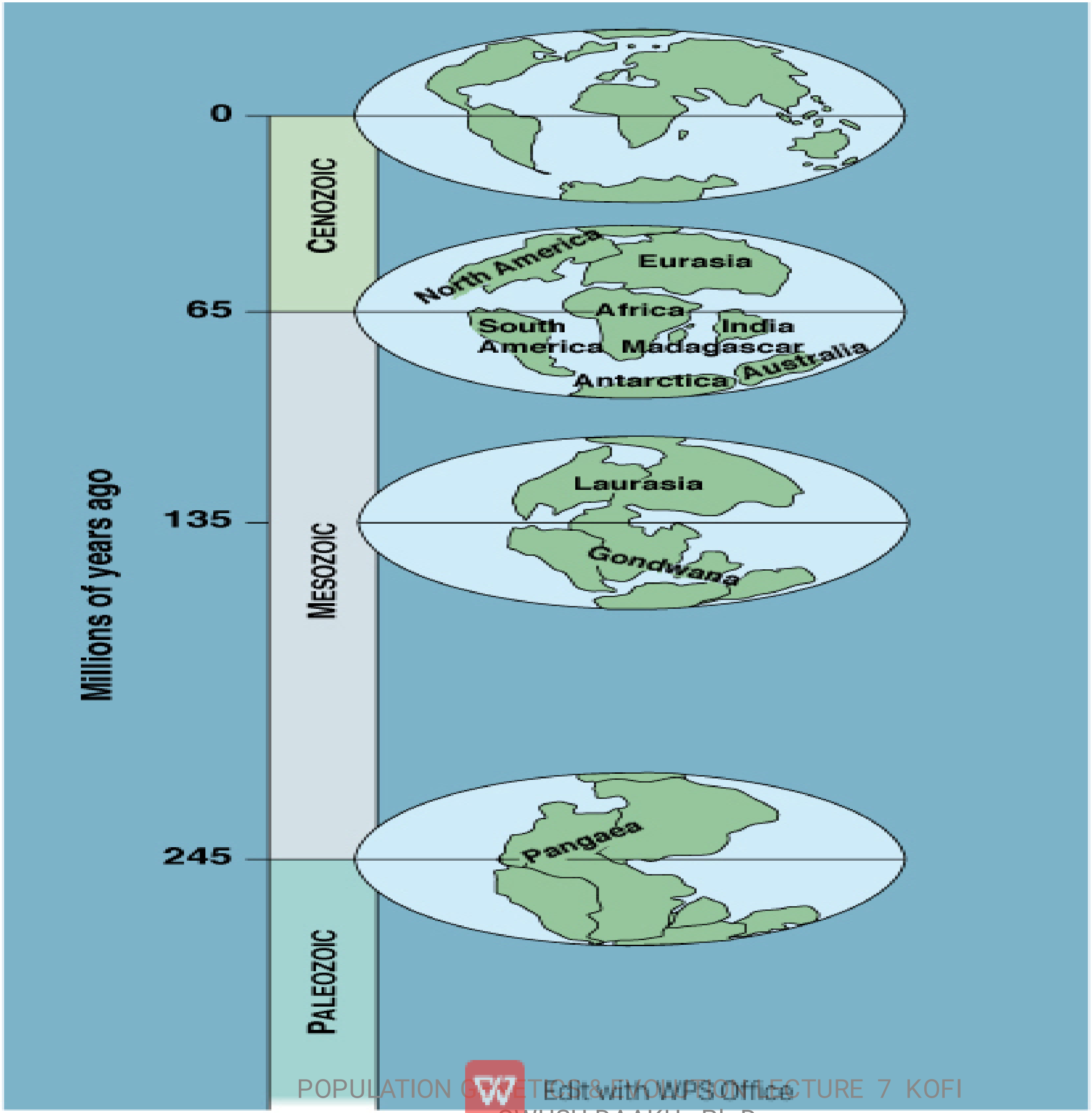
V. Evidence from Geographical Distribution of Animals

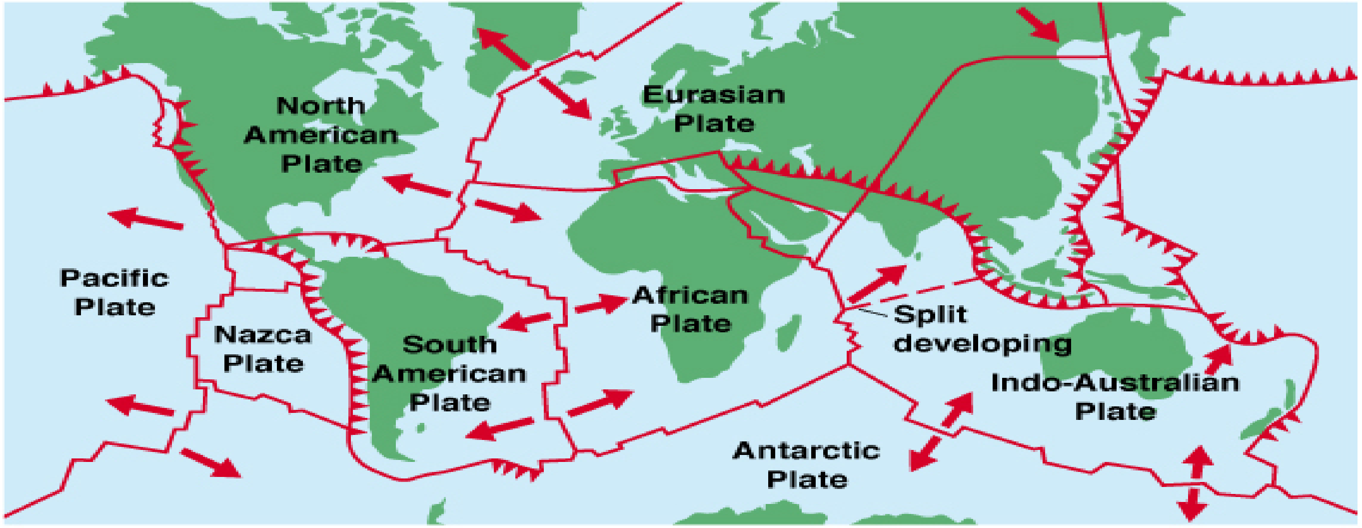
- Eutherian mammals, therefore, could not reach the Australian region.
- As a result of the evolution of eutherian mammals in the Asian continent, prototheria and metatheria disappeared from that region as eutherians were more efficient.

V. Evidence from Geographical Distribution of Animals

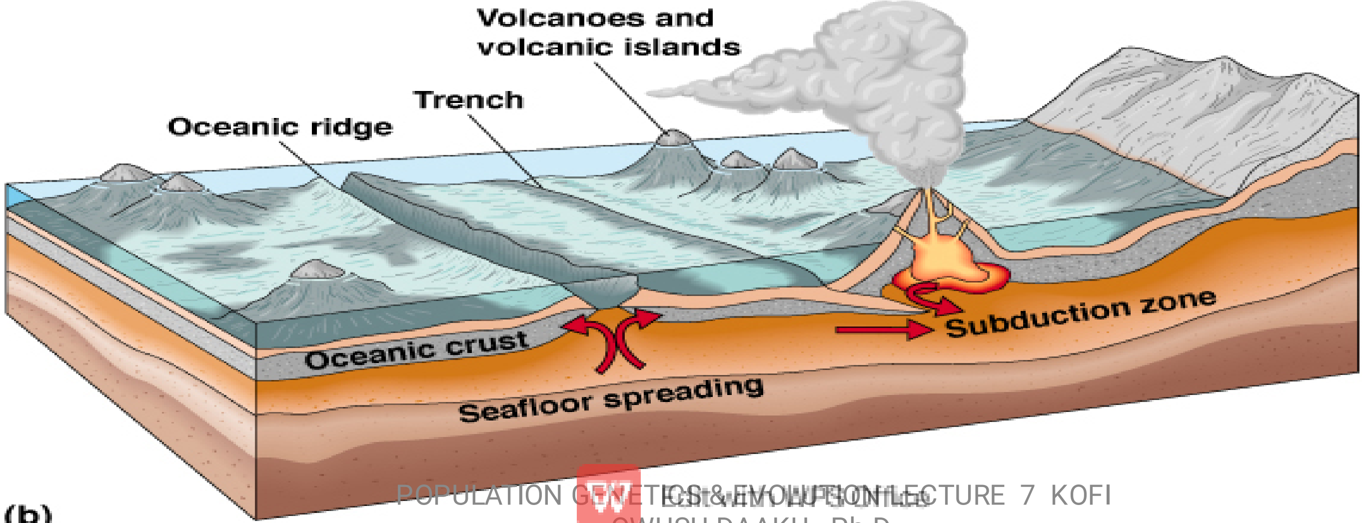
- On the other hand, in the absence of eutherian mammals in the Australian region, prototheria and metatheria had many opportunities
to flourish.

- The camel and the llama are closely related and are found in Asia and South America, respectively. It suggests that Asia and South America were once a continuous landmass.
- Consequent to the separation of these two landmasses, the ancestors of the camel and the llama inhabiting Asia adapted themselves to desert life and evolved into the camel, while those that remained in South America underwent an evolutionary change to the llama, according to environmental conditions.


0
65
135
245
Millions of years ago
CENOZOIC
MESOZOIC
PALEOZOIC
North America
Eurasia
Africa
South America
India
Madagascar
Australia
Antarctica
Laurasia
Gondwana
Pangaea


North American Plate
Eurasian Plate
Pacific Plate
Nazca Plate
South American Plate
African Plate
Split developing
Indo-Australian Plate
Antarctic Plate

(a)


Volcanoes and volcanic islands
Trench
Oceanic ridge
Oceanic crust
Subduction zone
Seafloor spreading

(b)

Extinctions

- Background extinction is the rather inevitable loss of species as local conditions change over periods (usually long) of time.
- Mass extinctions are abrupt disappearances due to catastrophic, global events.

- Thus, every region of the world has its own specific plants and animals and such distribution provides proof in favour of organic evolution.

Rules of Organic Evolution

- Some rules associated with evolution are as follows:
- Allen's **Rule** - Allen's Rule states that the extremities such as ears, tails and limbs of animals inhabiting colder regions are smaller than those of their counterparts living in warmer regions.
- Bergman's **Rule** - Warm-blooded animals living in colder regions have larger body parts than those living in a hot climate.

- Cope's **Rule** - Animals have a tendency to increase in body size during the course of evolution. However, this is not true for all taxonomic classes or clades.
- Dolle's **Rule** - Dolle's rule states that evolution does not occur in the opposite direction. Characteristics once developed do not develop again.

- Gause's **Principle** - It states that two or more species of organisms having similar environmental need cannot exist for a long time in an area due to similar needs; competition will develop between them in due course of time.
- Gloger's **Rule** - The colouration of some animals is effected by temperature, light and moisture. Many mammals, birds and insects living in a warm, humid climate have darker colour than their counterparts living in a dry climate.

Patterns of Organic Evolution

- **Divergent Evolution**

(a) The pattern of evolution in which two closely related species gradually become increasingly dissimilar in different habitats of the same area is called divergent evolution.

(b) Divergent evolution is confirmed by DNA analysis in which the species that diverged is genetically similar to the form from which it diverged.

Divergent Evolution cont`d

(c) Adaptive radiation is an example of divergent evolution.

(d) Any genus of plants or animals can show divergent evolution.

(e) A good example of divergent evolution is Darwin's finches. Presently there are 80 species of Darwin's finches, which have diverged from a single finch.

Divergent Evolution cont`d

(f) A very common example of divergent evolution is the vertebrate limbs. Whale flippers, forelimbs of frogs and human arms perform different functions but share a common evolutionary origin.

(g) Divergent evolution results in speciation.

II. Convergent Evolution

- (a) The pattern of evolution in which two unrelated species become similar to each other due to favourable changes in morphology, living in the same area due to natural selection is known as convergent evolution.


CONVERGENT EVOLUTION
Different starting materials come to perform the same function through convergent evolution.

Convergent Evolution cont`d

- (b) Convergent evolution often results in analogous structures.
- (c) The striking similarity in hummingbird moths and hummingbirds is an example of convergent evolution.

Convergent Evolution cont`d

- (d) The evolution of functionally similar but distinct antifreeze proteins in divergent species of fishes (one group living near Antarctica and the other found in the Arctic) is an example of convergent evolution

III. Co-evolution

- (a) Combined changes in two or more species which are in close interaction, usually dependent upon each other, is known as co-evolution.

(b) A good example of co-evolution is shown by insects in which the shape and structures of the body as well as the size of proboscis is of different types, according to the structures of flowers.

(c) Plants and animals that pollinate them are a common example of co-evolution.

IV. Parallel Evolution

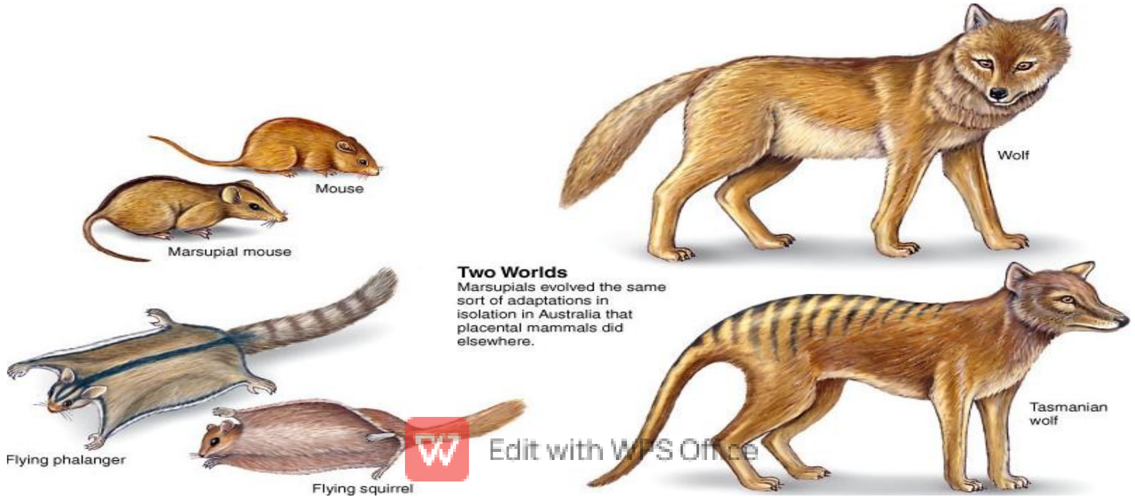
(a) The pattern of evolution in which independent development of similar characteristics in two groups of animals having common ancestry occurs due to similar environmental conditions is known as parallel evolution.

(b) Parallel evolution is more frequent between structures.

(c) In both parallel and convergent evolution, similar adaptations arise in different species. But in parallel evolution, the two species have a relatively recent common ancestor.

(d) The form of leaves in plants is a good example of parallel evolution. A similar pattern of leaves is found in separate genera and families.

(e) Several instances of parallel evolution are found in placental and marsupial mammals. Placental mammals like the anteater, house mouse, wolf, flying squirrel and groundhog are parallel in evolution to marsupials like the wombat, marsupial mouse, Tasmanian wolf, native cat, etc.



ADAPTATION

- Adaptation may be defined as a trait that enables an animal to become suited to its environment.
- Adaptations are the result of evolution and are one of the basic phenomena of biology.
- Adaptations generally take place because genes mutate or are changed by accident.

ADAPTATION cont`d

- Adaptation is a slow process caused by natural selection.
- Animals must adapt to their environment or face extinction.
- Adaptation may be structural or behavioural.

Structural (Physical) Adaptations

- Body adaptations are known as structural adaptations that help animals to survive in their environment.
- Structural adaptations are specially found in the bones and muscles that are adapted for running, swimming, climbing, flying, gliding, jumping, etc.

Behavioural Adaptations

- The adaptation that helps an organism to enhance either survival or reproduction is known as behavioural adaptation.
- Behavioural adaptation may be instinctive (occur naturally) or learnt (must be taught).
- Birds calls and migration are behavioural adaptations.

Adaptive Radiations

An adaptive radiation is a burst of microevolutionary activity that results in the formation of new species in a wide range of habitats.

- The presence of adaptive zones presents new ways of life by physical, evolutionary, or ecological access.

Adaptation

Is every trait an adaptation?

adaptation – trait that increases fitness and has evolved by natural selection

How can we test whether a trait is an adaptation?

adaptive – describes a trait that increases fitness

Ways to test the adaptive value of trait:

- measuring selection on a variable trait
- test the function of a trait
- comparing patterns across species

Adaptation

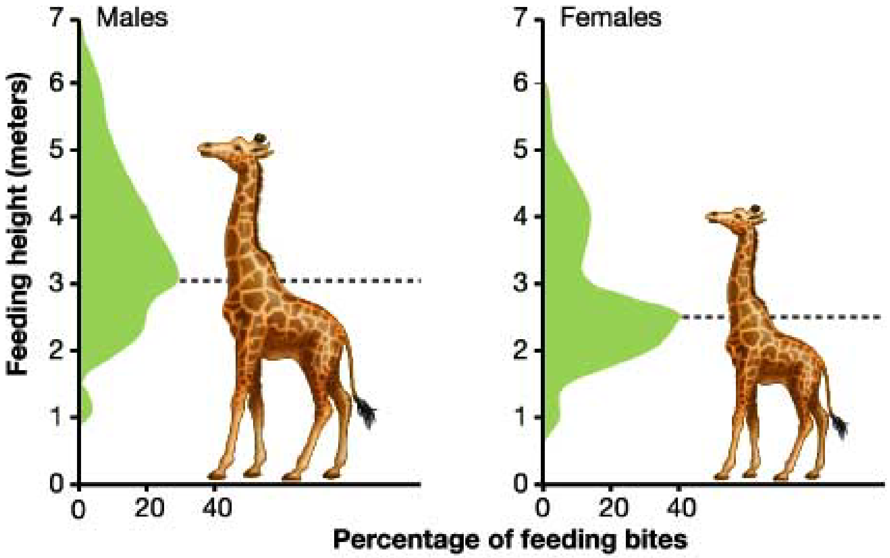
Is every trait an adaptation?

How can we test whether a trait is an adaptation?

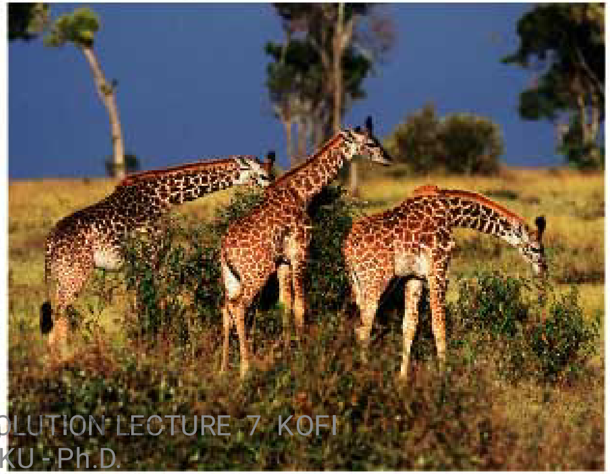
- measure selection on a variable trait
- test the function of a trait

Consider alternative hypotheses!

Most feeding is done below neck height.



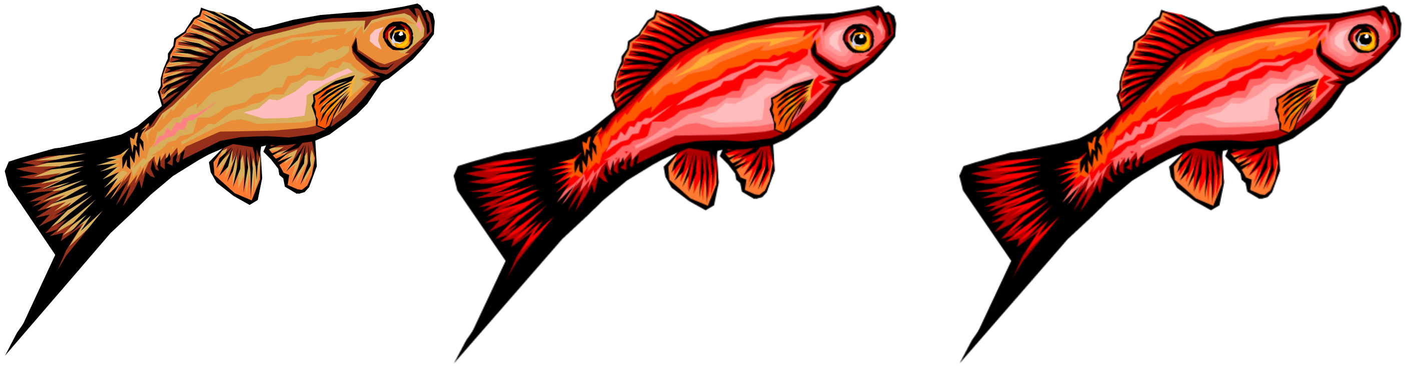
Typical feeding posture in giraffes



Testing for local adaptation

color polymorphism among male guppies

morph:



habitat:

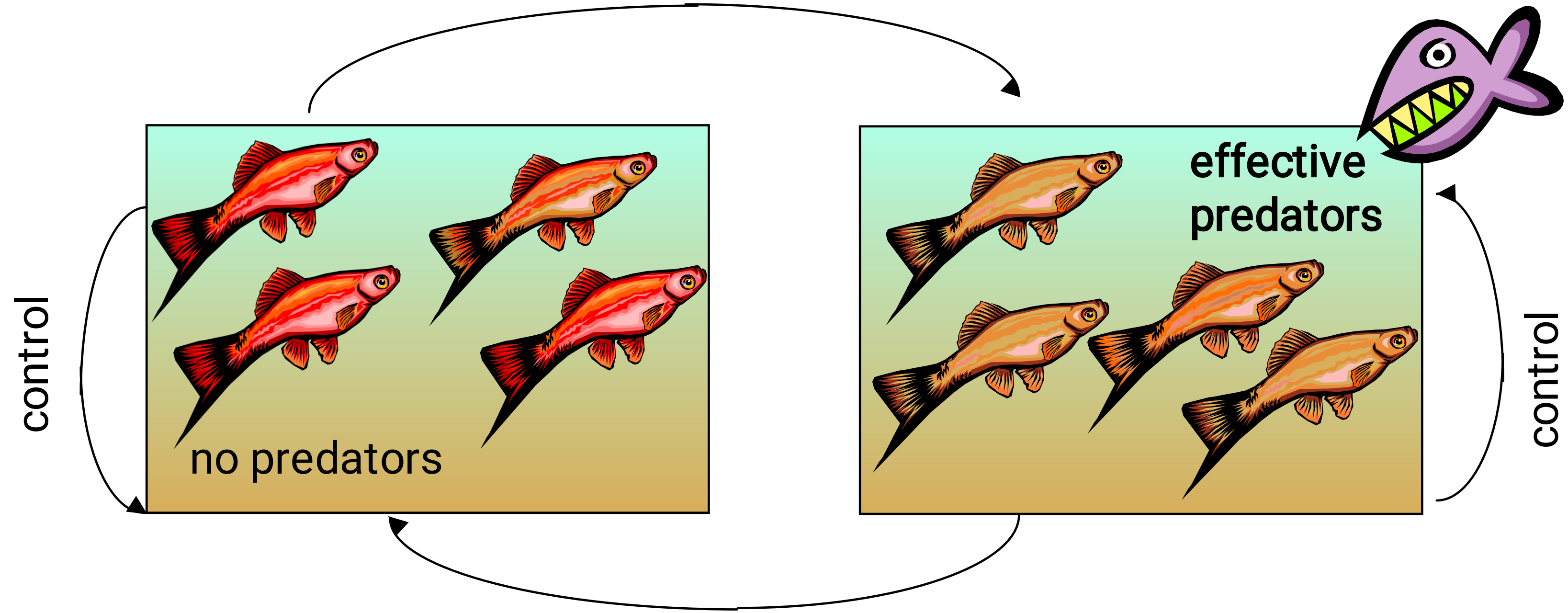
streams with effective predators	streams with ineffective predators	streams with no predators

How can we test whether the difference in coloration is an adaptation? What other explanations are possible?

Testing for adaptation:

reciprocal transplant experiment

guppies from no predator stream moved to stream with effective predators



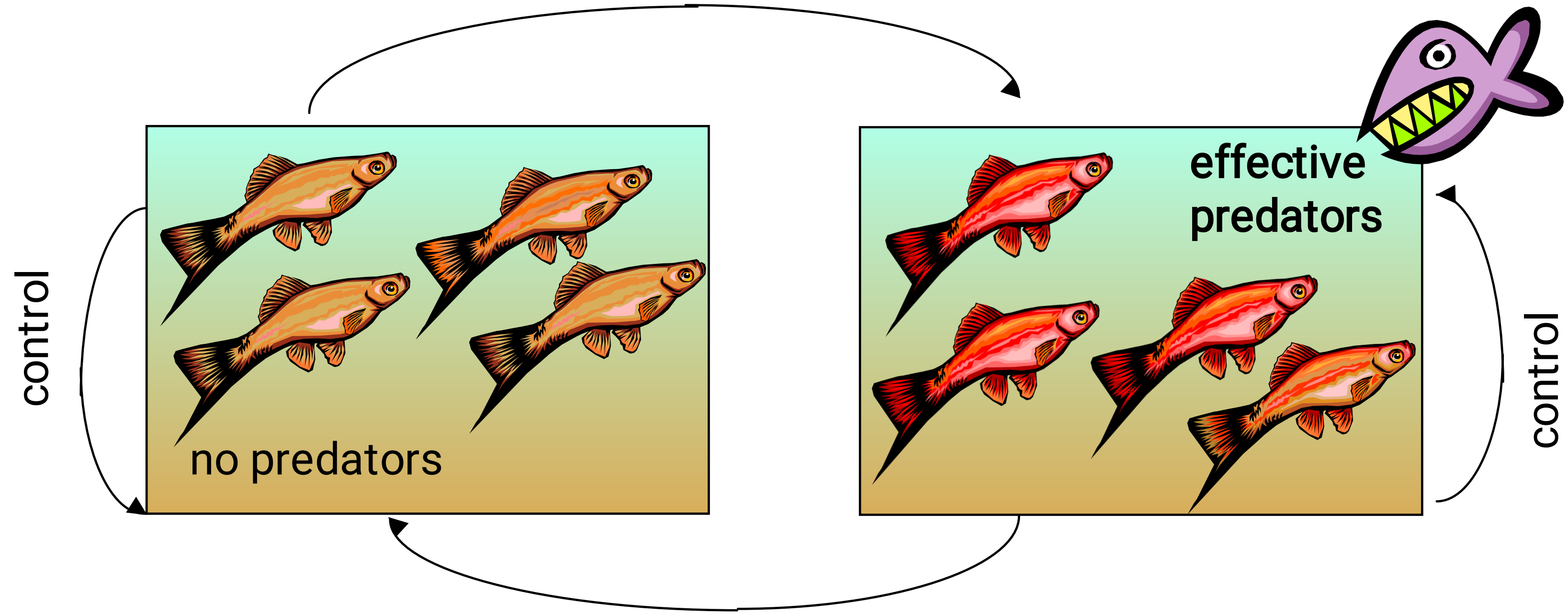
guppies from stream with effective predators moved to no predator stream

(Endler, 1980)

Testing for adaptation:

reciprocal transplant experiment

guppies from no predator stream moved to stream with effective predators



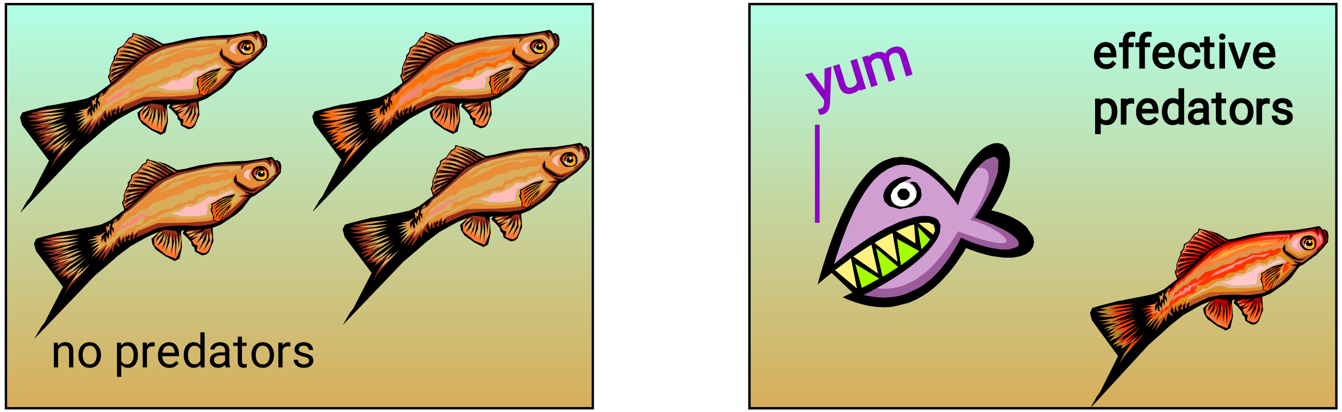
guppies from stream with effective predators moved to no predator stream

Who do we move?   Why the controls? What happens??

Testing for adaptation:

reciprocal transplant experiment

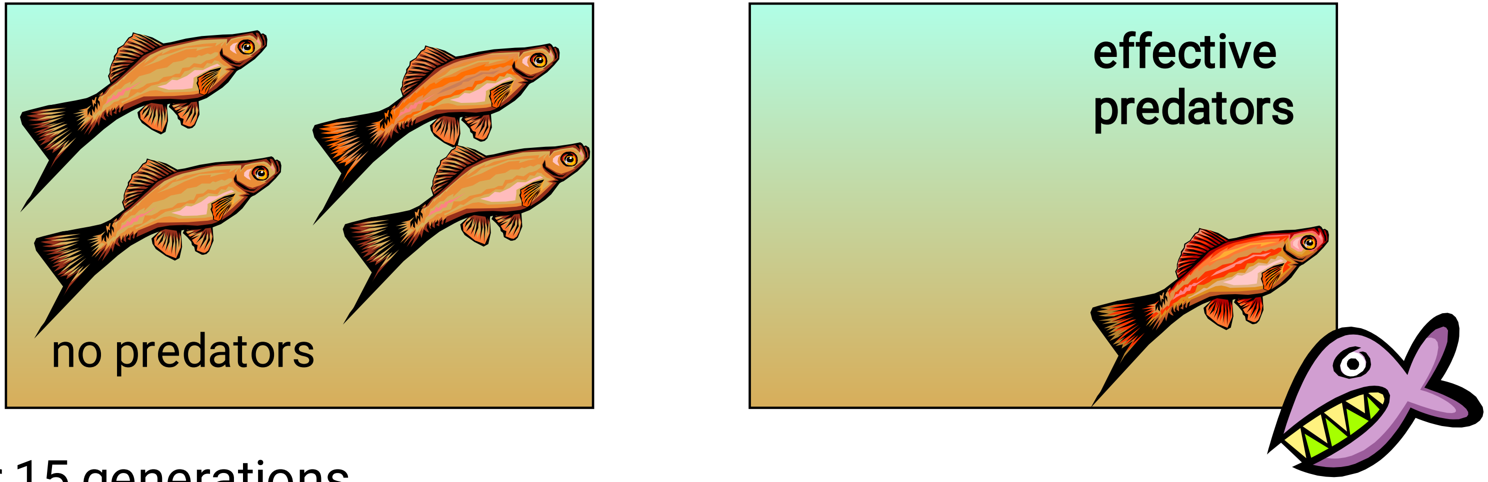
after one generation



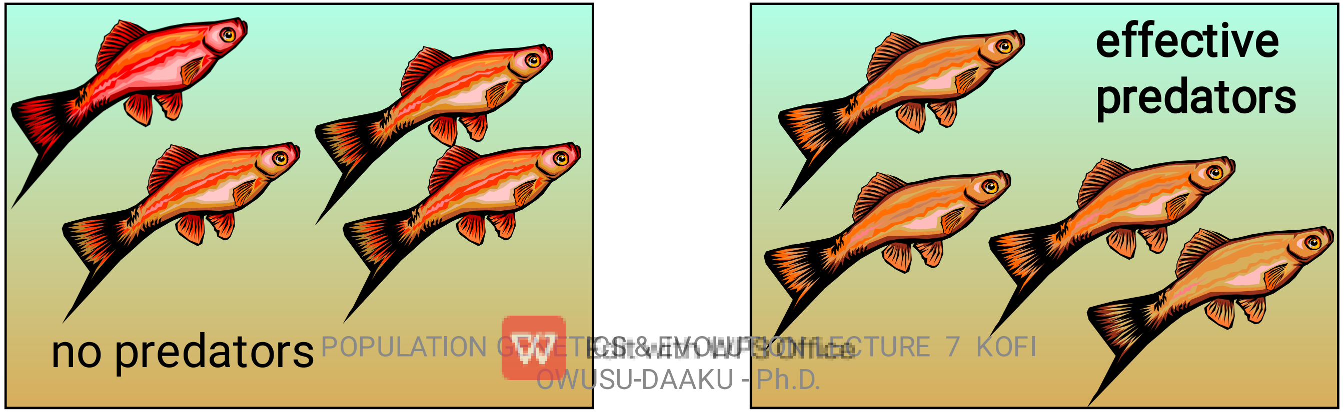
Testing for adaptation:

reciprocal transplant experiment

after one generation



after 15 generations



Limits on adaptation

Different challenges can impose selection on the same trait

Challenges may be conflicting → stabilizing selection

Challenges may be reinforcing → directional selection

Challenges may fluctuate in time or space

examples: Natural selection vs. sexual selection

Predation from birds vs. parasitism from wasps

Growth vs. reproduction

Many offspring vs. large offspring

Limits on adaptation

<u>Tradeoffs</u>

Resources are limited → organisms can't be perfect at everything

What is the <u>optimal</u> allocation of resources to:

growth vs. reproduction

many offspring vs. large offspring

many flowers vs. large flowers

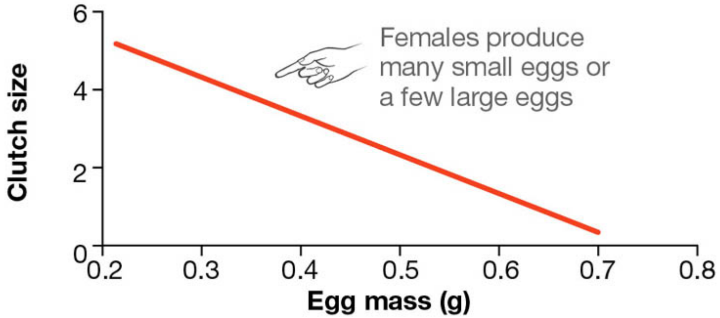
Limits on adaptation

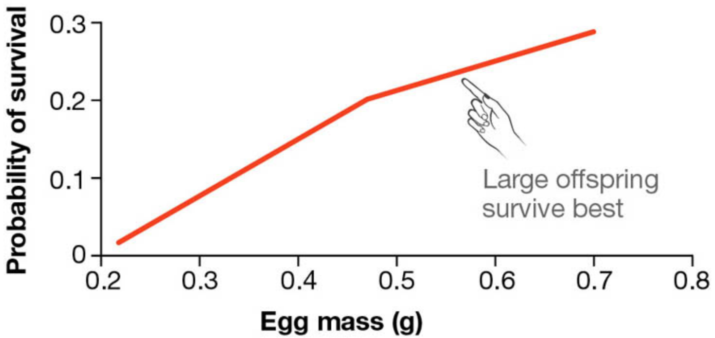
<u>Tradeoffs</u>

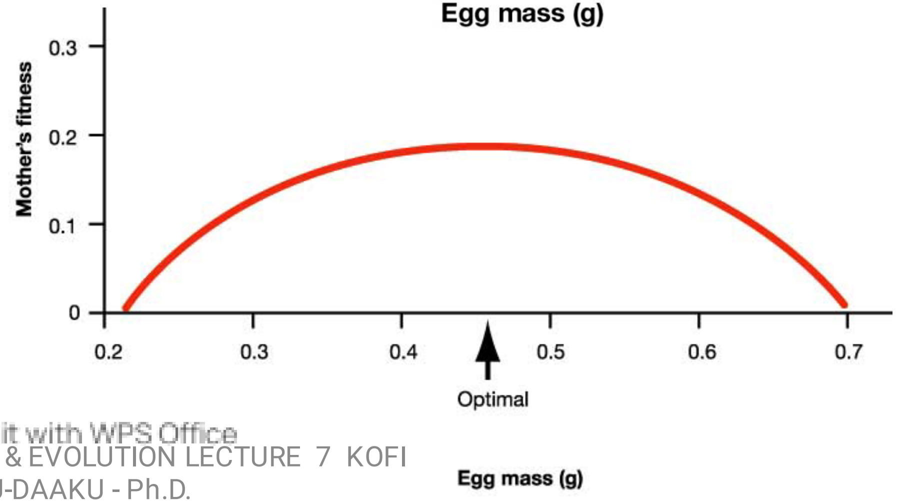
Resources are limited →
organisms can't be perfect at everything

<u>optimal</u> allocation of resources

Side-blotched lizard





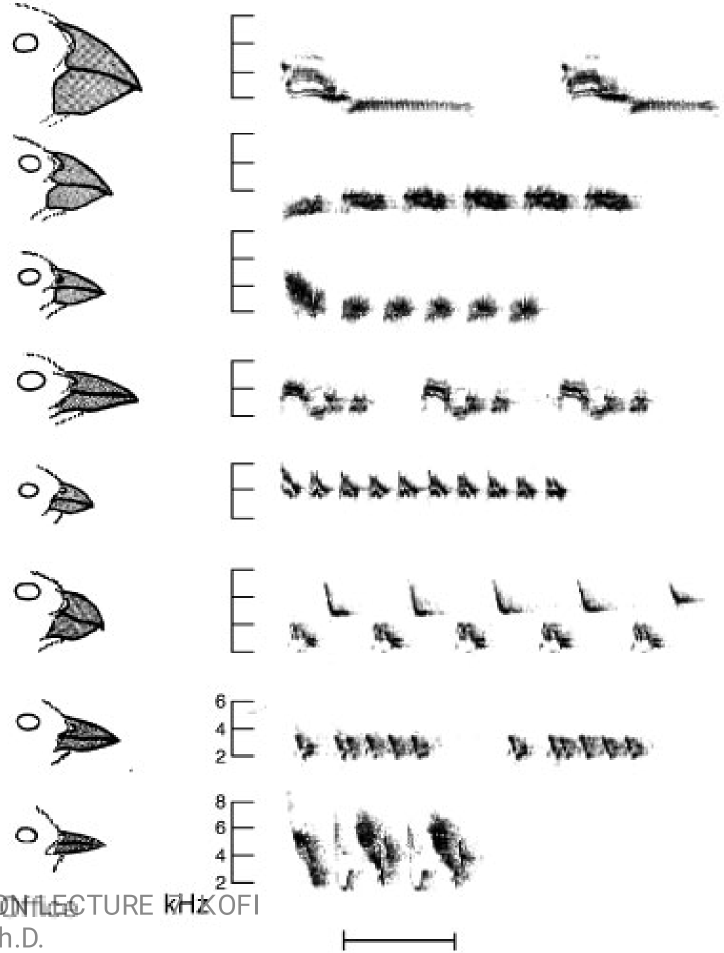


Limits on adaptation

<u>Constraints</u> – factors that slow or prevent the evolution of an ideal trait

Functional constraints

ex: Darwin's finches with large beaks can't sing complex songs



Limits on adaptation

<u>Constraints</u> – factors that slow or prevent the evolution of an ideal trait

Functional constraints

ex: Darwin's finches with large beaks can't sing complex songs

Physiological constraints

Why isn't this flower dropped after pollination?

→ find the answer in your textbook!

Developmental constraints

ex: panda's fifth digit can't be used to manipulate bamboo

- Adaption, which refers to the process by which organisms become better matched to their environment and to the specific traits that make an organism more fit, occurs as a result of natural selection.

ADAPTATION

- Cryptic Colouration
- Mimicry

  - Mulleriar

  -Batesian
- Aposematism

MIMICRY

- The resemblance of one organism to another or to natural objects in its surroundings, for protection from predators, is known as mimicry.
- The organism that mimics is known as the mimic and the organism that is copied is known as the model.
- The concept of mimicry was given by Henry W Bates (1962) based on *his* studies of butterflies in the forests of Brazil.

Mimicry Cont`d

- Mimicry takes place when a group of organisms (mimics), tend to share common perceived characteristics with another group (model).
- Mimicry is a form of co-evolution.
- In Batesian mimicry, the palatable and unprotected species of animals resembles an unpalatable and relatively protected species. This type of mimicry is beneficial only to the mimic.

Mimicry Cont`d

- In Mullerian mimicry, two or more unpalatable species resemble each other. In this type of mimicry, both the mimic and the model are benefited.
- Mimicry may be protective, aggressive and conscious.

Mimicry Cont`d

- Protective Mimicry - It occurs in organisms to protect themselves from predators. It is of the following two types:

(a) Concealing Mimicry - This is the most common type of mimicry. The animal hides itself according to its environment (e.g., the stick insect shows close similarities with a twig).

Mimicry Cont`d

- (b) Warning Mimicry - In warning mimicry, the organism resembles forms which are poisonous or harmless (e.g., snakes of genus *Elaps* mimic the poisonous coral snake).

Mimicry Cont`d

- Aggressive Mimicry - In aggressive mimicry, the animal either conceals itself for attack (e.g. , spiders living on flowers mimic the flower so that they become invisible to their prey) or allures the prey (certain spiders mimic the flowers of orchids and allure the insects).

Mimicry Cont`d

- Conscious Mimicry - Certain animals simulate death whenever in danger to protect themselves (e.g., the opossum becomes unconscious and simulates death, whenever in danger).