1 EVPP 110 Lecture
Dr. Largen - Fall 2002

**Life: Origin, Characteristics, Early Cells, Organization, Classification**

# 2 The origin of life

Definitions of “origin” and “life”

*from*

Webster’s Seventh New Collegiate Dictionary

3 **or - i - gin ** *noun*

1 **:** ancestry, parentage

2 **:** rise, beginning, or derivation from a source

3 **:** the point at which something **begins its course or existence**

4 **: applies to the things or persons from which something is ultimately derived and often to the point where something springs into being**

4 **life ** *noun*

1 a **: the quality that distinguishes a vital and functional being from a dead body or purely chemical matter**

1 b **: the state of a material complex or individual characterized by the capacity to perform certain functional activities including metabolism, growth and reproduction**

5 The origin of life

- ✓Key characteristics shared by living things
  - what is life?
- ✓Many ideas about the origin of life
  - ideas about the origin of life
  - what the early earth was like
  - testing the spontaneous origin hypothesis
- ✓The first cells
  - origin of cells
  - the earliest cells - bacteria
- ✓The first eukaryotic cells
- ✓The kingdoms of life

# 6 Ideas about the origin of life

7 ☐ Ideas about the origin of life

✓There are many ideas about the origin of life

– ideas about the origin of life

• can't definitively answer question of how life originated

– its impossible to go back in time and observe life's beginnings

– some questions about life's origins can be answered from evidence in rocks

– other questions cannot be answered at this time

• in general, there are **three possible explanations for the origin of life**

8 ☐ Ideas about the origin of life

✓ideas about the origin of life

– **three possible explanations for the origin of life**

• **special creation**

• **extraterrestrial origin**

• **spontaneous origin**

9 ☐ **Three possible explanations for the origin of life**

✓**special creation**

– the hypothesis that life forms were put on earth by supernatural or divine forces

• hypothesis of divine creation is at the core of most major religions

– oldest and most widely accepted hypothesis

– considered an "unscientific" explanation

• because it cannot be tested and potentially disproved

– assumes forces operating in the past are different than those operating today

10 ☐ **Three possible explanations for the origin of life**

✓**extraterrestrial origin**

– hypothesis that life did not originate on earth but was carried to earth by meteors or cosmic dust as an extraterrestrial "infection"

– cannot be rejected based on evidence currently available to science

• recent discovery of possible fossils in Mars rocks

• recent discovery of liquid water under surface of Jupiter's ice-shrouded moon Europa

– however, also considered an "unscientific" explanation because it cannot be tested and potentially disproved

11 ☐ **Three possible explanations for the origin of life**

✓**spontaneous origin**

– the hypothesis that life evolved from inanimate matter, as associations among molecules became more and more complex

• in this view, the force leading to life was selection

– as changes in molecules increased their stability and caused them to persist longer, these molecules could initiate more and more complex associations

• this culminated in the evolution of cells

12 ☐ **Three possible explanations for the origin of life**

✓**spontaneous origin**

– this view is not definitely the correct one

– this view does not preclude the other two possibilities

- that a divine entity may have acted via evolution
- that life may have infected the earth from some other world and then evolved

13 **Three possible explanations for the origin of life**

✓**spontaneous origin**

– this view is considered the only “scientific” explanation of the three because it is the only one that can be tested and potentially disproved
- as such, it is the only explanation to be focused on in this text and in this course

14 **Three possible explanations for the origin of life**

✓**spontaneous origin**

– the goal is attempting to understand whether
- the forces of evolution could have led to the origin of life and, if so
- how might the process have occurred

# 15 What is Life?

## 16 What is Life?

✓What is **life**?

– What qualifies something as "living"?

– must distinguish between *necessary* and *sufficient* criteria
- *necessary* criteria
  – possessed by all life
- *sufficient* criteria
  – possessed only by life

## 17 What is Life?

✓What is **life**?

– four possible criteria of life
- movement
- sensitivity (responding to stimuli)
- death
- complexity

## 18 What is Life?

✓four possible criteria of life

– movement
- not necessary
  – not all living plants and animals move
- not sufficient
  – non-living clouds do move

– sensitivity (responding to stimuli)
- not necessary
  – kicking a redwood tree
- not sufficient
  – non-living street light w/ photo cell responds to light

19 What is Life?

✓four possible criteria of life

- death
  - necessary
    - all living things die
  - not good criterion because of circular definition
- complexity
  - necessary
    - all living things possess complexity
  - not sufficient
    - many non-living things, like computers, all possess complexity

# 20 All living things share key characteristics

21 All living things share key characteristics

✓All organisms on earth exhibit these 7 fundamental properties

- **cellular organization**
- **sensitivity**
- **growth**
- **development**
- **reproduction**
- **regulation**
- **homeostasis**
- **heredity**

22 All living things share key characteristics

✓**cellular organization**

- all organisms consist of one or more **cells**
  - complex, organized assemblages of molecules enclosed within membranes

✓**sensitivity**

- all organisms respond to stimuli
- not all organisms respond to stimuli in the same way

23 All living things share key characteristics

✓**growth**

- all living things assimilate energy and use it to grow via a process called **metabolism**
  - all life on earth is based upon the transfer of the energy in covalent bonds
    - resulting from the ability of plants, algae and some bacteria to carry out the process of photosynthesis
      - » in which carbohydrates, with energy-storing covalent carbon-carbon bonds, are created from $CO_2$ and $H_2O$ using energy from the sun

24 All living things share key characteristics

✓**development**

– multi-cellular organisms undergo systematic, gene-directed changes as they grow and mature

## 25 All living things share key characteristics

✓**reproduction**

– all living things reproduce, passing on traits from one generation to the next

– no organism lives for ever, as far as we know, although some organisms can live for a very long time

– since all organisms die, ongoing life is not possible without reproduction

## 26 All living things share key characteristics

✓**regulation**

– all organisms have regulatory mechanisms that coordinate internal processes

✓**homeostasis**

– all living things maintain relatively constant internal conditions, different from their environment

## 27 All living things share key characteristics

✓**heredity**

– all organisms on earth possess a genetic system that is based on the replication of a long, complex molecule called **DNA**

– this mechanism allows for adaptation and evolution over time and for the distinguishing characteristics of living things

# 28 What was the early earth like?

## 29 What was the early earth like?

✓exact composition of early earth and its atmosphere is not agreed upon by all scientists

✓but **some fundamental characteristics** are agreed upon

- **reducing atmosphere**
- **high temperatures**

## 30 What was the early earth like?

✓**some fundamental characteristics**

– **reducing atmosphere**

- early atmosphere contained
  - principally $CO_2$ and nitrogen gas
  - significant amounts of water
  - H atoms bonded to other light elements such as S, N, and C
  - hydrogen gas
  - little, if any, oxygen gas
  - no layer of ozone ($O_3$) to protect from ultraviolet light

## 31 What was the early earth like?

✓**some fundamental characteristics**

– **reducing atmosphere**
  - such an atmosphere called “reducing” atmosphere due to ample availability of hydrogen atoms and their associated electrons
    – takes less energy than today to form the C-rich molecules from which life evolved
  - today’s atmosphere is considered an “oxidizing” atmosphere, which contains app. 21% oxygen
    – in today’s oxidizing atmosphere, the spontaneous formation of complex carbon molecules cannot occur

32 ## What was the early earth like?

✓**some fundamental characteristics**

– **high temperatures**
  - between 4.6 and 3.8 billion years ago the surface of the earth was kept molten hot as a result of bombardment from rubble from the forming solar system
  - around 3.8 billion years ago the bombardment stopped, temperatures dropped, ocean temperature was 49 to 88 °C (120-190°F)
  - between 3.8 and 3.5 billion years ago life appeared

33

# 34 Testing the spontaneous origin hypothesis

## 35 Testing the spontaneous origin hypothesis

✓What kinds of molecules might have been produced on the early earth?

– the **Miller-Urey** experiment attempted to answer this question

## 36 Testing the spontaneous origin hypothesis

✓the **Miller-Urey** experiment attempted to answer this question

– by repeating the process
  - assemble an atmosphere similar to that thought to have existed
  - exclude gaseous oxygen from the atmosphere
  - place this atmosphere over liquid water
  - maintain this mixture at a temperature somewhat below 100 °C
  - simulate lightning by bombarding the mixture with energy in the form of sparks

37

## 38 Testing the spontaneous origin hypothesis

✓Results of the **Miller-Urey** experiment

– w/in 1 week, 15% of C originally present as methane gas ($CH_4$) was converted into other simple C compounds such as formaldehyde and hydrogen cyanide
  - these compounds in turn combined to form molecules such as formic acid, urea, and the amino acids glycine and alanine, some of the basic building blocks of proteins

– in similar, later experiments, even the complex ring-shaped molecule adenine – a base found in DNA and RNA – was formed

39

40 # Evolution of early cells

41 ## Evolution of early cells

✓Theories about the **evolution of cells**

– the evolution of cells required early organic molecules to assemble into functional, **independent units**

- cells are essentially little bags of fluid
- every cells' content differs from the environment outside the cell
  - early cells may have floated along in an environment of "primordial soup" but its interior would have had a higher conc.of specific organic molecules

42 ## Evolution of early cells

✓Theories about the **evolution of cells**

– how did these "bags of fluid" evolve from simple organic molecules?

- most scientists believe **bubbles** were involved in this evolutionary step
  - bubbles are spherical & hollow
  - certain molecules spontaneously form bubbles in water (ex. phospholipids)
  - the structure of the bubble shields the hydrophobic regions from contact with water

43 

44 # The Earliest Cells

45 ## The Earliest Cells

✓Earliest evidence of life appears in **microfossils**

– fossilized forms of microscopic life

46 

47 ## The Earliest Cells

✓Characteristics of earliest life forms

– small (1-2 nanometers)
– single-celled
– lacked external appendages
– little evidence of internal structure
– did not have nucleus
– in general, physically resembled today's **bacteria**

- organisms with this general body plan are called **prokaryotes** ("before nucleus")

48 ## The Earliest Cells

✓Bacteria

– are now divided into two groups

- archaebacteria
- eubacteria

## 49 The Earliest Cells

✓Archaebacteria

- present day organisms that differ in form and metabolism from other living things
- are found in areas sheltered from evolutionary alteration
  - unchanging habitats that resemble earth's early environment
- these living relics are the surviving representatives of the first ages of life on earth

## 50 The Earliest Cells

✓Archaebacteria

- are found in extreme environments
  - methanogens
    - exist in warm, oxygen-free environments
    - ingest $CO_2$ and H to produce methane
    - unusual lipids in their cell membranes (which aren't found anywhere else)
  - extreme halophiles (salt lovers)
  - extreme thermophiles (heat lovers)
    - boiling waters of springs & deep sea vents

## 51 The Earliest Cells

✓Eubacteria

- are the second group of bacteria
- characteristics
  - strong cell walls with peptidoglycan
  - simpler gene architecture
  - some evolved ability to photosynthesize
    - **cyanobacteria** (formerly blue-green algae)
      - » appeared ~ 3 billion years ago, contributed to increasing atmosphere oxygen concentration

## 52 The First Eukaryotic Cells

✓**Eukaryotes**

- eukaryote means "true nucleus"
- first appeared ~ 1.5 billion years ago
- are larger than bacteria
- have internal membranes, membrane-bound structures including nucleus
- they rapidly evolved to produce the diverse life forms that inhabit the earth today
- all organisms other than bacteria are eukaryotes

## 53 The First Eukaryotic Cells

✓**Endosymbiont theory**

- suggests that a critical stage in the evolution of eukaryotic cells involved symbiotic relationships with prokaryotic organisms (bacteria)
  - energy producing bacteria may have come to reside within larger bacteria, eventually evolving into mitochondria
  - photosynthetic bacteria may have come to reside within larger bacteria, eventually evolving into

chloroplasts
- flagellated bacteria may have come to reside within larger bacteria, eventually evolving into motile eukaryotes

54

## 55 The First Eukaryotic Cells

✓Support for the endosymbiont theory
- observation of many symbiotic relationships
- observation of DNA in organelles
  - many organelles have their own DNA
    - mitochondria
    - chloroplasts
    - centrioles
  - organelle DNA is remarkably similar to bacterial DNA in size and character

56

## 57 Levels of Organization of Life

✓Levels of organization of life
- non-living components of life
  - atom
  - molecule
- within cells
  - macromolecule (biological)
  - organelle
  - cell

## 58 Levels of Organization of Life

✓Levels of organization of life
- within multicellular organisms
  - tissue
  - organ
  - organ systems

## 59 Levels of Organization of Life

✓Levels of organization of life
- among organisms
  - species
  - population
  - community
  - ecosystem
  - biosphere

- ecosphere

60 Levels of Organization of Life

✓Levels of organization of life

- these levels represent a hierarchy
  - each level is built of parts at successively lower levels of organization

61

62 Evolution, Unity and Diversity

✓The diversity of life can be arranged into three domains

63 Evolution, Unity and Diversity

✓The diversity of life can be arranged into three domains

- **how we classify organisms**

64 The Classification of Organisms

✓Millions of different organisms inhabit our planet

✓To make some order of this diversity, biologists have developed a system of classification

✓**Taxonomy is** the science of classifying and naming organisms

- 300 years ago, scientists first began to develop an overall classification system for organisms

65 The Classification of Organisms

✓The binomial system

- developed by Swedish biologist, Carl Linnaeus (1707-1778)
  - he gave a two-part (binomial) name to each species

✓the names of genera (genus, singular) were the basic point of reference in classification systems

- and these names eventually came to be written in Latin

66 The Binomial System of Classification

✓A system based on a unique two-part name for each organism (hence **bi - nomial**)

- First part of name designates the genus, the second part the species
- Species name always used together with full or abbreviated genus name preceding it
- Genus is capitalized, species is not, both are underlined or italicized

67 The Binomial System of Classification

✓Examples

- Homo sapiens or H. sapiens (human)
- *Quercus alba* or *Q. alba* (white oak)

68 Taxonomic Classification is Hierarchical

- ✓The taxonomic heirarchy
  - – in the decades following Linnaeus, taxonomists began to group genera into large, more inclusive categories known as families
    - membership in these families was intended to reflect perceived relationships between the genera included
  - – the taxonomic system was eventually extended to include several, more inclusive units

69 Taxonomic Classification is Hierarchical

- ✓**Species** are grouped to form a genus
- ✓**Genera** (plural of genus) are grouped together to form a family
- ✓**Families** are grouped to form orders
- ✓**Orders** are grouped to form classes
- ✓**Classes** are grouped to form divisions (fungi, plants) or phyla (protists, animals)
- ✓**Phyla** (divisions) grouped into **kingdoms**

70 

71 The Kingdoms of Life

- ✓All organisms are grouped into a few major categories
  - – the earliest classification systems recognized only two kingdoms of living things
    - animal kingdom
    - plant kingdom
  - – as biologists discovered new organisms and learned more about existing ones, kingdoms were added in recognition of the fundamental differences being found

72 

73 Domains

- ✓ as biologists learned more about the Archaebacteria it became clear that this ancient group was very different from other living organisms
  - – to reflect these significant differences, biologists are increasingly adopting a classification system that recognizes a taxonomic level higher than kingdom
    - three domains
      - – Archaea
      - – Bacteria
      - – Eukarya

74 

75 

76 The Kingdoms of Life

- ✓How many kingdoms?
  - – most biologists now use a six-kingdom classification system first proposed by Carl

Woese of the University of Illinois

- all “life” currently classified into 6 kingdoms
  - **Archaebacteria**
  - **Eubacteria**
  - **Protista**
  - **Fungi**
  - **Plantae**
  - **Animalia**

77 The Kingdoms of Life

✓**Prokaryotic kingdoms**

– **Archaebacteria**

– **Eubacteria**

✓**Eukaryotic kingdoms**

– **Protista**

– **Fungi**

– **Plantae**

– **Animalia**

78 The Kingdoms of Life

✓**Domain Archaea**

– **Kingdom Archaebcateria**

✓**Domain Bacteria**

– **Kingdom Eubacteria**

✓**Domain Eukarya**

– **Kingdom Protista**

– **Kingdom Fungi**

– **Kingdom Plantae**

– **Kingdom Animalia**

79 Classification of the Human Being

✓**Domain:** Eukarya

✓**Kingdom:** Animalia

✓**Phylum:** Chordata

✓**Class:** Mammalia

✓**Order:** Primates

✓**Family:** Hominidae

✓**Genus:** *Homo*

✓**Species:** *sapiens*

80 Evolution, Unity and Diversity

✓Unity in diversity

– All forms of life have common features

- Life is diverse, but there are common themes that all living things exhibit

81 ☐ Evolution, Unity and Diversity

✓All forms of life have common features

– Basic characteristics of life

- order
- cellular organization
- movement
- growth and development
- reproduction
- regulation
- ability to evolve and adapt as a population

82 ☐ Evolution, Unity and Diversity

✓All forms of life have common features

– Basic characteristics of life

- order
  - complexity - high degree of organization
- cellular organization
  - cell theory
    - » sensitivity
    - » responsiveness to stimuli
    - » movement

83 ☐ Evolution, Unity and Diversity

✓All forms of life have common features

– Basic characteristics of life

- growth and development
- reproduction
- regulation
  - coordination of an organisms internal functions
    - » homeostasis
    - » metabolism
- ability to evolve and adapt as a population

84 ☐ Evolution, Unity and Diversity

✓Evolution explains the unity and diversity of life

– theory of evolution explains the unity and diversity of life

- theories are much broader in scope than hypotheses and have much greater explanatory power

85 ☐ Evolution, Unity and Diversity

✓Evolution explains the unity and diversity of life

– Darwin showed that evolution can explain the diversity of life and the underlying commonalities of life's diversity

86 Evolution, Unity and Diversity

✓Living organisms and their environments form interconnecting webs

87 Evolution, Unity and Diversity

✓Living organisms and their environments form interconnecting webs

– living organisms do not exist in isolation

– an organism's environment includes both living and non-living components

88 Evolution, Unity and Diversity

✓Living organisms and their environments form interconnecting webs

– plants, some prokaryotes and protistans make food from carbon dioxide, water and the energy of the sun

• via the process of photosynthesis

– all animals ultimately depend on these photosynthetic organisms for food

– decomposers help recycle organic matter back to photosynthetic organisms

89 Evolution, Unity and Diversity

✓Living organisms and their environments form interconnecting webs

– relationships among the living and non-living components of an ecosystem can be illustrated as a web

90