ENVE203
Environmental Engineering Ecology
(Oct 22, 2012)

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Elif Soyer

'Ecosystems and Living Organisms'

Evolution: How Populations Change Over Time

All species living today are thought to have descended from earlier species by the process of evolution.

Evolution
Cumulative genetic changes that occur over time in a population of organisms; evolution explains many patterns of distribution and abundance displayed in the natural world.

Evolution: How Populations Change Over Time

Charles Darwin, 19th century naturalist

Environment plays a crucial role in Darwin's theory of natural selection

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Natural Selection
The process in which better-adapted individuals –those with a combination of genetic traits better suited to environmental conditions- are more likely to survive and reproduce, increasing their proportion in the population.

Evolution: How Populations Change Over Time

Charles Darwin, 19th century naturalist

From one generation to the next, inherited traits favorable to survival in a given environment would be preserved, whereas unfavorable ones would be eliminated.

Adaptation:

Evolutionary modification of an individual that improves that individual's chances of survival and reproductive success in its environment.

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Evolution: How Populations Change Over Time
NATURAL SELECTION

Theory of 'natural selection' was proposed in book '*The Origin of Species by Means of Natural Selection*' in 1859 by Charles Darwin.

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There are biologists still do not agree completely on aspects of how evolutionary changes occur

Evolution: How Populations Change Over Time

NATURAL SELECTION

Evolution by natural selection consists of 4 observations about the natural world:

1. High reproductive capacity
2. Inheritable variation
3. Limits on population growth
4. Differential reproductive success

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Evolution: How Populations Change Over Time
NATURAL SELECTION

1. High reproductive capacity

Each species produces more offspring than will survive maturity

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2. Inheritable variation

Each individual has a unique combination of traits, such as size, color, and ability to tolerate harsh environments.

The variation necessary for evolution by natural selection must be inherited so that it can be passed to offspring

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NATURAL SELECTION

3. Limits on population growth, or a struggle for existance

Organisms compete with one another for the limited resources available for them.

Not all the offspring will survive to reproductive age because there are more individuals than the environment can support.

Other limits on population growth: predators and diseases

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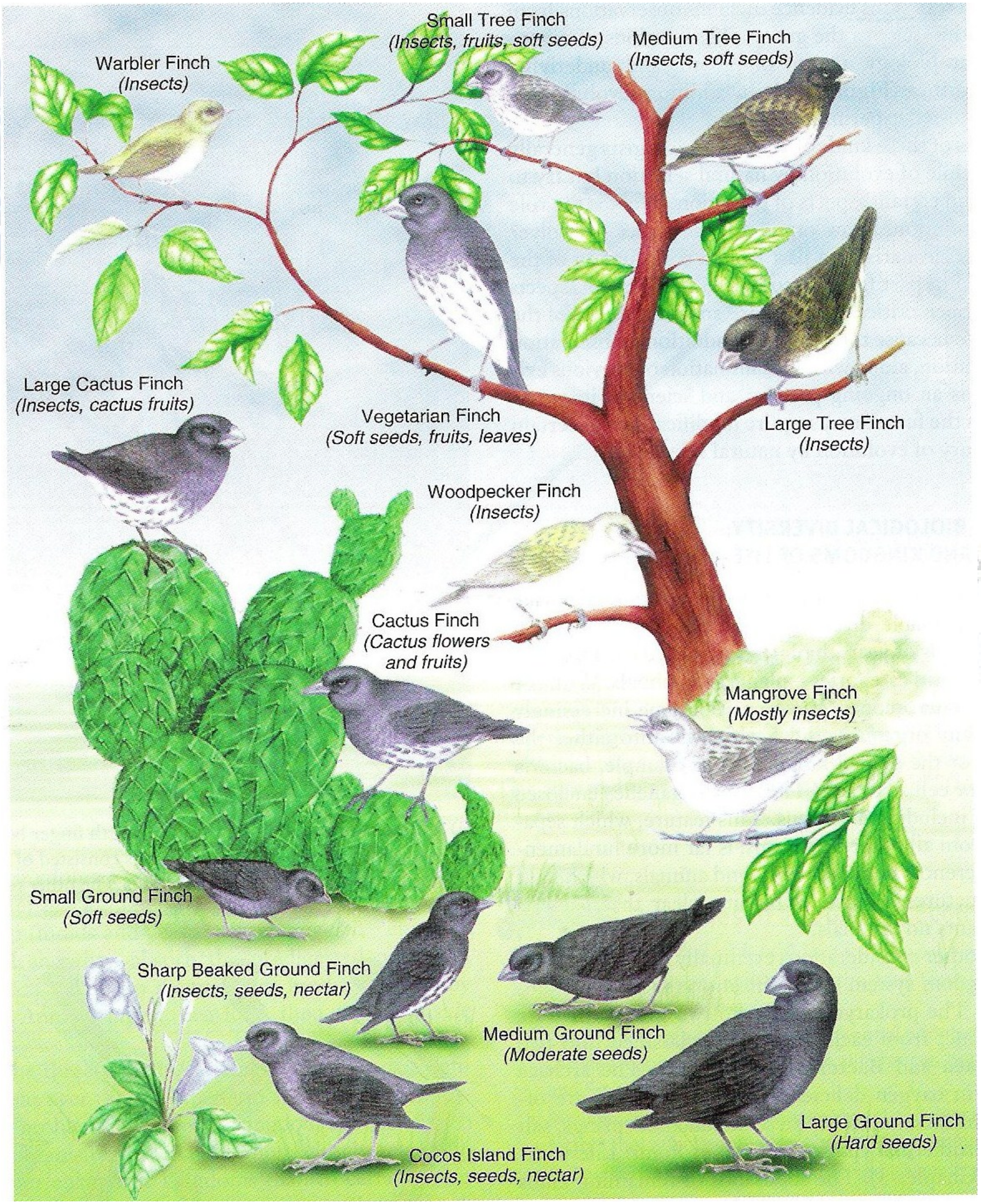
4. Differential reproductive success

The best-adapted individuals reproduce most successfuly, whereas less fit individuals die prematurely or produce fewer or inferior offspring.



Galapagos Islands
off the cost of Ecuador

Darwin’s finches
with various beak sizes and shapes which are related to diet

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NATURAL SELECTION

Charles Darwin:

'14 species of Galapagos finches descended from a single common anchester'

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Over many generations, the surviving finch populations underwent natural selection, making them better adapted to their environments, including feeding on specific food sources

Evolution: How Populations Change Over Time

THE MODERN SYNTHESİS

Darwin could not explain:

- How individuals transmit traits to the next generation?
- Why individuals vary within a population?

In 1930s and 1940s

Biologists combined the principles of genetics with Darwin’s theory of natural selection

Evolution: How Populations Change Over Time
THE MODERN SYNTHESİS

Modern synthesis explains Darwin’s observation of variation among offspring in terms of **mutation**,

↓

changes in the nucleotide base sequence of a gene, or deoxyribonucleic acid (DNA) molecule.

Some new traits may be beneficial, whereas others may be harmful or have no effect at all.

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Evolution: How Populations Change Over Time

EVOLUTION OF BIOLOGICAL DIVERSITY: THE DOMAINS AND KINGDOMS OF LIFE

For hundered of years, organisms have been divided into two broad categories:

- Plants kingdom
- Animals kingdom

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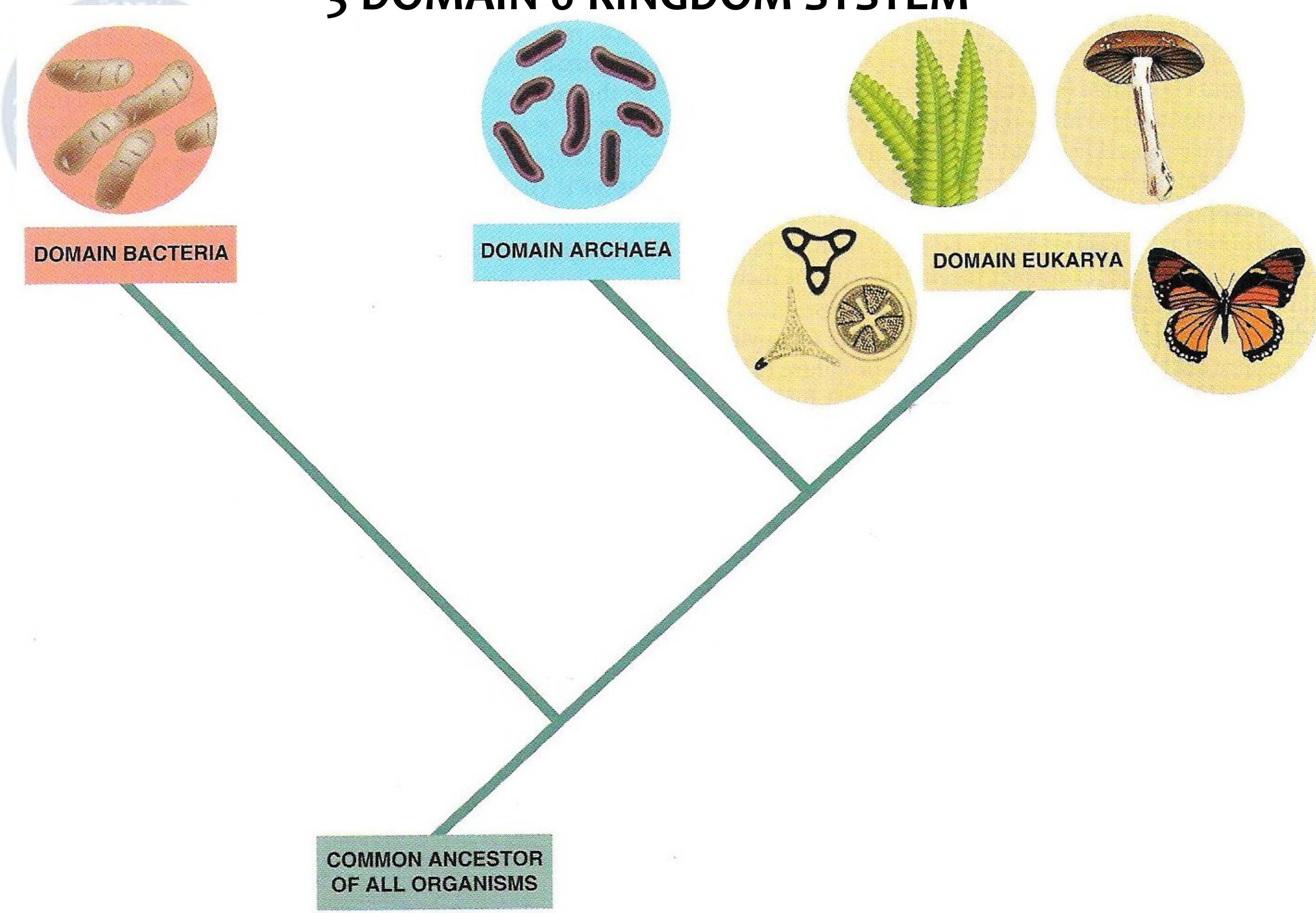
with the development of microscopes, however many organisms did not fit well into either group.

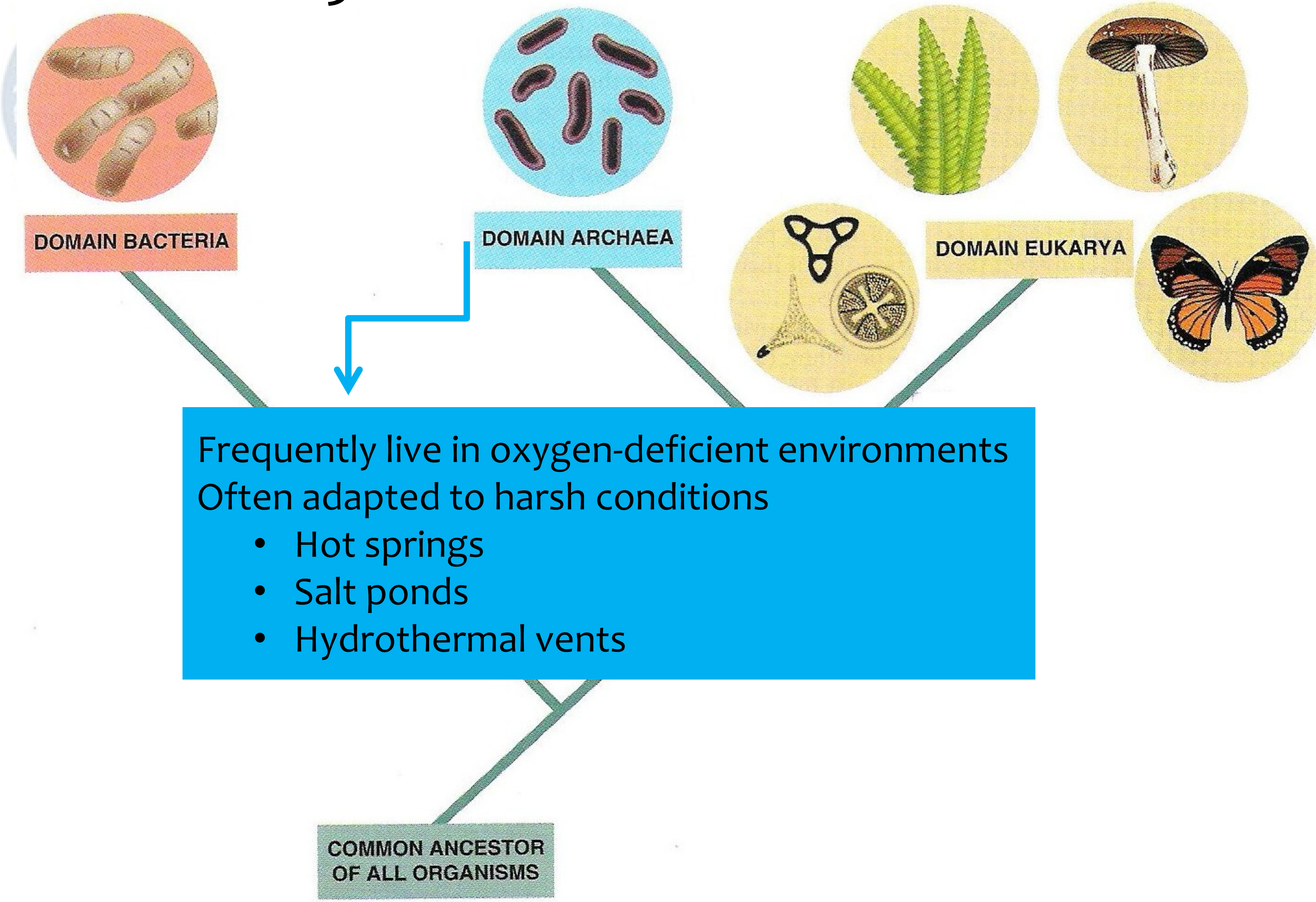
e.g. Bacteria: neither plants nor animals

Have a prokaryotic cell structure: lack organelles enclosed by membranes, including a nucleus

3-DOMAIN 6-KINGDOM SYSTEM



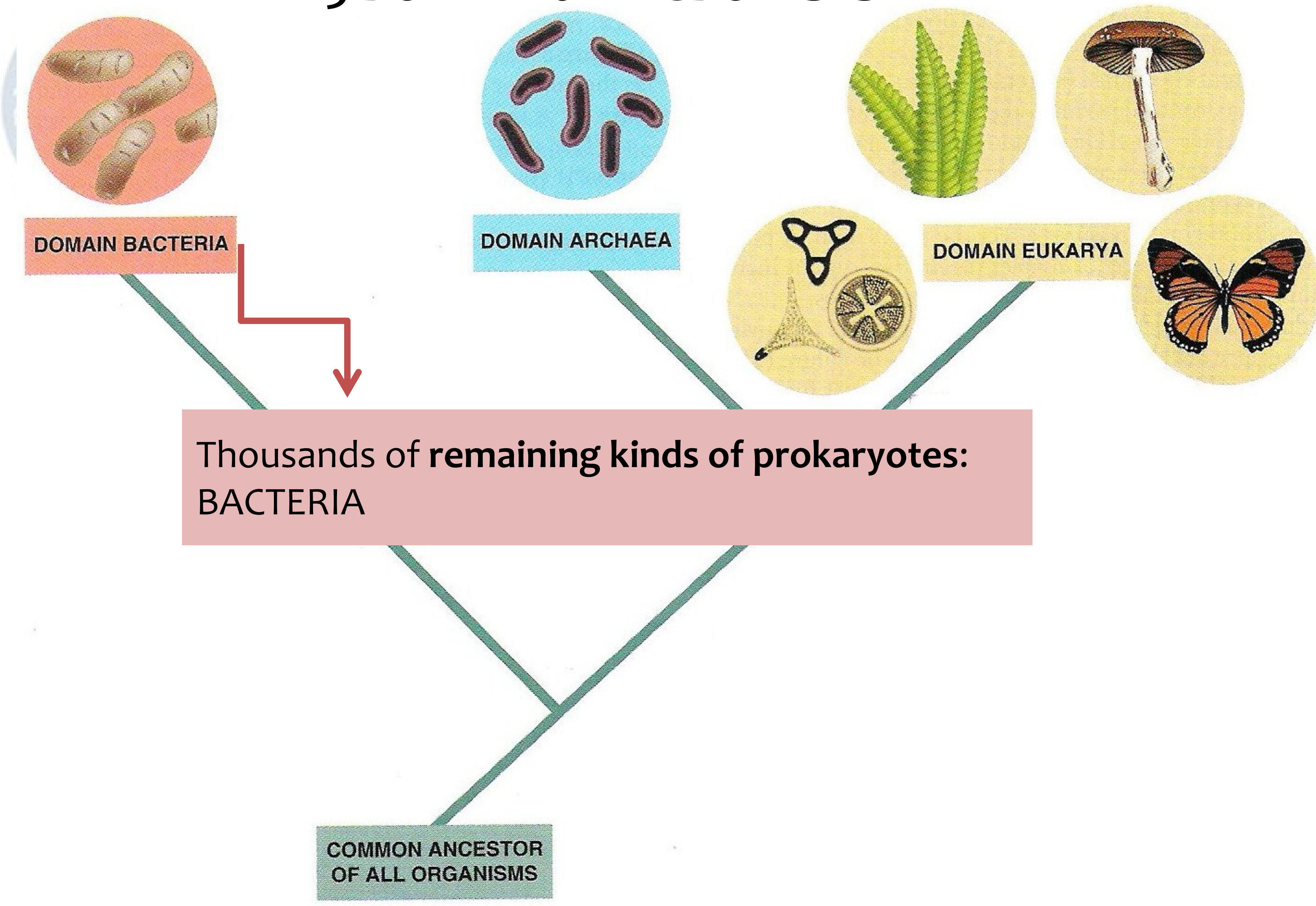
3-DOMAIN 6-KINGDOM SYSTEM



Frequently live in oxygen-deficient environments
Often adapted to harsh conditions

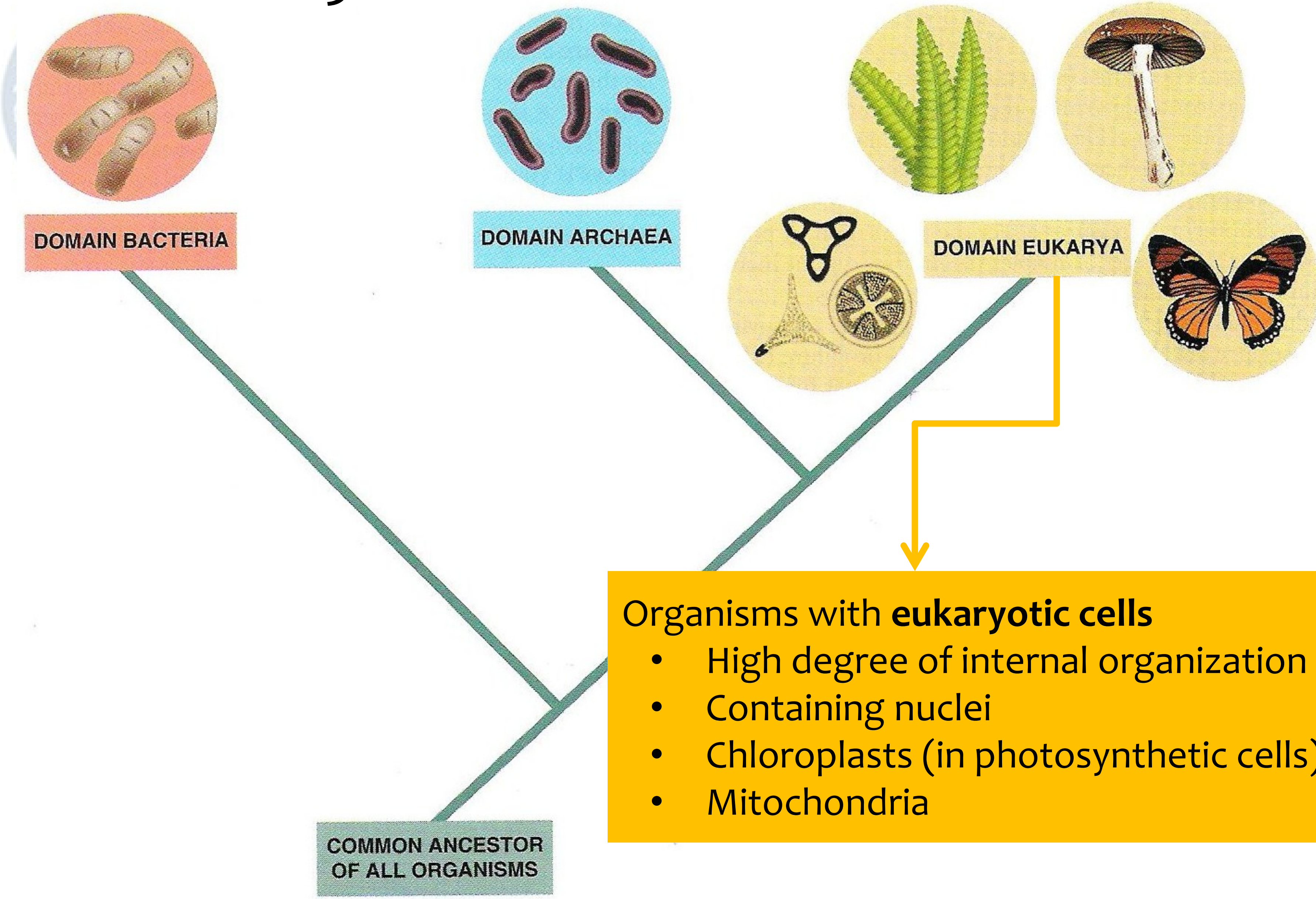
- Hot springs
- Salt ponds
- Hydrothermal vents

3-DOMAIN 6-KINGDOM SYSTEM



Thousands of **remaining kinds of prokaryotes:** BACTERIA

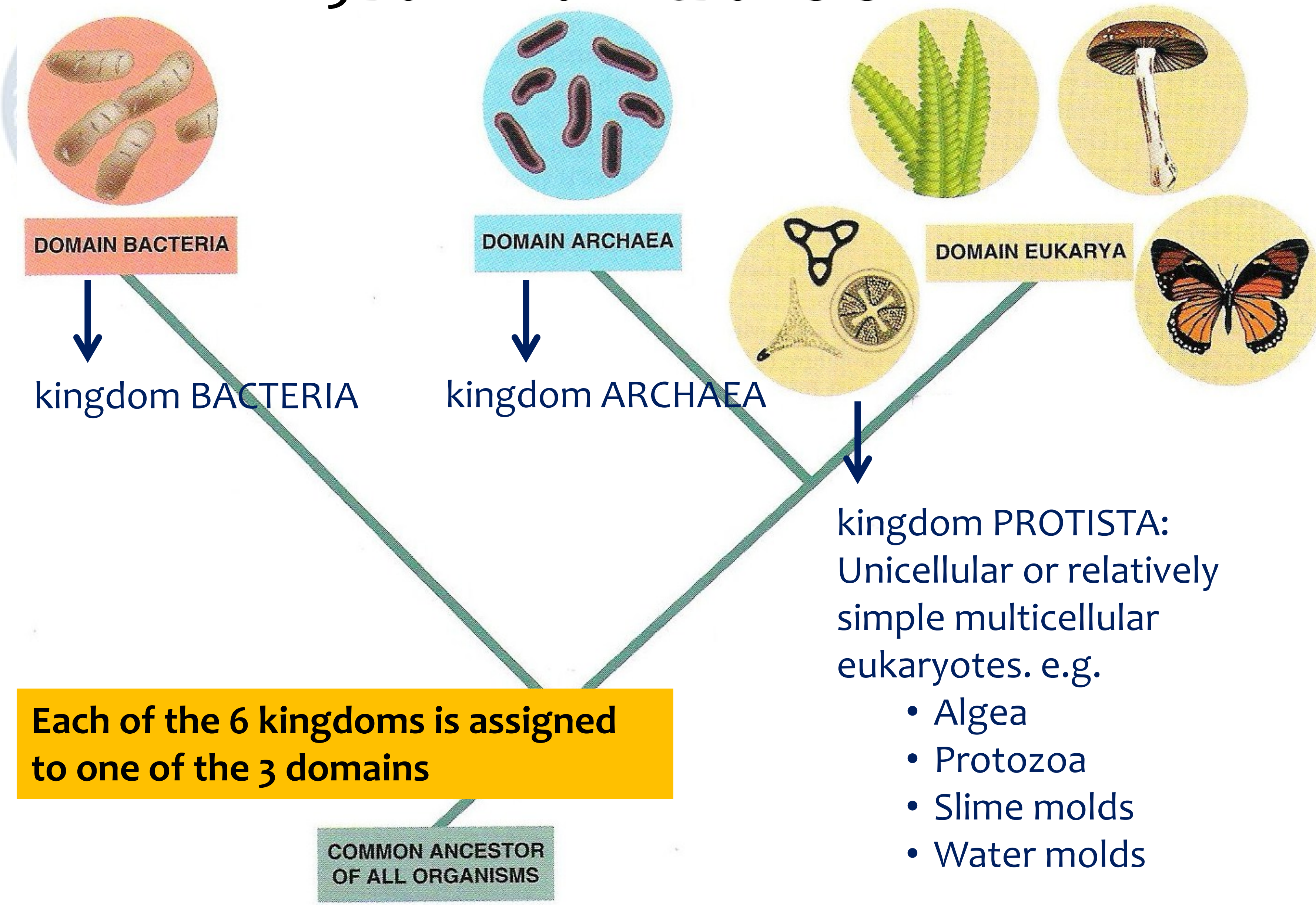
3-DOMAIN 6-KINGDOM SYSTEM



Organisms with **eukaryotic cells**

- High degree of internal organization
- Containing nuclei
- Chloroplasts (in photosynthetic cells)
- Mitochondria

3-DOMAIN 6-KINGDOM SYSTEM



kingdom BACTERIA

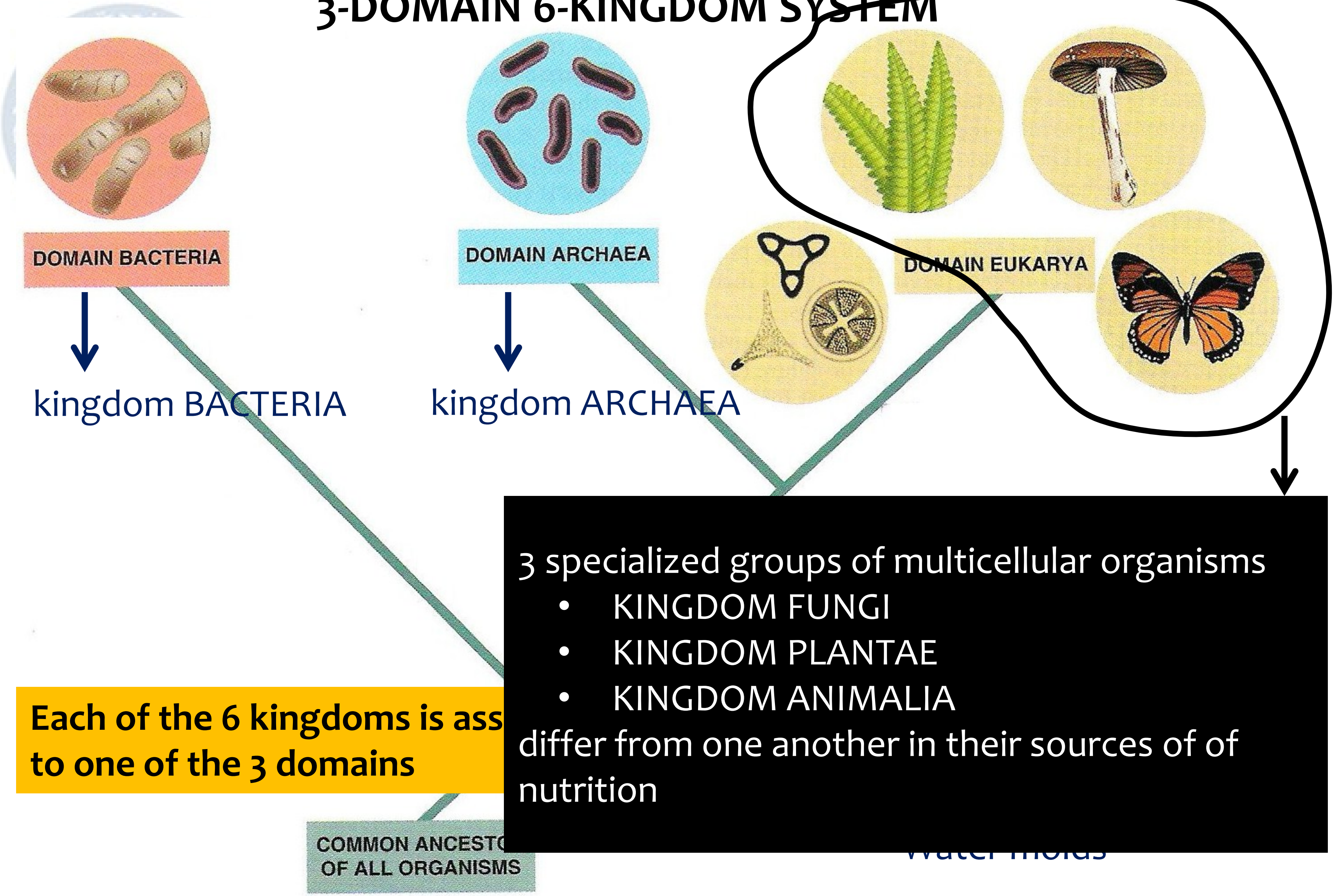
kingdom ARCHAEA

kingdom PROTISTA: Unicellular or relatively simple multicellular eukaryotes. e.g.

- Algea
- Protozoa
- Slime molds
- Water molds

Each of the 6 kingdoms is assigned to one of the 3 domains

3-DOMAIN 6-KINGDOM SYSTEM



kingdom BACTERIA

kingdom ARCHAEA

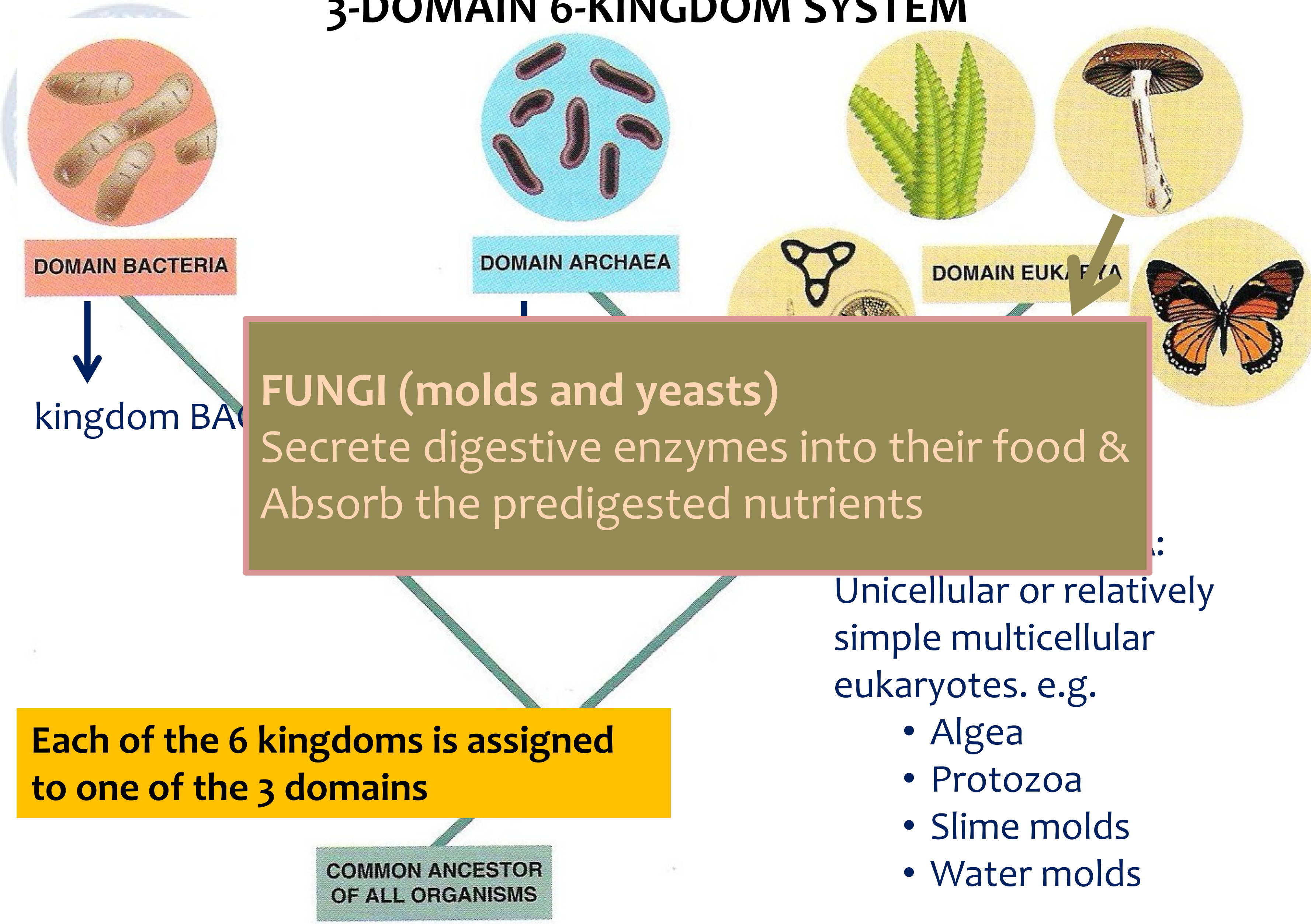
3 specialized groups of multicellular organisms

- KINGDOM FUNGI
- KINGDOM PLANTAE
- KINGDOM ANIMALIA

differ from one another in their sources of of nutrition

Each of the 6 kingdoms is ass to one of the 3 domains

3-DOMAIN 6-KINGDOM SYSTEM



kingdom BA

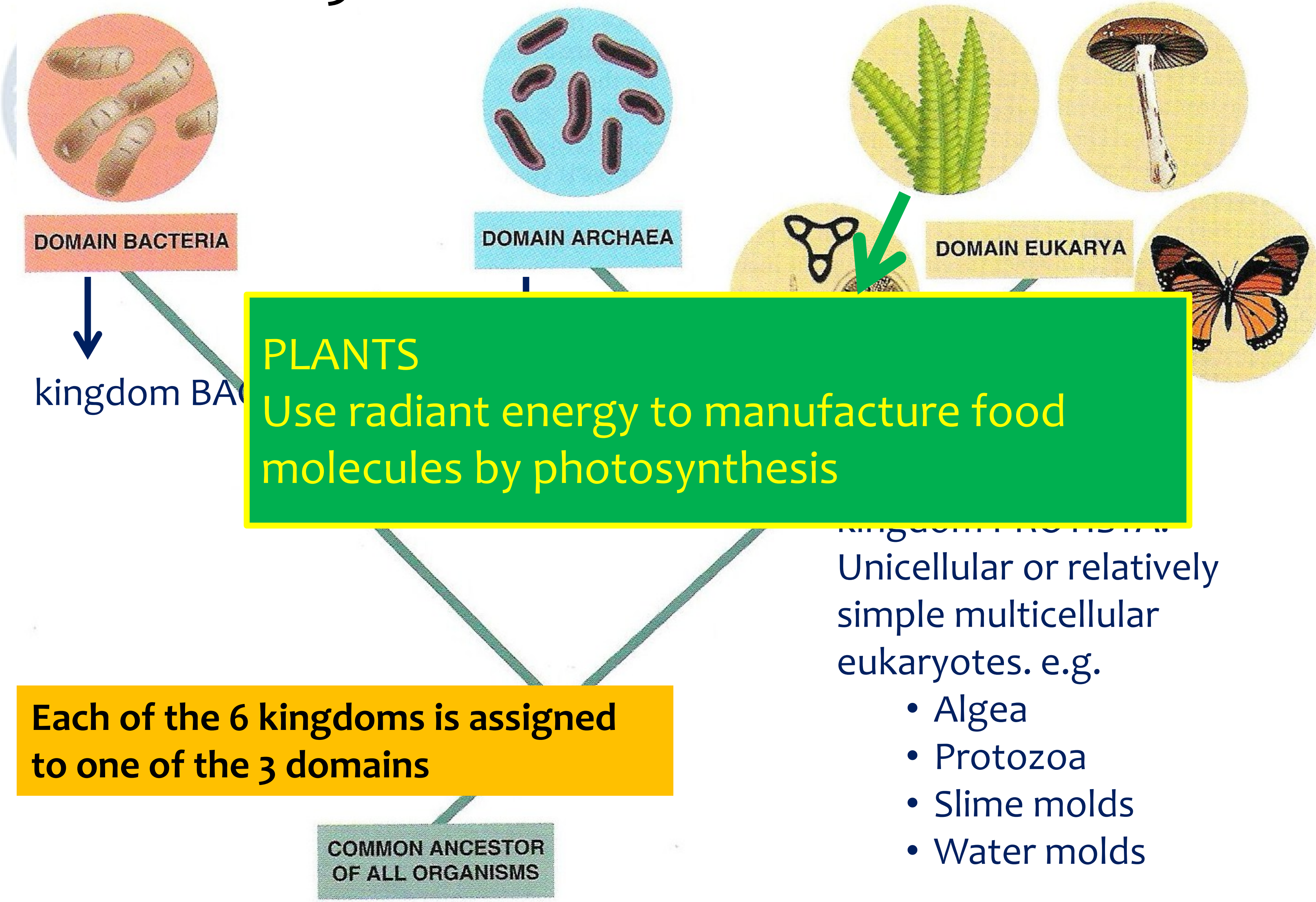
FUNGI (molds and yeasts)
Secrete digestive enzymes into their food &
Absorb the predigested nutrients

Unicellular or relatively simple multicellular eukaryotes. e.g.

- Algea
- Protozoa
- Slime molds
- Water molds

Each of the 6 kingdoms is assigned to one of the 3 domains

3-DOMAIN 6-KINGDOM SYSTEM



kingdom BA

PLANTS
Use radiant energy to manufacture food molecules by photosynthesis

Unicellular or relatively simple multicellular eukaryotes. e.g.

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- Protozoa
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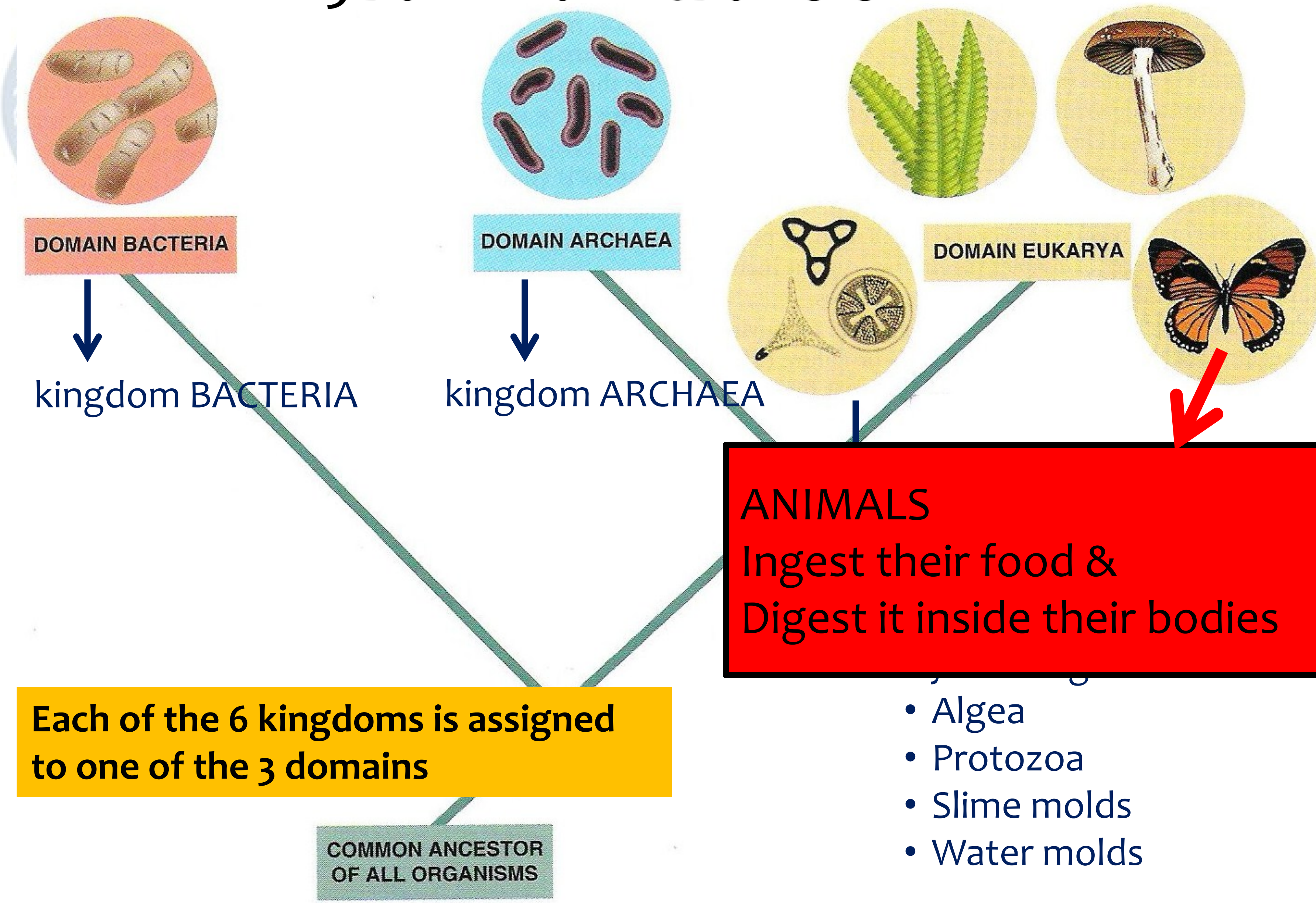
- Water molds

Each of the 6 kingdoms is assigned to one of the 3 domains

3-DOMAIN 6-KINGDOM SYSTEM



kingdom BACTERIA

kingdom ARCHAEA

ANIMALS
Ingest their food &
Digest it inside their bodies

- Algea
- Protozoa
- Slime molds
- Water molds

Each of the 6 kingdoms is assigned to one of the 3 domains

Evolution: How Populations Change Over Time

EVOLUTION OF BIOLOGICAL DIVERSITY: THE DOMAINS AND KINGDOMS OF LIFE

3-DOMAIN 6-KINGDOM SYSTEM is a definite improvement over **2-KINGDOM SYSTEM**

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but is not perfect:

Concerns are about the **KINGDOM PROTISTA**

Includes some organisms that may be more closely related to the members of other eukaryotic kingdoms than to certain protists

e.g. GREEN ALGAE: are protists similar to plants but are closely related to other protists, such as slime molds and brown algae

Principles of Population Ecology

Population
A group of individuals of the same species that live in the same geographic area at the same time.

Populations exhibit characteristics distinct from those of the individuals that comprise them.

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Features characteristics of populations but not of individuals:

- Population density
- Birth rate
- Death rate
- Growth rate
- Age structure

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Population Ecology:

- Branch of biology
- Deals with the numbers of a particular species found in an area
- How those numbers change over time?
- Why those numbers change over time?
- Or how/why those numbers remain fixed over time?

Principles of Population Ecology

Population Ecologists:

Study how a population responds to its environment, such as

- How individuals in a population compete for food and other resources?
- How predation affects the population?
- How diseases affect the population?
- How other environmental pressures affect the population?

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Principles of Population Ecology

POPULATION DENSITY

Size of a population tells us relatively little

is meaningful only when the boundaries of the population are defined

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consider the difference between:

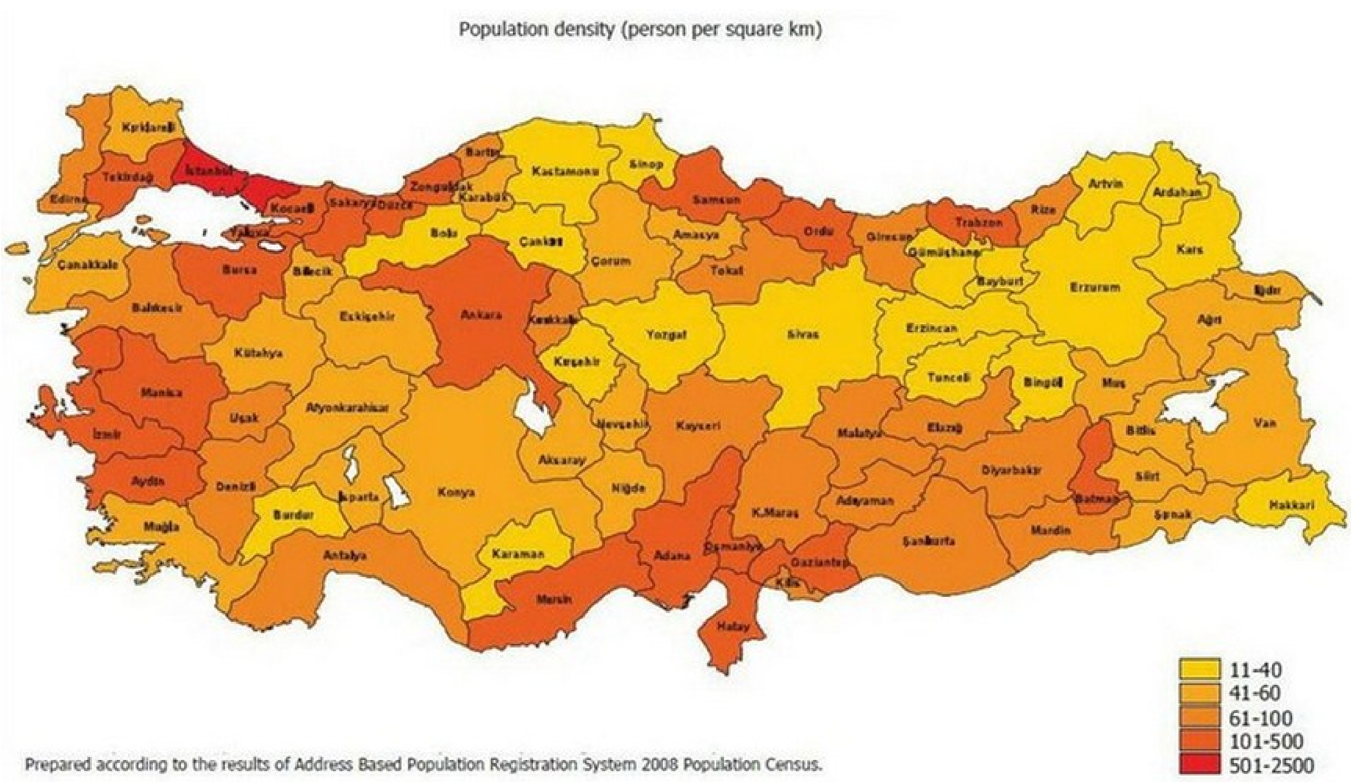
- 1000 mice in 1000 hectares &
- 1000 mice in 1 hectare!

Population Density
The number of individuals of a species per unit area or volume at a given time.

Principles of Population Ecology

POPULATION DENSITY

External factors in the environment determine population density to a large extent



Principles of Population Ecology

HOW DO POPULATIONS CHANGE IN SIZE?

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Populations whether they are sunflowers, eagles, or humans, **change over time**.

On a global scale this change is due to 2 factors:

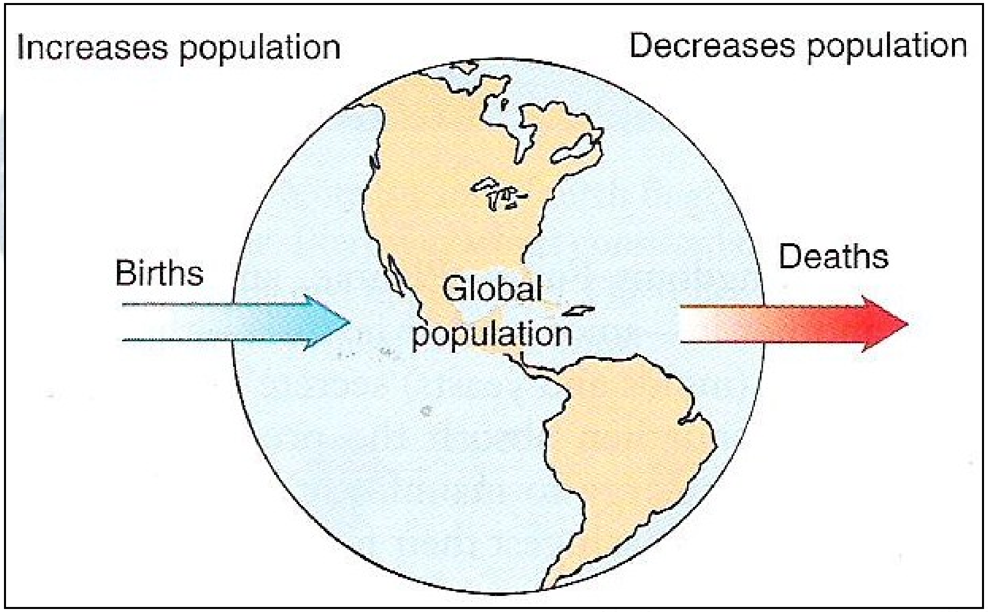
- The rate at which individuals produce offspring (THE BIRTH RATE)
- The rate at which organisms die (THE DEATH RATE)

In humans:

the birth rate (*b*) number of births per 1000 people per year

the death rate (*d*) number of deaths per 1000 people per year

Growth rate (*r*) $r = b - d$



On a **global scale**, the change in a population is due to the number of births and deaths

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Growth rate (r):

The rate of change of a population's size, expressed in percent per year. Also called natural increase in human populations.

Example

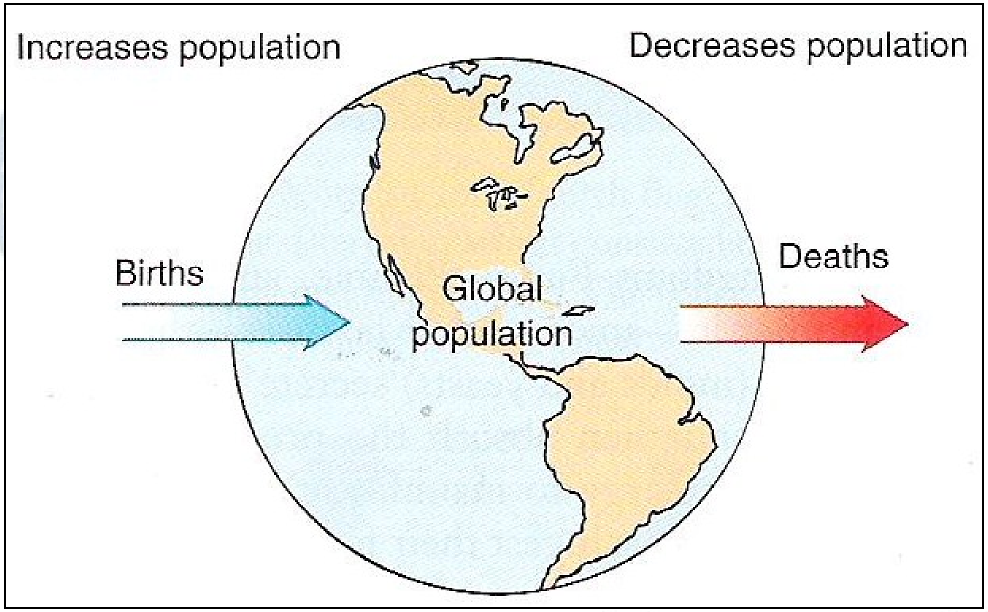
Human population: 10,000

200 births per year ⟶ 20 births per 1000 people

100 deaths per year ⟶ 10 deaths per 1000 people

$$r = \underbrace{20/1000}_{b} - \underbrace{10/1000}_{d}$$

$$r = 0.02 - 0.01 = 0.01, or\ 1\%\ per\ year$$



On a **global scale**, the change in a population is due to the number of births and deaths

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Growth rate (*r*):

r is a positive value if individuals in the population are born faster than they die, and population size increases

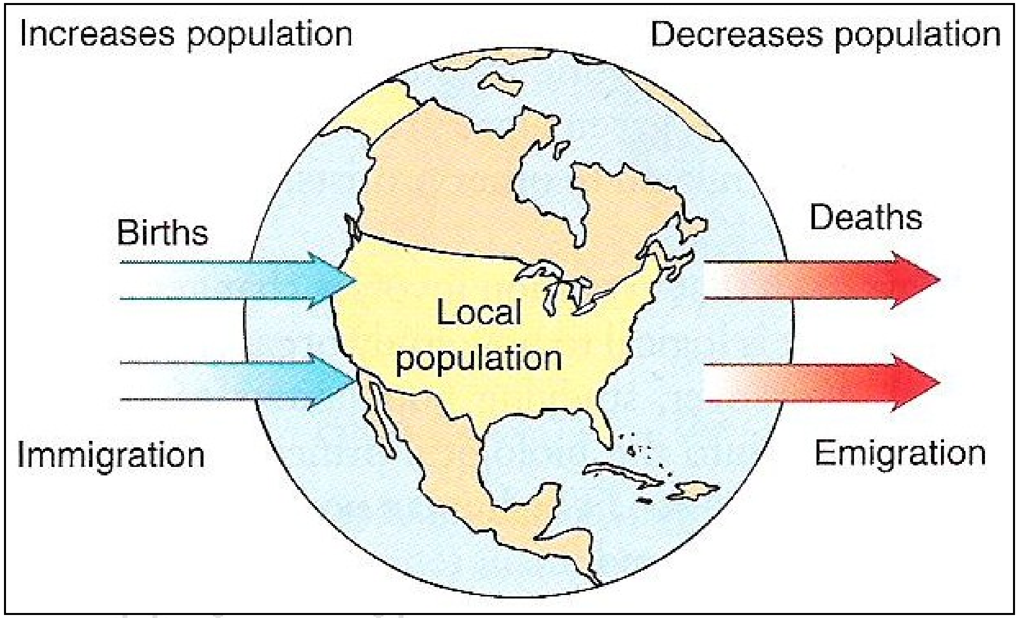
r is a negative value if individuals die faster than they are born, and population size decreases

In **local populations**:

e.g. the population of the United States, the number of

- Births
- Deaths
- Immigrants
- Emigrants

affects population size.



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Changes in populations on a local scale:

Consider **dispersal**, or *movement from one region or country to another* in addition to birth & death rates

In **local populations:**

e.g. the population of the United States, the number of

- Births
- Deaths
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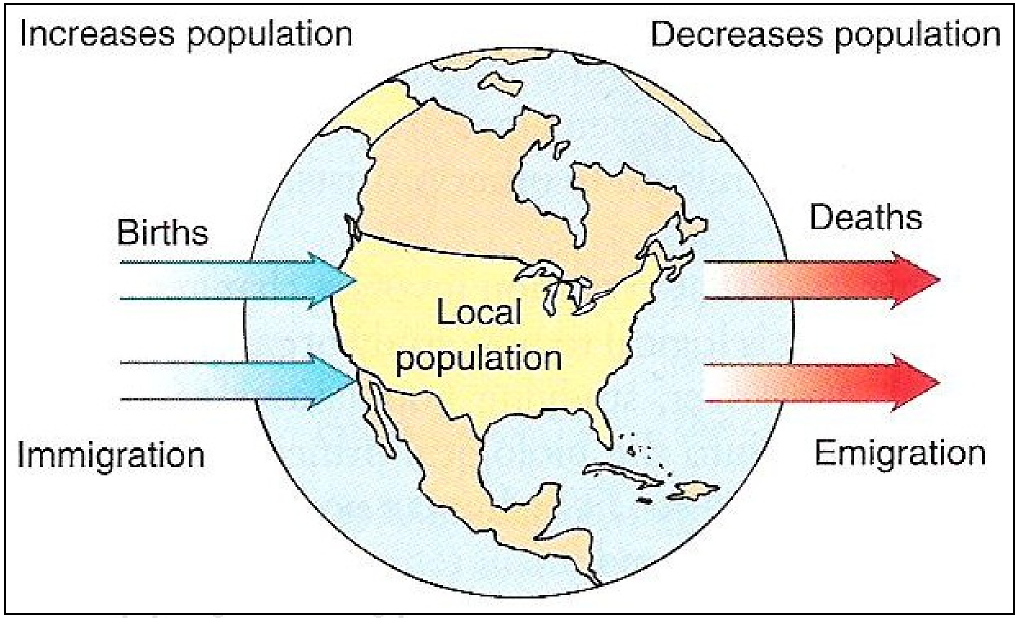
- Emigrants

affects population size.



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2 types of dispersal

IMMIGRATION (i)	EMIGRATION (e)
Individuals enter a population & increase its size	Individuals leave a population & decrease its size

Growth rate (r)

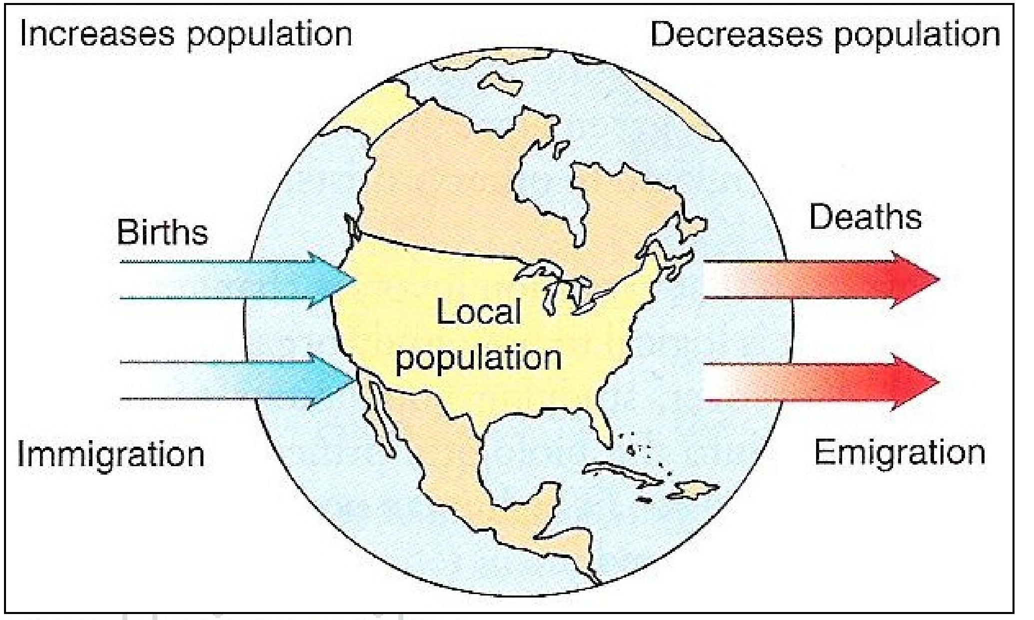
$$r = (b - d) + (i - e)$$

In **local populations**:

e.g. the population of the United States, the number of

- Births
- Deaths
- Immigrants
- Emigrants

affects population size.



<u>Example</u>

Human population: 10,000

100 births per year

50 deaths per year

10 immigrants per year

100 emigrants per year

r = ?

Is this population increasing or decreasing in size?

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Principles of Population Ecology

MAXIMUM POPULATION GROWTH

The maximum rate that a population could increase under ideal conditions is its **intrinsic rate of increase** (also called ***biotic potential***)

The exponential growth of a population that occurs under ideal conditions

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Different species → different intrinsic rate of increase

A particular species has a large or small intrinsic rate of increase?

- Age at which reproduction begins
- The fraction of the life span during which an individual can reproduce
- The number of reproductive periods per lifetime
- Number of offspring produced during each period of reproduction

life history characteristics

Principles of Population Ecology

MAXIMUM POPULATION GROWTH

Generally,

Larger organisms, *e.g. blue whales, elephants* *have the smallest intrinsic rates of increase*	**Smaller organisms**, *e.g. microorganisms* greatest intrinsic rates of increase

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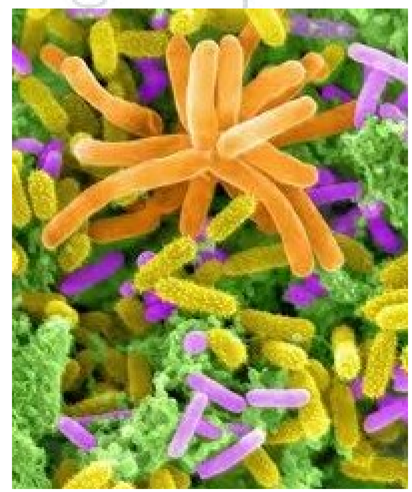
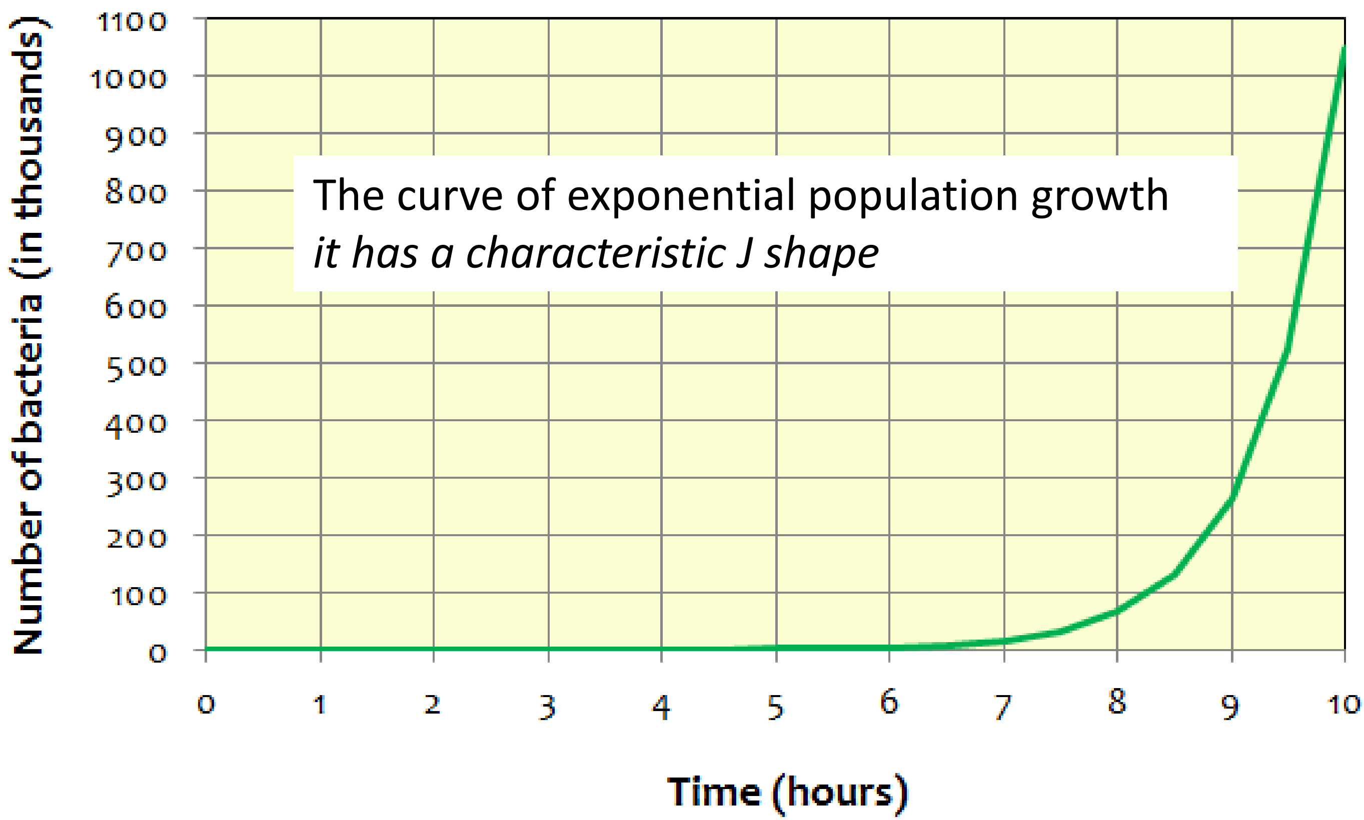


Time (hours)	Number of bacteria
0	1
0.5	2
1.0	4
1.5	8
2.0	16
2.5	32
3.0	64
3.5	128
4.0	256
4.5	512
5.0	1,024
5.5	2,048
6.0	4,096
6.5	8,192
7.0	16,384
7.5	32,768
8.0	65,536
8.5	131,072
9.0	262,144
9.5	524,288
10.0	1,048,576

Certain bacteria reproduce by dividing in half every 30 minutes under **ideal conditions**

an environment with unlimited resources

A single bacterium would increase to a population of more than 1 million in just 10 hours! (> 1 billion in 15 hours!)



Principles of Population Ecology

MAXIMUM POPULATION GROWTH

Exponential population growth
The accelerating population growth that occurs when optimal conditions allow a constant reproductive rate over a period of time.

When a population grows exponentially, the larger the population gets, the faster it grows.