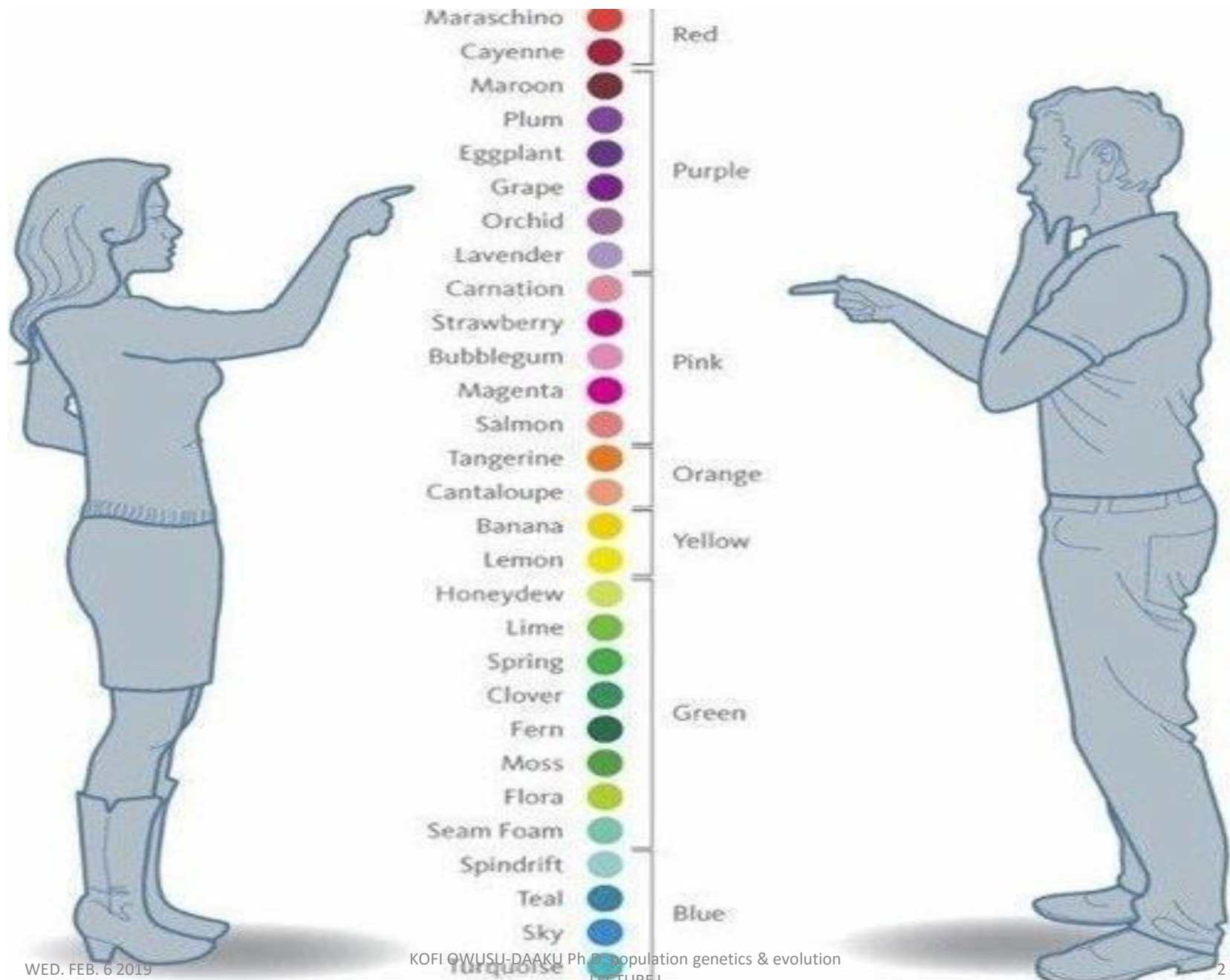


# POPULATION GENETICS AND EVOLUTION LECTURE 1 KOFI OWUSU-DAAKU –Ph.D.



# MODULE ONE EVOLUTION

## Origin of Life

# Four Unifying Themes of Biology

- 1) The Cell Theory
  - First cells discovered by Robert Hooke in England in 1665 using 30X microscope
  - Anton van Leeuwenhoek then used more powerful microscope (300X) to discover diversity of life in pond water
  - German biologists Matthias Schleiden and Theodor Schwann (1839) propose cell theory

# Four Unifying Themes of Biology

- 2) Molecular Basis of Inheritance
  - Hereditary information encoded in DNA
  - Sequences of nucleotides in DNA make up genes
  - An organism's complete set of genes/DNA is called a genome

# Four Unifying Themes of Biology

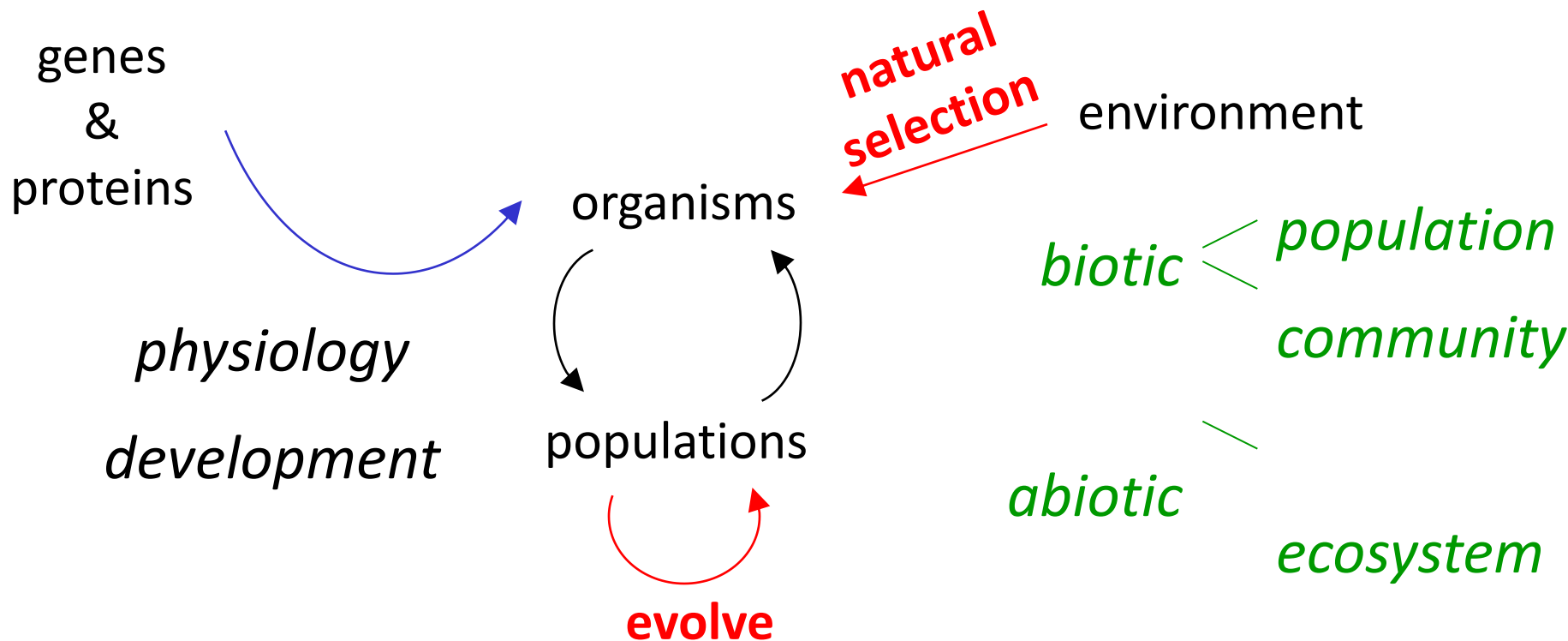
- 3) Diversity of Life and Evolutionary Change
  - Incredible diversity of living things on earth
  - Eubacteria, Archaea, Eukarya domains, with Eukarya being comprised of 4 kingdoms (Protista, Plantae, Fungi and Animalia)
  - All evolved from a common ancestral form through evolution

# Four Unifying Themes of Biology

- 4) Evolutionary conservation
  - All living things descended from simple cellular creature which existed about 2.5 billion years ago
  - Characteristics of common ancestors are preserved in the subsequent life forms
    - Protein classes are conserved even between kingdoms

# Evolution is a unifying theme in biology

connects all levels of biological organization





**Table 1**

<i>S. No.</i>	<i>Theories</i>	<i>Founders</i>	<i>Principles</i>
1.	Theory of Autogenesis	Plato, Aristotle	Life originated spontaneously (from nonliving substances).
2.	Theory of Special Creation	Religious Mythology	Life originated at the mercy of a supernatural power.
3.	Theory of Catastrophism	Cuvier (1776)	Life originated due to sudden changes on the earth.
4.	Cosmozoic Theory	Richer (1865), Helmholtz (1884)	Life originated somewhere else in the cosmos and was blown to the earth in the form of spores, germs, etc.
5.	Theory of Conservation	Oparin (1938)	Life originated from inorganic substances in sequential stages.
6.	Theory of Organic Evolution	Lamarck, Darwin	Life originated slowly and steadily from simpler to complex forms.

- The evolution of the environment having definite biosphere zones facilitated the evolution of higher animals including humans.
- The overall sequence of evolution as suggested by Oparin (1938) may be summarised in following phases:

- (a) Atomic phase
- (b) Molecular phase
- (c) Organic phase
- (d) Colloidal phase
- (e) Autocatalytic phase
- (f) Primordial cellular phase
- (g) Autotrophic phase
- (h) Prokaryotic phase
- (i) Eukaryotic phase

# ORIGIN OF LIFE

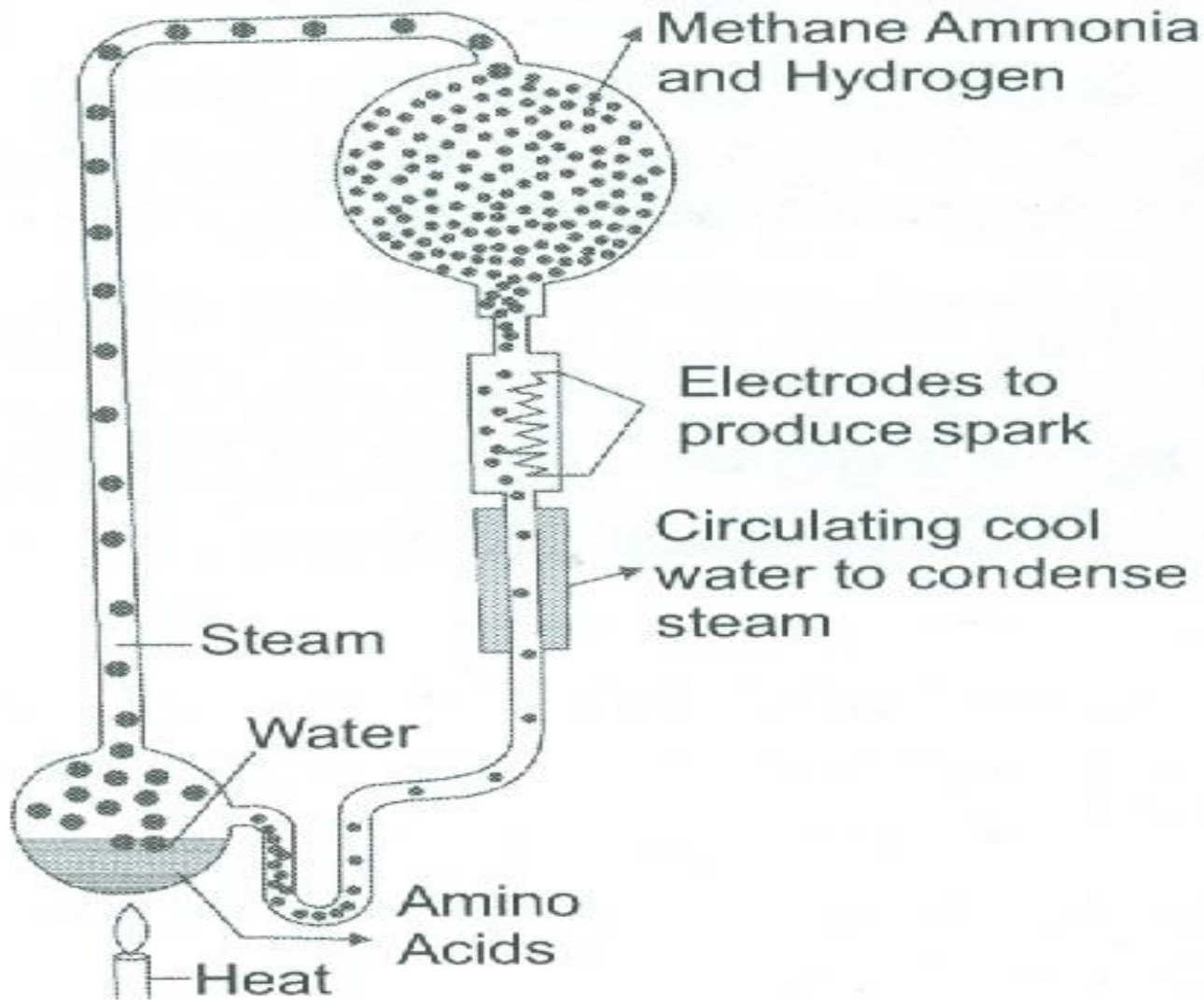
- The earth is also called 'the blue planet' or 'the planet with life'. It originated about 4.8 billion years ago.
- The primitive atmosphere of the earth contained nitrogen, hydrogen and carbon, but no oxygen or ozone, all found in the atomic state due to extreme heat and ultraviolet insulation.

# ORIGIN OF LIFE

- Chemical evolution continued for about 2,000 million years, by which various inorganic and organic compounds appeared.
- The chief inorganic compounds that evolved during this period were  $N_2$ ,  $H_2CH_4$ ,  $NH_3$ ,  $CO$ ,  $CO_2$ ,  $H_2O$ , etc., but no  $O_2$  or  $O_3$ , as the primitive environment was reducing.

# ORIGIN OF LIFE

- Miller in 1953 during his experiments on molecular evolution found that when a mixture of  $\text{H}_2$ ,  $\text{CH}_4$ ,  $\text{NH}_3$  and  $\text{H}_2\text{O}$  is exposed to high electric discharge for weeks, a gaseous phase of advanced molecules including  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{N}_2$  etc., and a liquid condensate phase, -including a variety of amino acids like glycine, valine, etc., and other organic molecules were obtained.



**Fig. 1** Miller and Urey's experiment

# ORIGIN OF LIFE

- During this period, certain compounds that favoured molecular evolution survived, while the compounds disfavouring it were destroyed by predator molecules like hydrated electrons, poly anions, etc.



# ORIGIN OF LIFE

- The culmination of chemical evolution was the polymerisation of monomers.
- As a result, certain biopolymers like proteins, polysaccharides, lipids and polynucleotides were formed.

# ORIGIN OF LIFE

- Certain polymers like histones and protamines are positively charged and called polycations and when such polycations enclosed polynucleotides, the latter were protected from the predator molecules.

# ORIGIN OF LIFE

- The earliest life originated in a primitive broth, which provided easy accessibility to the polymers essential for self-replication.
- The first life form had the unique property of self-replication and it became the first and foremost characteristic of life.

# ORIGIN OF LIFE

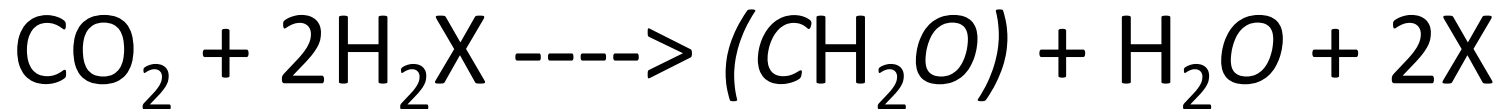
- Although the sun is the ultimate source of energy, the first transformed energy was obtained from the mobility of the molecules.
- The second primitive characteristic of tiny life was to use the ATP, the condensed energy source for all life activities.

# ORIGIN OF LIFE

- The two other prerequisites of life were a definite catalytic system and an information transfer system, also formed by the conversion of the two polymers.
- Certain theories and principles regarding origin of life are given in the following table:

# ORIGIN OF LIFE

- The first life form produced food from inorganic substances by the photoreduction reaction in which sulphur or other organic groups were produced as byproducts.



# ORIGIN OF LIFE

- The above hypothesis has been confirmed by the tracer carbon technique and chromatographic identification of the products (Arnon, 1960).

# ORIGIN OF LIFE

- The evolution of chlorophyll molecule was a landmark in the origin of photosynthetic life because the magnesium porphyrin of chlorophyll molecule is capable of emitting electrons, when excited by the radiant energy of even visible range.



# ORIGIN OF LIFE

- The evolution of photosynthetic life could change the reducing environment to oxidising due to release of oxygen.
- $6\text{CO}_2 + 6\text{H}_2\text{O} \text{ ----> } \text{C}_6\text{H}_{12}\text{O}_2 + 6\text{CO}_2$

# ORIGIN OF LIFE

- At the time of origin of animals, the atmosphere contained  $N_2$ ,  $CO_2$  and  $O_2$  gases, while the land mass contained soil rich in soluble nitrates, sulphates, phosphates and organic materials.

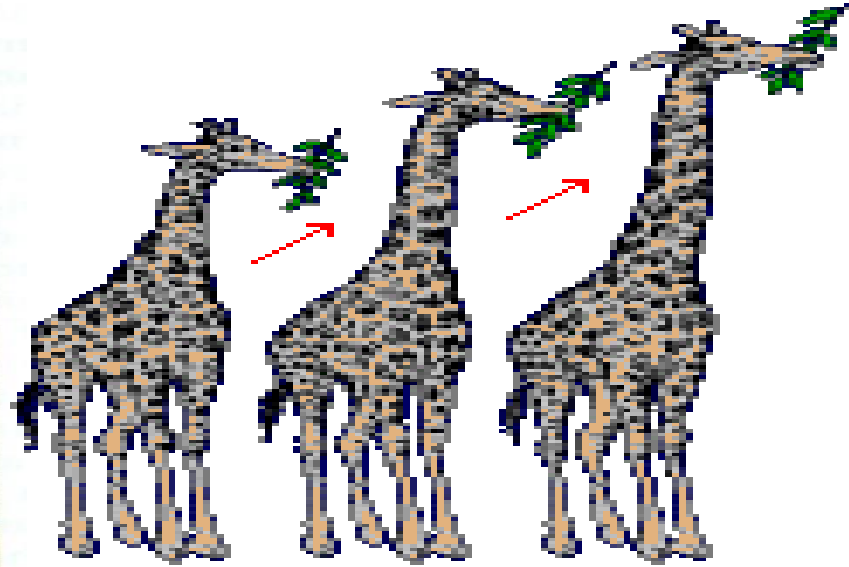
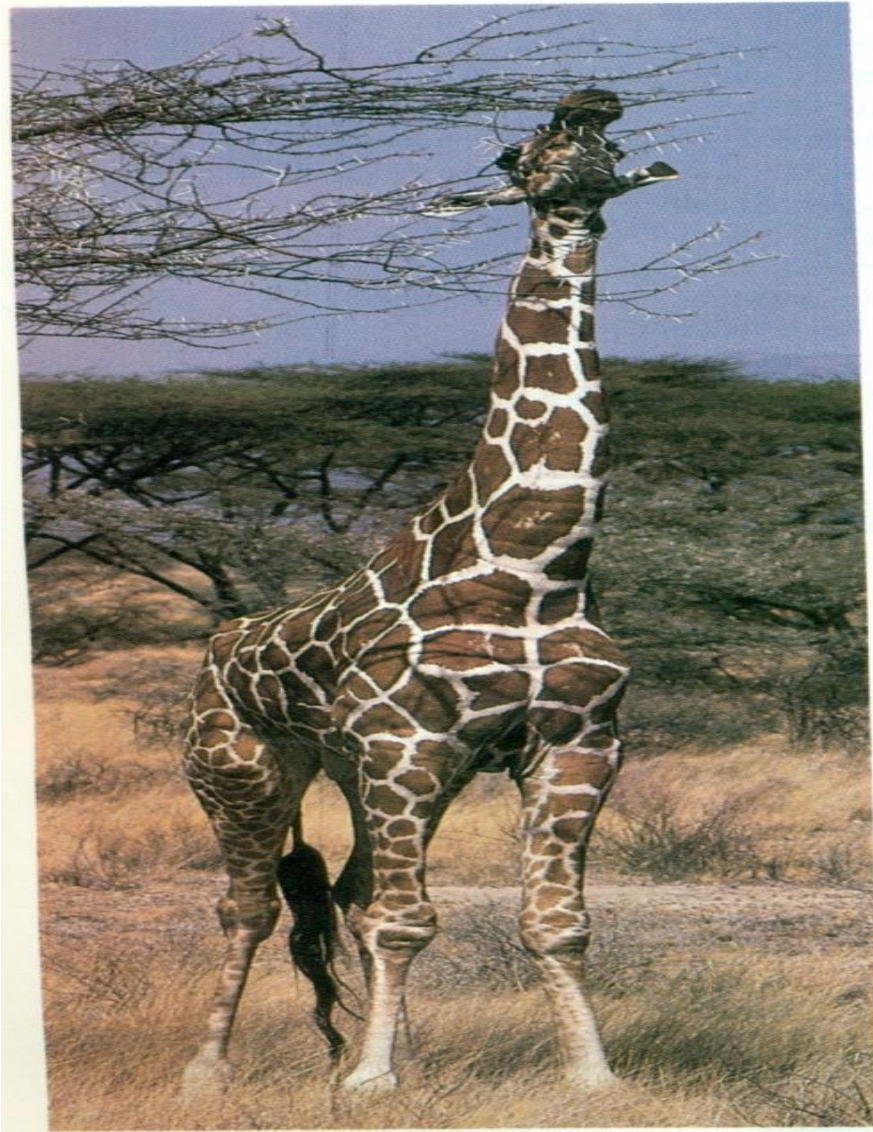
# LAMARCKISM

- Jean Baptiste de Lamarck (1744-1829) was a French scientist who for the first time put forth an evolutionary theory.
- He published his ideas in the book, *Philosophie Zoologique* in 1809.

# LAMARCKISM

- Lamarckian theory is also known as 'Theory of Inheritance of Acquired Characters' or the 'Theory of Use or Disuse of Organs' .





ACCORDING TO LAMARCK'S THEORY, AS GIRAFFES STRETCHED TO REACH THE HIGH BRANCHES THEIR NECKS LENGTHENED AND THIS WAS PASSED ON TO THEIR OFFSPRINGS

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# LAMARCKISM

- The basic ideas of Lamarckism are as follows:

(a) Complex plants and animals are produced from the simpler ones in due course of time under the influence of nature.

# LAMARCKISM

- (b) Living organisms have a tendency to continuously increase in size.
- (c) There is a change in the needs of an animal due to changes in the surrounding environment. As a result, new organ(s) is/are formed to cater the needs of the animal.

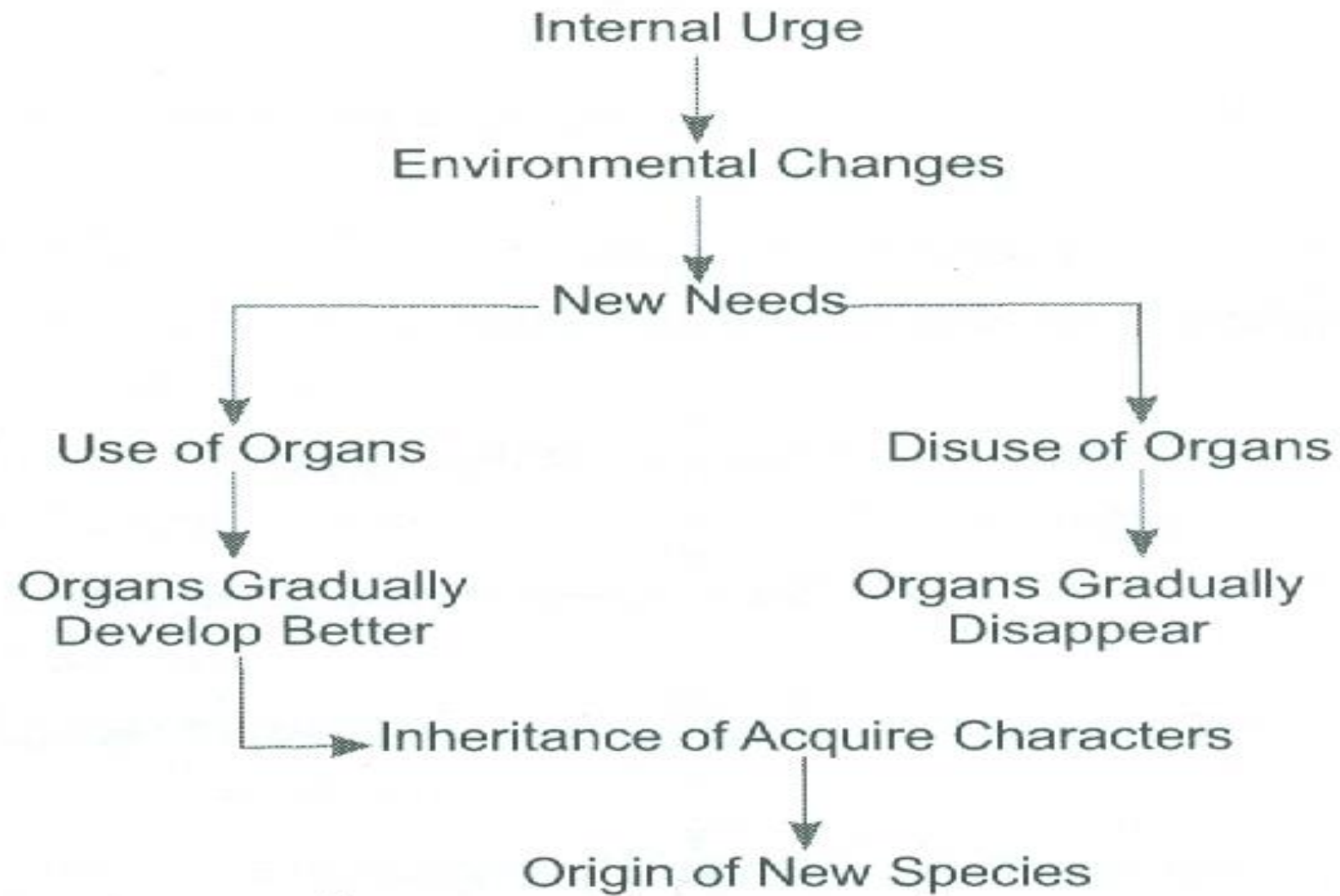
# LAMARCKISM


(d) If an organ is used continuously, it will be more powerful. If it is not used for a long time, it gradually weakens and finally disappears.

(e) The characters acquired during the lifetime of individuals will be transmitted to the next generation. This is called the 'inheritance of acquired characters'.



Individuals will be transmitted to the next generation.  
,



**Fig. 2**  Lamarck's theory of evolution

# Critical Analysis

- Lamarck based his idea of use and disuse on the evidences in the form of vestigial organs and rudimentary organs. The idea is true, but it cannot be treated as a basis of evolution.
- As far as the theory of inheritance of acquired characters is concerned, it cannot be accepted.

# Critical Analysis

- Weismann (1890) for the first time provided experimental proof against this assumption.
- Weismann cut off the tails of mice for many generations and kept them in breeding, but not a single mouse was born without a tail.

- Weismann proposed the 'Theory of Continuity of Germplasm'.
- It is now quite clear that only those changes are inherited which are in the germ cells.
- No somatic changes can be inherited. Whatever one acquires in one's lifetime passes away with the end of one's life.

# Neo Lamarckism

- A few scientists notably, Herbert Spencer, Haeckel, Gadow, etc., have supported Lamarckism in a modified form and this is called Neo Lamarckism. Neo Lamarckism can be explained as listed below.
  - a) Only those acquired characters are inheritable, which are incorporated in the genetic makeup.

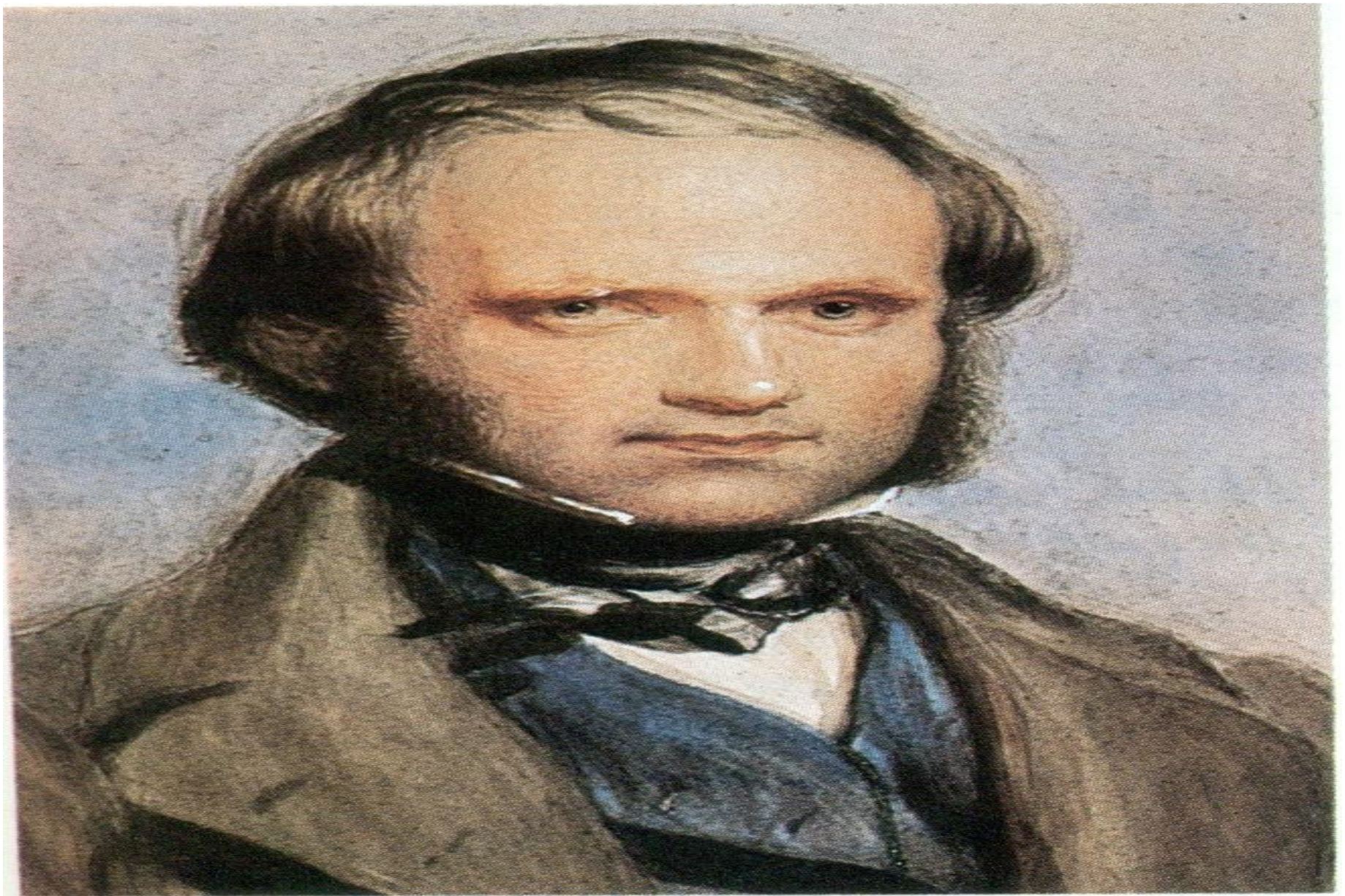
# Neo Lamarckism cont`d

B) Environmental changes create needs in an organism. Such needs rarely cause changes in the genetic makeup. Somatic changes are not heritable.

# Neo Lamarckism cont`d

(c) It may be that environmental changes and thereby the needs emanating from them may not reach up to a mutational threshold and genetic effect will not be expressed. The inheritance of acquired characters depends upon its reaching the mutational threshold.





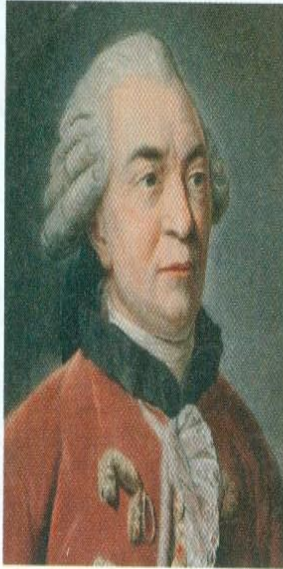
## CHARLES DARWIN IN 1840

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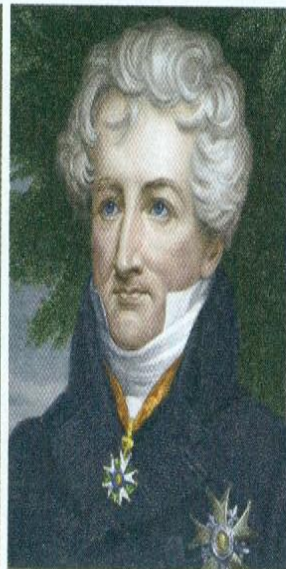
## DARWIN'S INFLUENCES



**GEORGES BUFFON**

(1707–1788)

Suggested that the earth was much older than previously believed.



**GEORGES CUVIER**

(1769–1832)

By documenting fossil discoveries, showed that extinction had occurred.



**JEAN-BAPTISTE LAMARCK**

(1744–1829)

Suggested that living species might change over time.



**CHARLES LYELL**

(1797–1875)

Argued that geological forces had gradually shaped the earth and continue to do so.



The young Charles Darwin

**FIGURE 8-3** Scientists who shaped Darwin's thinking.

# Darwin Influenced by Others

## ◎ Malthus

- “Essay of the Principle of Population” (1798)
- Populations of plants/animals can increase geometrically
- Populations of plants/animals remain relatively constant
- Death limits populations

◎ Darwin hypothesized natural selection as a means by which selective survival of individuals with superior attributes gradually changes the average characters of the population as a whole over many generations

# Additional Evidence Supporting Darwin/Wallace Theory

- Molecular biology
  - DNA
  - Genetic code, gene expression
- Development
  - An organism's development (ontogeny) provides insights into its evolutionary history (phylogeny)
  - Human embryos with gills, tails and fur

- In the 18<sup>th</sup> and 19<sup>th</sup> centuries, scientist began to overturn many commonly held beliefs in the Western world, including that the earth was only about 6,000 years old and that all species had been created separately and were unchanging.
- These gradual changes in scientist's belief helped shape Charles Darwin's thinking.

# DARWINISM

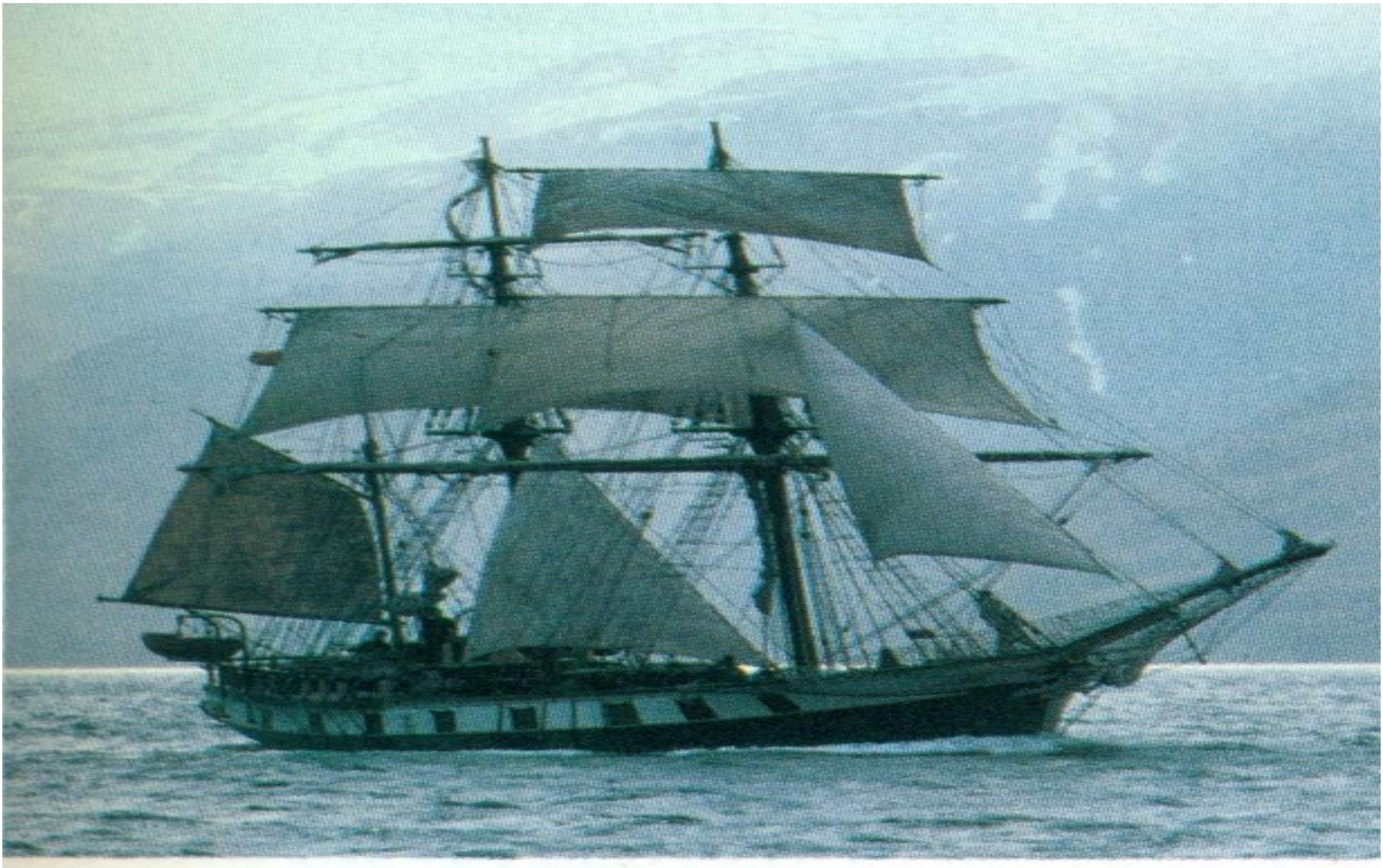
- Charles Darwin (1809-1882) was the first individual who categorically explained organic evolution in detail.
- Charles Darwin joined a sea voyage that continued for five years in a ship named *HMS Beagle* and collected flora and fauna of many continents and islands.





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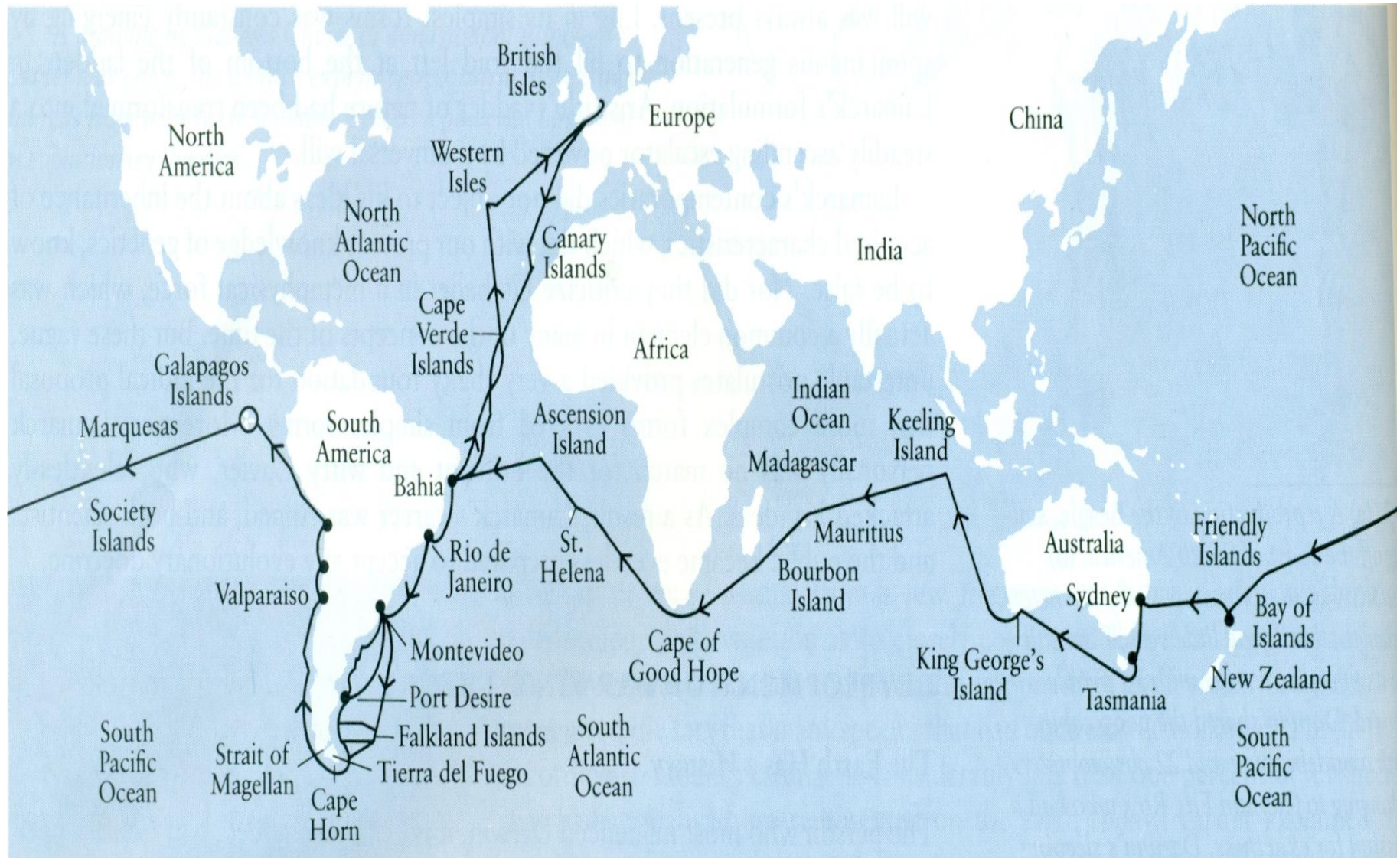
H. M. S. BEAGLE

IN WHICH CHARLES DARWIN SET SAIL FROM ENGLAND TO EXPLORE THE  
RICH FOSSIL BEDS OF SOUTH AMERICA

- Darwin noted unexpected patterns among fossils he discovered and living organisms he observed while on the voyage of the Beagle. Fossils resembled but were not identical to the living organisms in the same area where they were found.

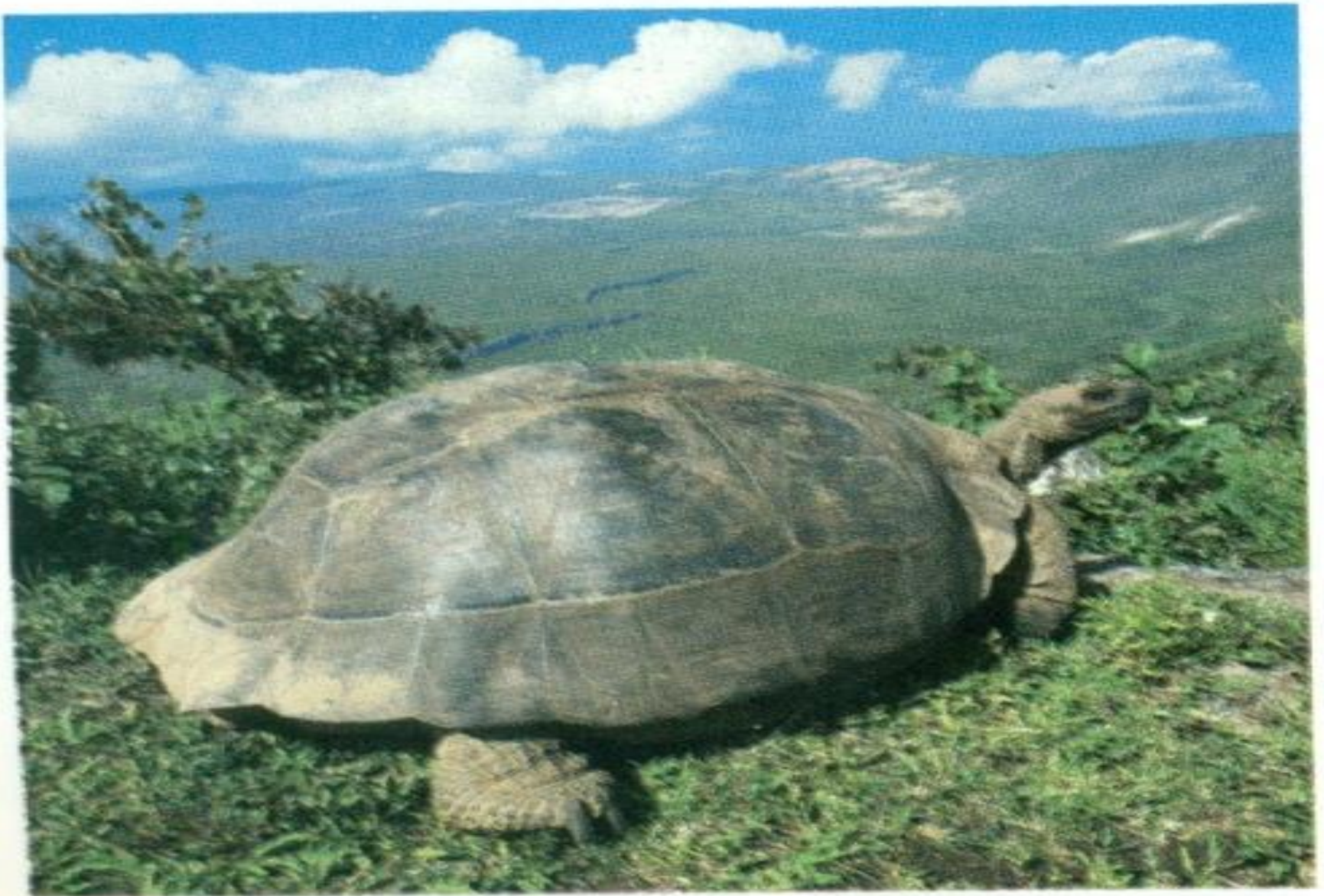


- And finch species on each of the Galapagos Islands differed from each other in the small but significant ways. These observations helped Darwin develop his theory of how species might change over time.



## THICK LINES SHOW THE BEAGLES VOYAGE





**DISTINGUISHING FEATURE OF GALAPAGOS TORTOISE IS THE SHAPE OF THE SHELL WHICH VARIES ACCORDING TO IT'S ISLAND OF ORIGIN**

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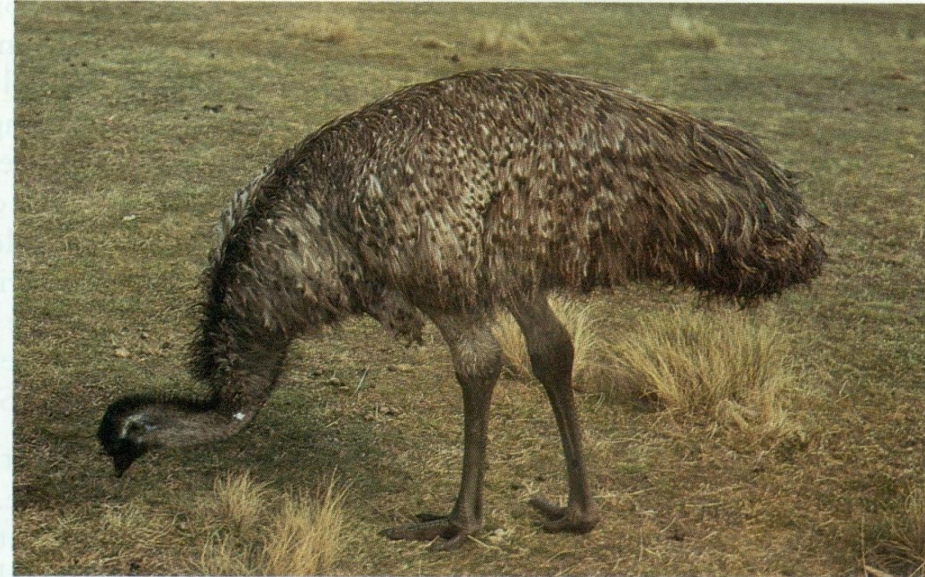
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51





(a)



(b)



(c)

46-8 The rhea of South America (a), the emu of Australia (b), and the ostriches of Africa (c) are all very large, flightless birds found in similar habitats on the different continents. Was each a product of a separate act of special creation? For Darwin, biogeographic differences such as these cast doubts on the doctrine of special creation.

## A. THE RHEA OF SOUTH AMERICA    B. THE EMU OF AUSTRALIA    C. AFRICAN OSTRICHES





## ALFRED RUSSEL WALLACE(1823 - 1913)

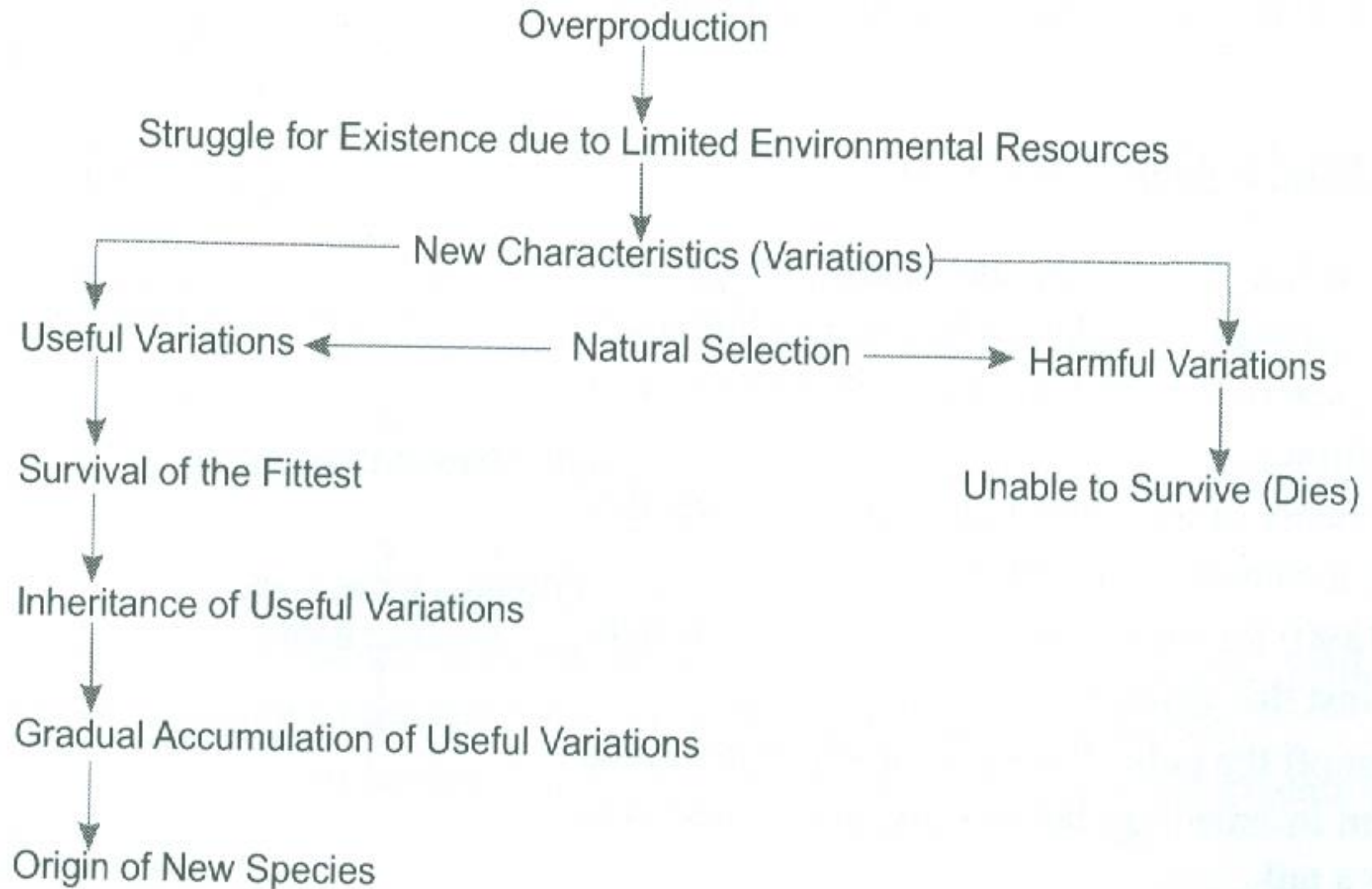
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LECTURE I

53

- After putting off publishing his thoughts on natural selection for more than 15 years, Darwin did so only after Alfred Wallace independently came up with the same idea. The two men published a joint presentation on their ideas in 1858, and Darwin published a much more detailed treatment in the Origin of the Species in 1859, sparking wide debate and discussion of natural selection.

- The view of A R Wallace regarding organic evolution was much similar to that of Darwin.
- The ideas of both scientists were greatly influenced by the writings of T R Malthus on the growth of population.



**Fig. 3**  Darwin's concept of evolution



# DARWINISM CONT'D

- Darwin published his detailed theory on organic evolution in 1859 in his book entitled *Origin of Species*
- He argued that natural selection is the main cause of origin of new species.
- The presentation of Darwin's theory was based on the following facts:

# DARWINISM CONT'D

- (a) Overproduction - Organisms have the capacity of enormous reproduction, i.e., they produce much more than required.
- (b) Limited Environmental Resources
  - The population of each species tends to increase in a geometric ratio but remains almost constant.

# DARWINISM CONT'D

- (c) Struggle for Existence - To check the increase in the number of each species, there is a struggle for existence, which may be intraspecific, interspecific and environmental. Of these, the intraspecific struggle is very severe.

# DARWINISM CONT'D

- (d) Variations - Darwin thought that each member of a sexually reproducing species is different from the others. The cause of difference among the members of a species is variation and the variations are heritable.

# DARWINISM CONT'D

- (e) Survival of the Fittest (Natural Selection) - Among these variations, some are useful and some are harmful. Useful variations make some individuals more suited to the environment than others in the struggle for existence.
- In this struggle, the most suitable individuals survive. Thus, the paradigm of 'survival of the fittest' is in operation.

- The survival of the fittest is made possible due to useful or beneficial variations, which is why the survival of the fittest is by natural selection.

- Fitness is a measure of the relative amount of reproduction by an individual with a particular phenotype, compared with the reproductive output of individuals with alternative phenotypes. An individual's fitness can vary, depending on the environment in the which it lives.

# Criticism of Darwinism

- Darwin could not explain the origin and cause of inheritance of variations. Further, he could not differentiate heritable and non heritable variations.
- Although Darwin termed as 'sports' the sudden change in the genetic material, he was unable to explain it.



# Criticism of Darwinism

- There are examples of overgrowth/over specialisation of useful organs that become instrumental in the extinction of that species.
- Darwin did not explain the occurrence of vestigial organs.

# Neo Darwinism

- Neo Darwinism is the modification of Darwin's theory in the light of modern genetic findings.
- Neo Darwinism is based on three facts, viz., genotypic variations, natural selection and isolation.

# Neo Darwinism cont`d

- Neo Darwinism assumes that natural selection acts on the heritable variations in individuals in populations and mutations provide the main source of these genetic variations.
- Neo Darwinism separates the Darwinian idea of natural selection from his hypothesis of pangenesis.

# Neo Darwinism cont`d

- Neo Darwinism states that organic evolution takes place by natural selection of inherited characters.
- According to Neo Darwinism, evolution occurs because the environment is slowly changing.
- This exerts a selection pressure on individuals within a population.

# Neo Darwinism cont`d

- The characteristics that adapt to a new environment are able to survive and pass on to the next generation.
- These result in variations and accumulate in the gene pool of the organisms.
- With the passage of time, the genetic makeup of the population changes and ultimately a new species is formed.