Cell Biology

Level: Undergraduate

Fall, 2017

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What is cell biology?

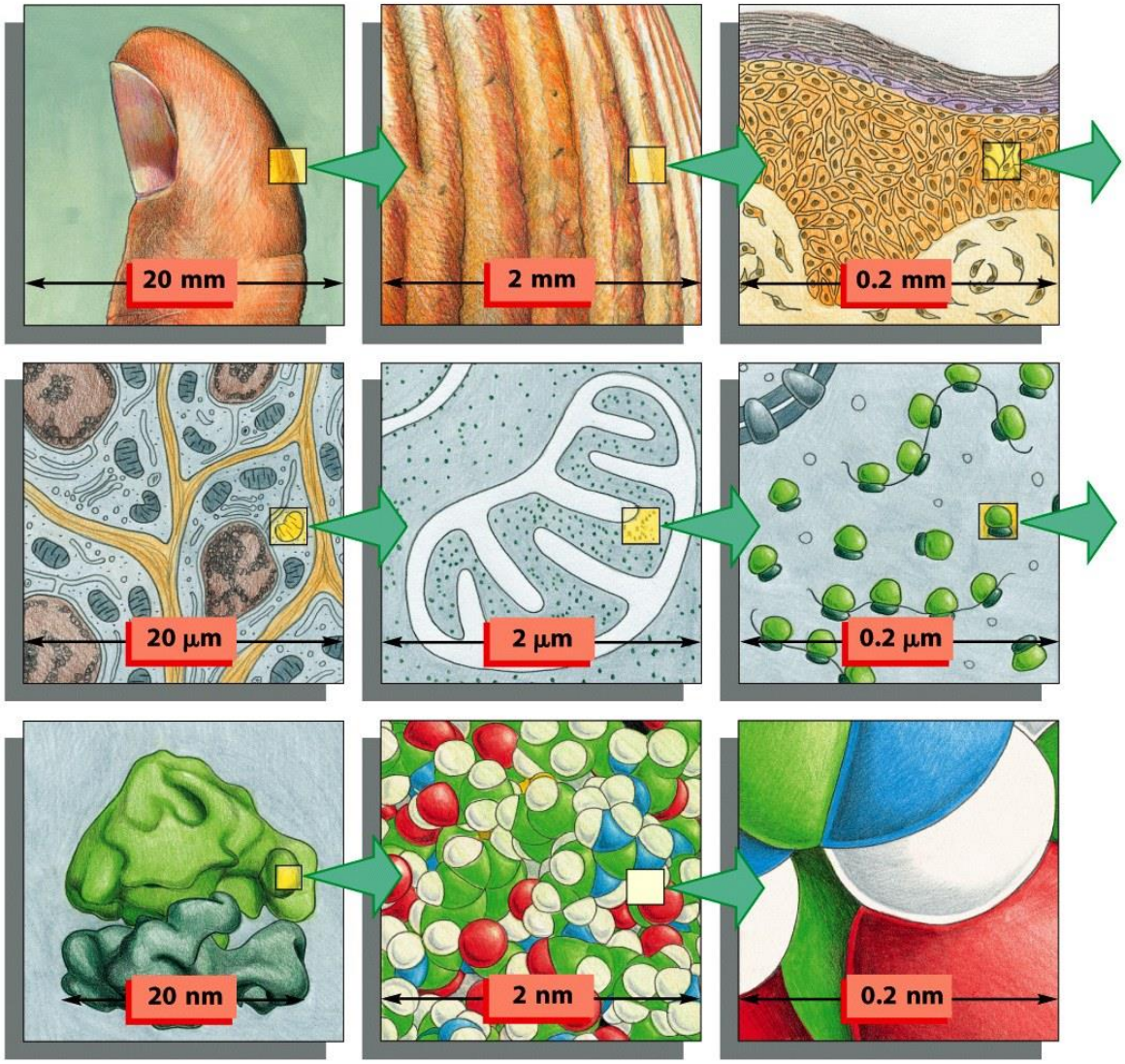


Figure 1-9 Essential Cell Biology 3/e (© Garland Science 2010)

Physiology

Cell Biology

Biochemistry

Why can Cell Biology tell us?

The mystery of longevity

Live up to 2 years old

Live up to 80 years old

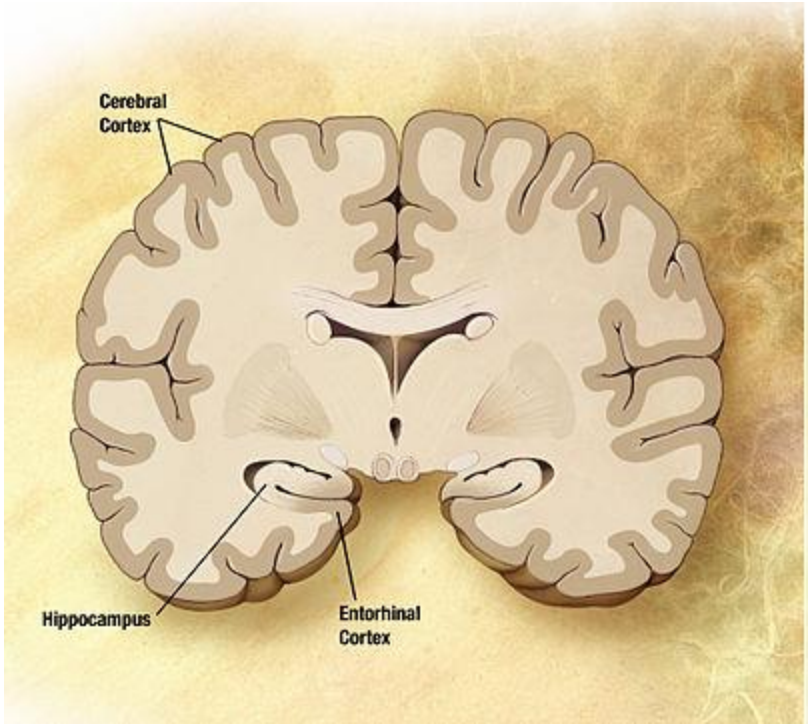
	Genome size	proteins	chromosomes
Live up to 2 years old	**3421 million bp**	**22085**	**20**
Live up to 80 years old	**3279 million bp**	**21077**	**23**

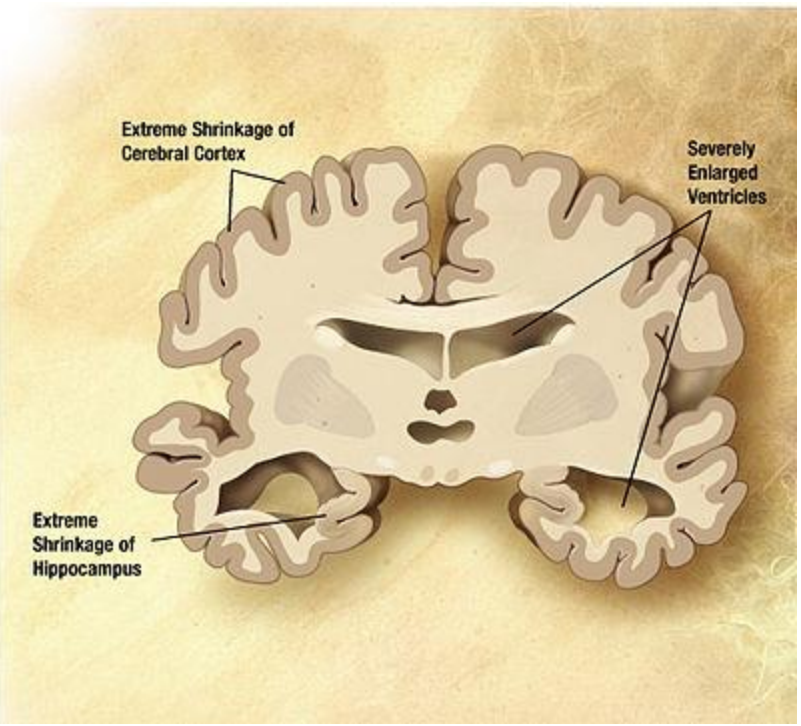
Over than 99% of human genes have homologs in mice, vice versa.

But what decides mice live a shorter life?

Why Cell Biology can tell us?

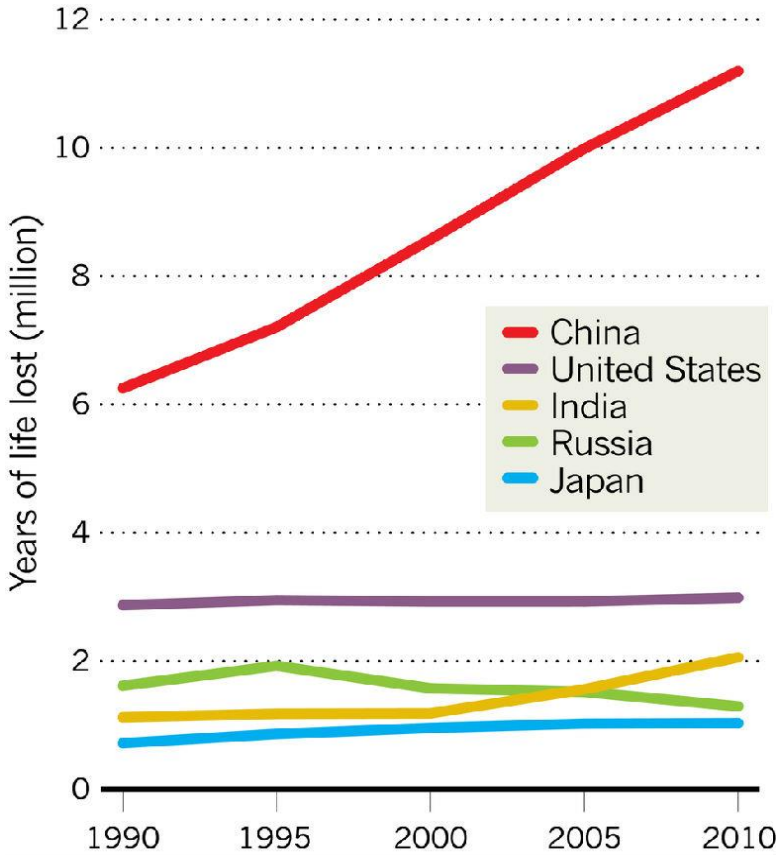
The mystery of human diseases





Cause of Alzheimer's disease remains a mystery, no cure

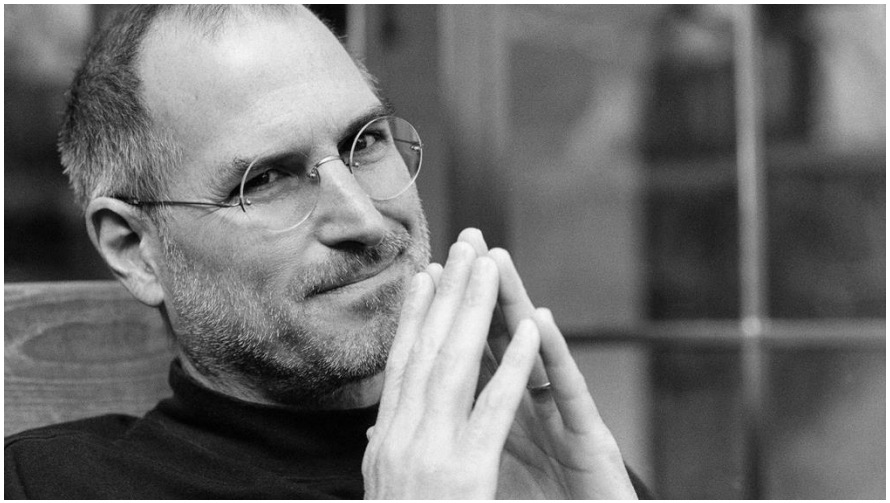
Increase in premature mortality in China



Nearly 600,000 people die from lung cancer every year in China

Why can Cell Biology tell us?

How elephants avoid cancer?



http://www.nature.com/news/how-elephants-avoid-cancer-1.18534

How can p53 protect cells from cancer progression?

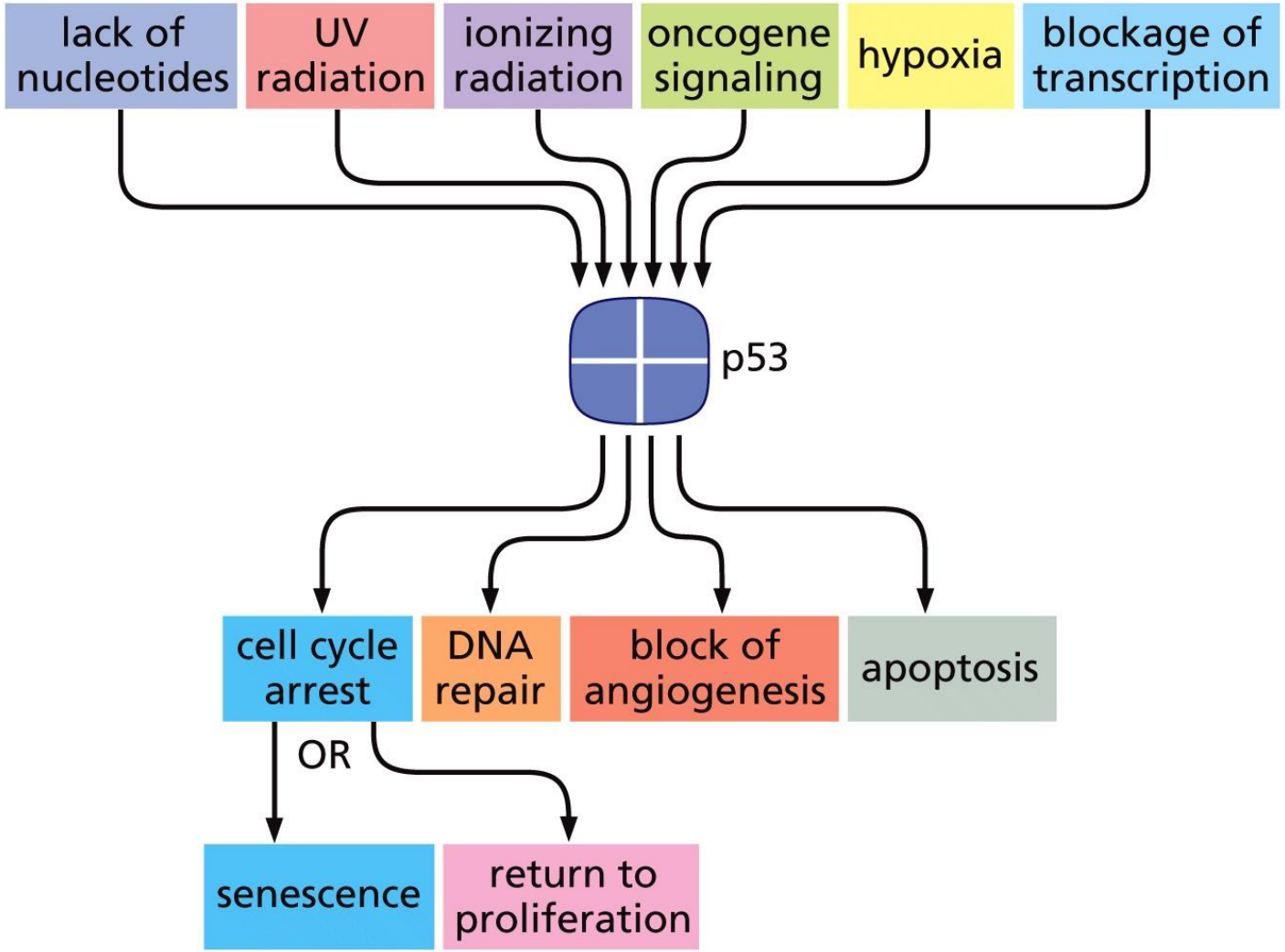


Figure 9.8 The Biology of Cancer (© Garland Science 2014)

Cell therapy

1. Tissue-specific stem cells

2. Engineered immune cells

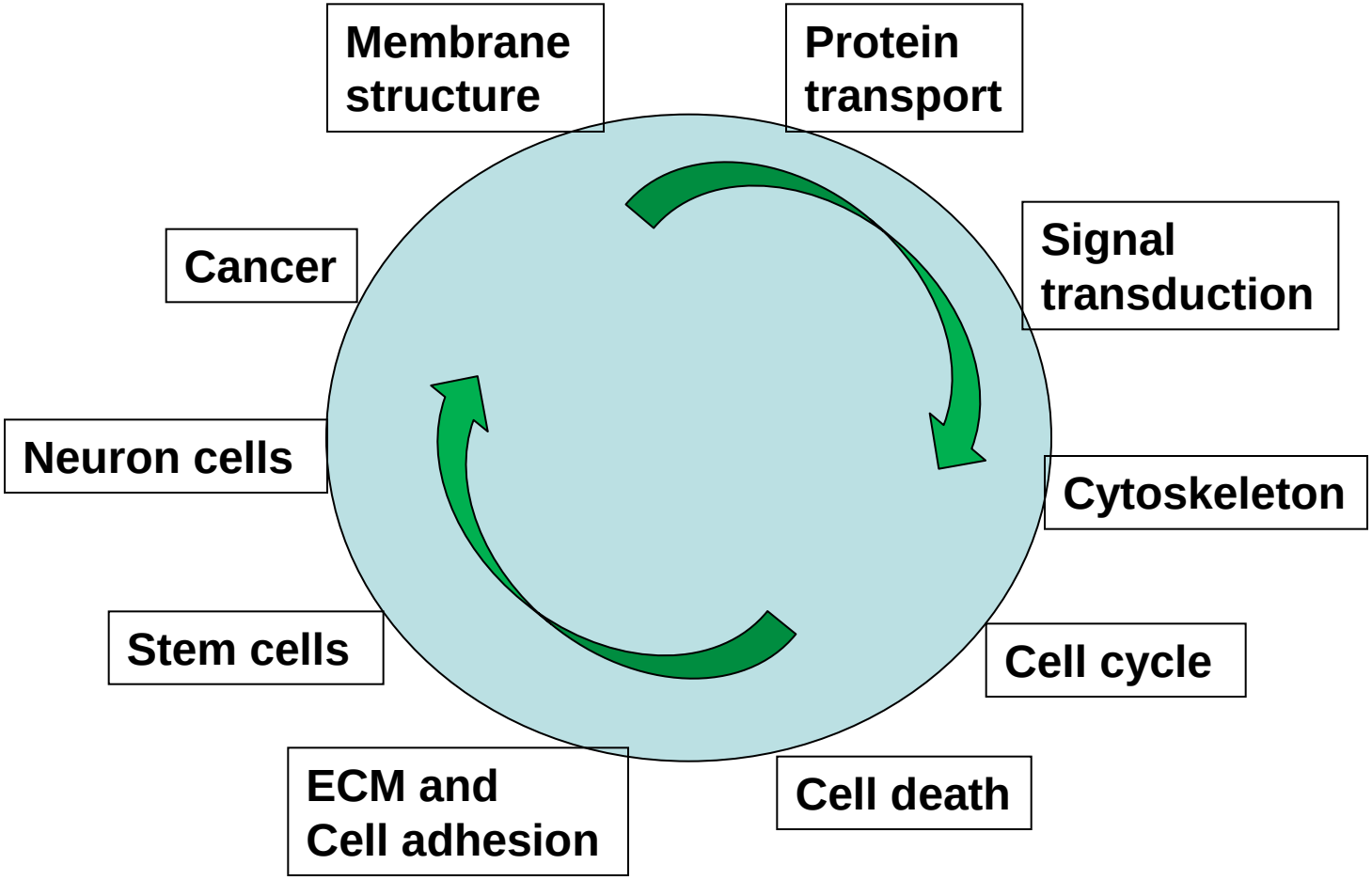
Emily Whitehead
CD19-CAR-T therapy

A case of how these cells cure ALL

03/2013, NEJM

http://emilywhitehead.com/

The structure for this course



Overview of Lecture 1

1.1 Cell theory

1.2 The difference between eukaryotic cell and prokaryotic cell

1.3 The constancy of all cells

1.4 How do cells evolved

1.5 The use of model system to study cell biology

1. 1 Discovery of cell and the Cell theory

1665

In 1665, Robert Hooke saw a network of tiny boxlike compartments that reminded him of a honeycomb. He called these little compartments "*cellulae*", a Latin term meaning little room. It is from this word we get our present-day term, cell.

Robert Hooke
1653-1703, England

In fact these are cell wall left by dead cells

~1670s

Antoni van Leeuwenhoek
1632-1723, Netherlands

As a good lensmaker, Leeuwenhoek greatly increased the resolution of lens.

Leeuwenhoek was the first to observe and describe single-celled organisms, which he originally referred to as "*animalcules*". He was also the first to record observations of muscle fibers, bacteria ,spermatozoa, and blood flow.

Actually he is the first to observe live cells

1838-1839

Original Cell Theory proposed by Matthias Shleiden(1838) and Theodor Schwann (1839)

M.J. Schleiden

German botanist (1804-1881)

Theodor Schwann

German physiologist (1810-1882)

Schwann is also famous for the discovery of nerve sheath cells : “schwann” cells.

They systematically studied the tissues of plants and animals under the Microscope, and showed：

1. cells are the building blocks of all living things.
2. All have similar structure: nucleus and membrane.

1855

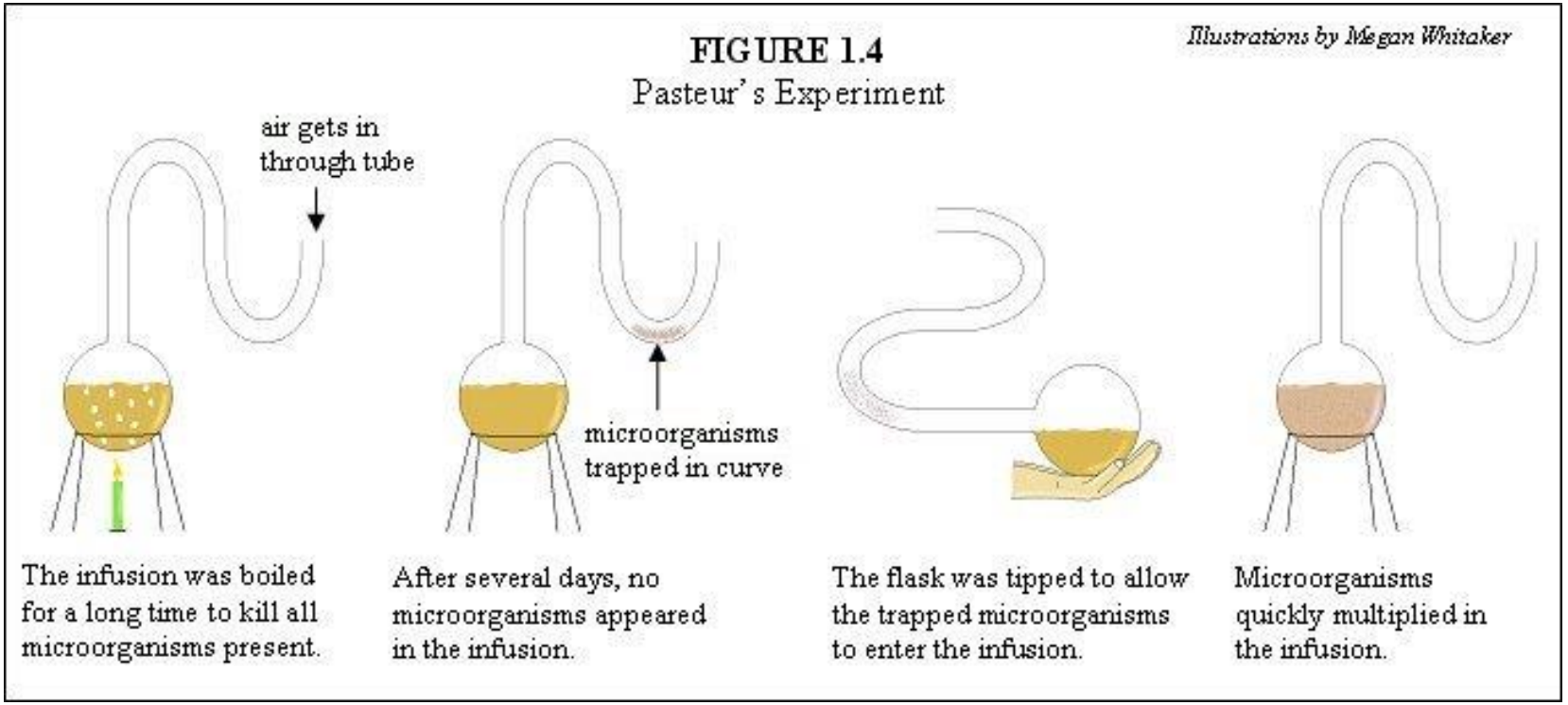
Are cells from pre-existing cells or because in instinct it has vitalism?

Rudolf Virchow (1821-1902)
German Doctor

He proposed cells are from
pre-existing cells, but no experimental proof, until...

1860s

Key experiment by Louis Pasteur to defy “vitalism”(spontaneous generation):The famous swan neck flask experiment



3. Cells only originated from an pre-existing living cell

1880

Additional proof from the observation of cell division

Eduard Strasburger in 1880

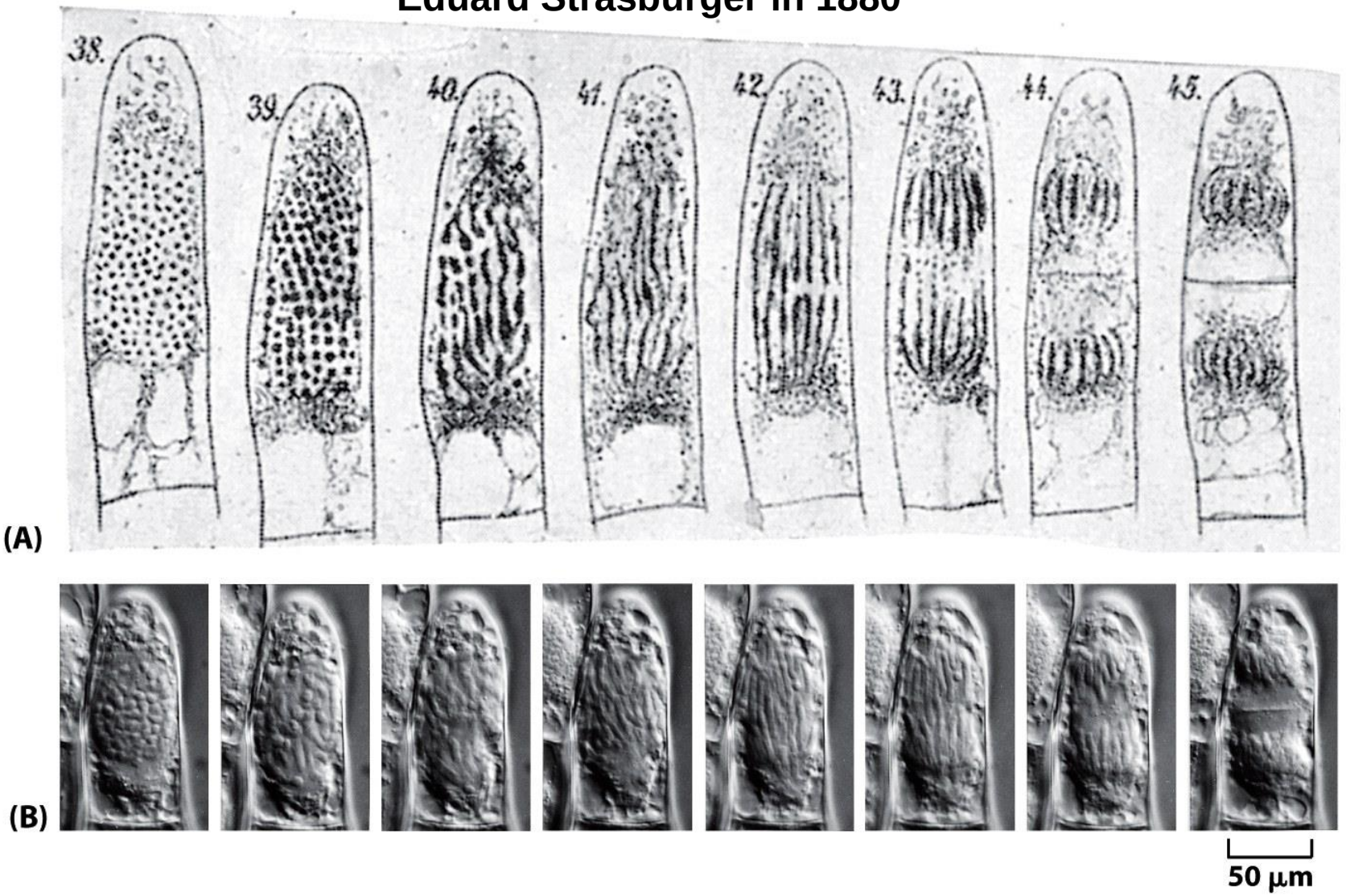


Figure 1-4 Essential Cell Biology 3/e (© Garland Science 2010)

The Cell Theory

The three tenets:

1. All living organisms are composed of one or more cells.

2.The cell is basic unit of structure and function for all organisms.

3.All cells arise only from preexisting cells by division.

1.2 The difference between prokaryotic cell and eukaryotic cell

"eu" means "true" , "good"

"karyote" means "kernel"

"pro" means "before"

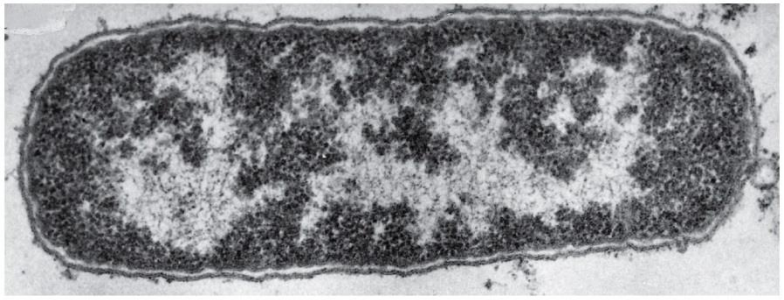


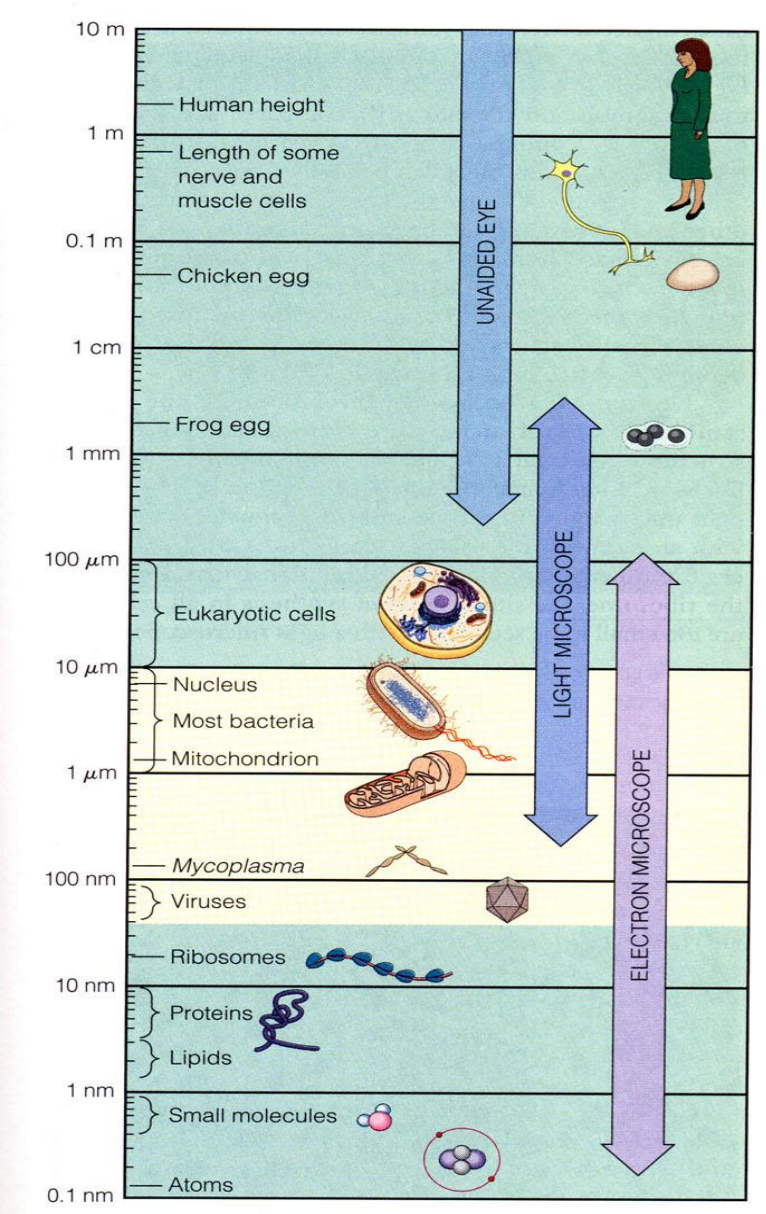
Figure 1-11 Essential Cell Biology 3/e (© Garland Science 2010)

E.coli

Most cells are small

Prokaryotic: 1-10 µm

Eukaryotic: 10-100 µm



Comparison between prokaryotic and eukaryotic cell

EUKARYOTIC Cells vs PROKARYOTIC Cells

CHARACTERISTIC	PROKARYOTES	EUKARYOTES
Size	0.2-2.0μm in diameter	10-100μm
Nucleus	x	ALL
Organelles with Phospholipid membrane	x	**ER, Golgi bodies, Lysosome mitochondrial, chloroplasts**
Glycocalyx	**capsule** (organize) **slime layer** (unorganize)	Surround some animal cells
Motility	*rotating* **Flagella** (some)	*undulated* Flagella & Cilia ("9+"2 arrangement microtubles others by *amboid action*
Flagella	some	some
Cilia	x	some
Fimbriae & Pili	some	x
Cell Wall	most, bacteria (peptidoglycan)	most: protein, cellulose, algin agar, carrageenan, silicate, glucomanna, chitin
Plasma membrane	Lacking carbs and sterols	has: glycoproteins, glycolipids, sterols
Cytosol	ALL	ALL
Inclusions	ALL	ALL
Endospores	some	x
Ribosomes	Cytoplasm (70s)	Cytoplasm (80s) Mitochondria & Chloroplast (70s)
Chromosomes	single, circular, lack **histones**	More than one, linear, contain **histones**
Cytoskeleton	**simple**	**complex**
Cell division	**amitosis**	**mitosis and meiosis**
Biochemical diversity	**much more**	**much less**

Structure of an animal cell

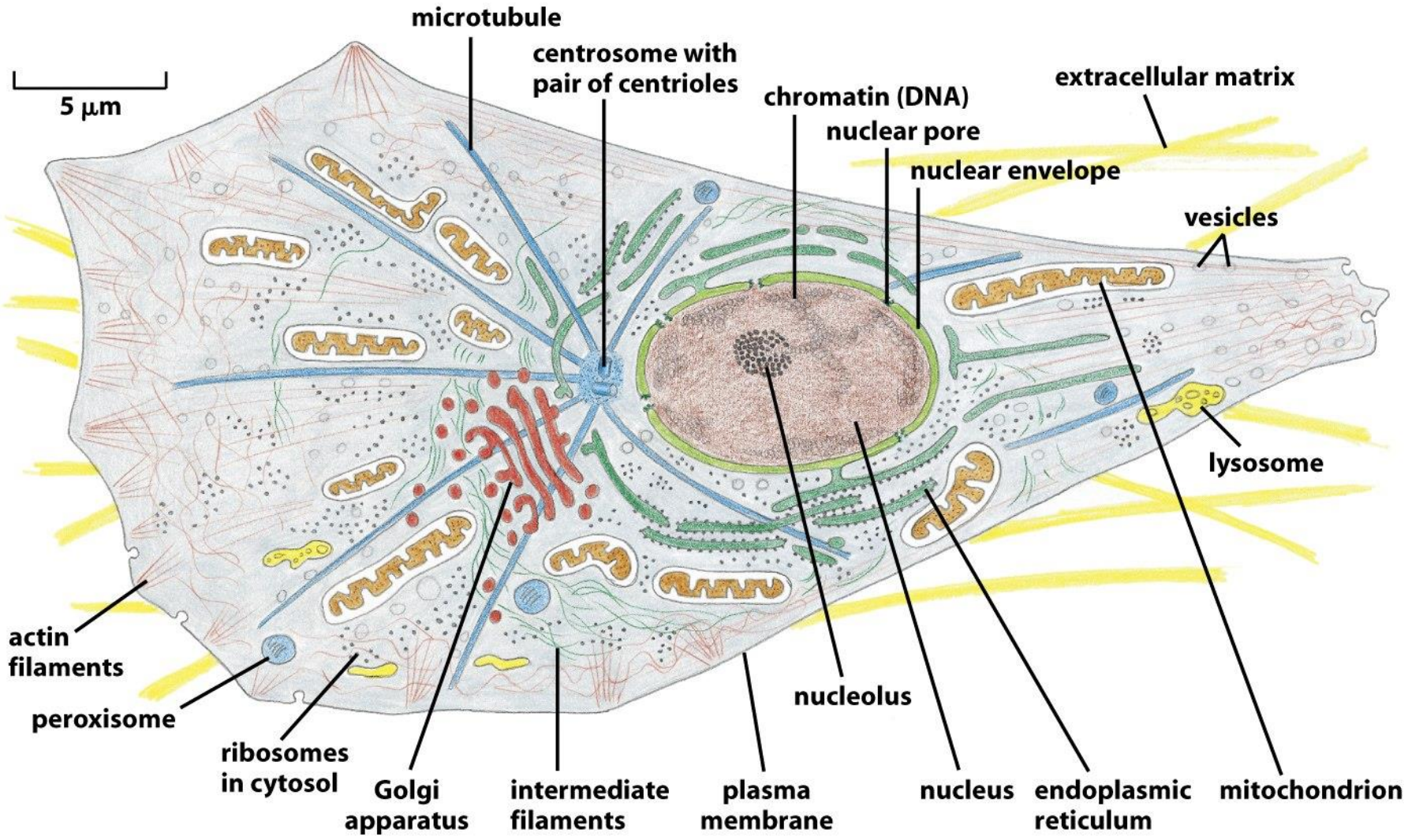


Figure 1-30 Molecular Biology of the Cell 5/e (© Garland Science 2008)

Cells visualized under microscopes

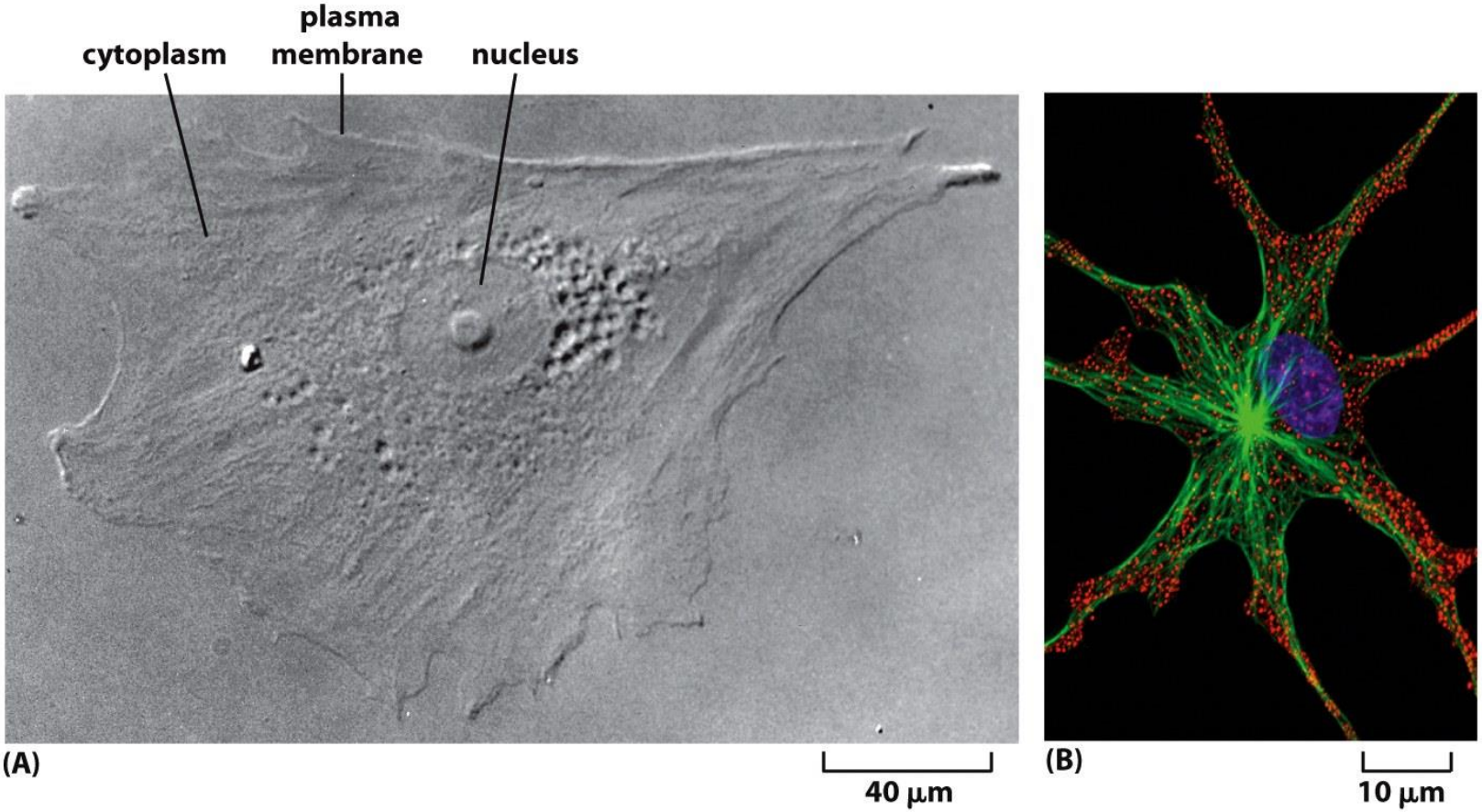


Figure 1-7 Essential Cell Biology 3/e (© Garland Science 2010)

Image of cell under Transmission Electron Microscope (TEM)

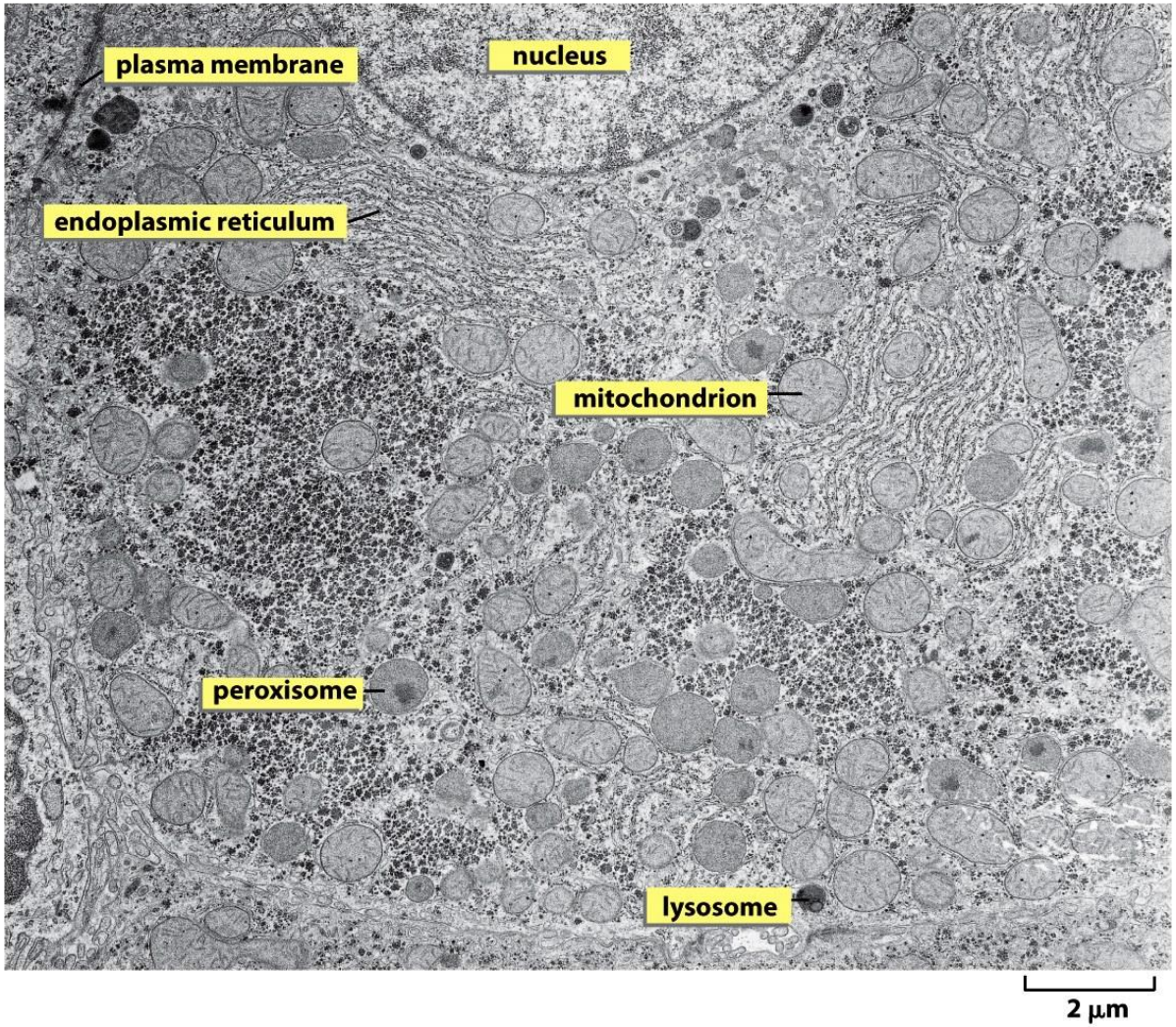
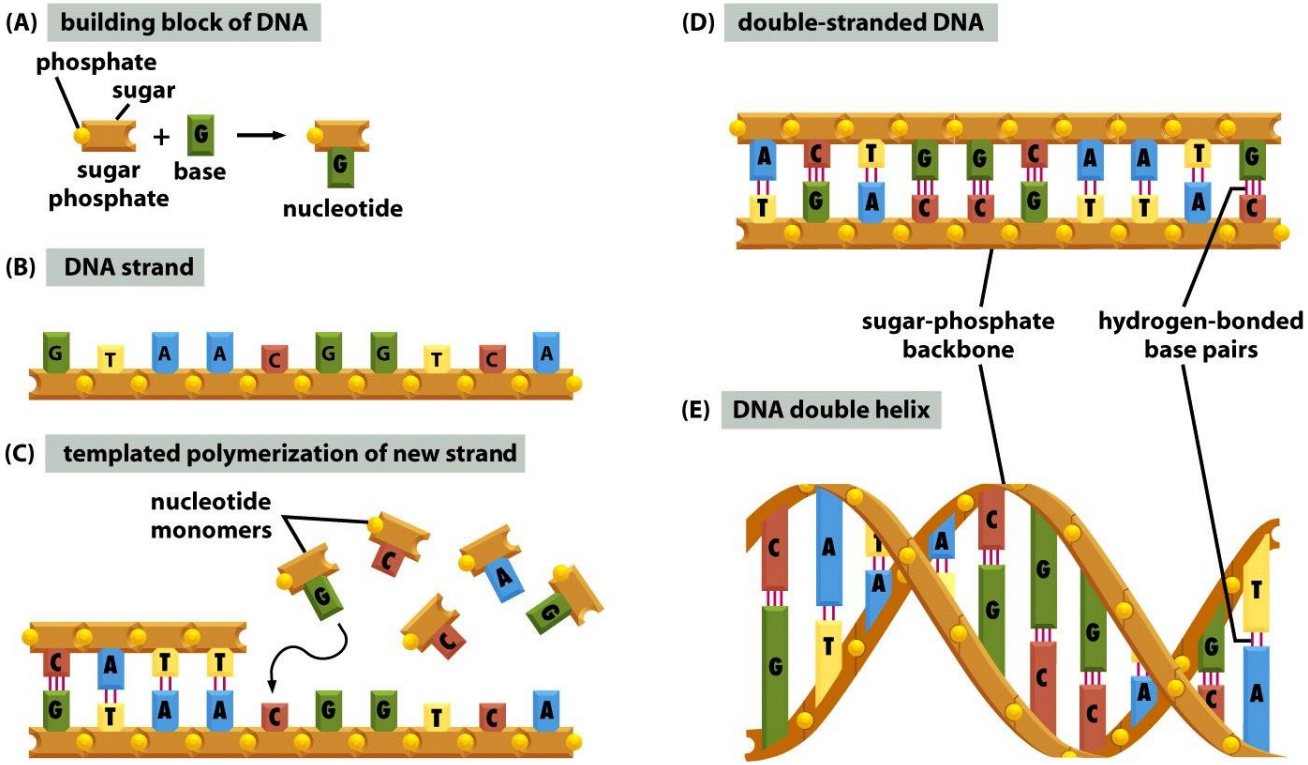


Figure 1-8a Essential Cell Biology 3/e (© Garland Science 2010)

1.3 The astonishing constancy of all cells

Cells are much more complicated than any other known chemical system
Nothing in cells disobeys chemical and physical laws. All cells are composed of small molecules, from which large polymers are assembled to execute the cell function, but with remarkable constancy.

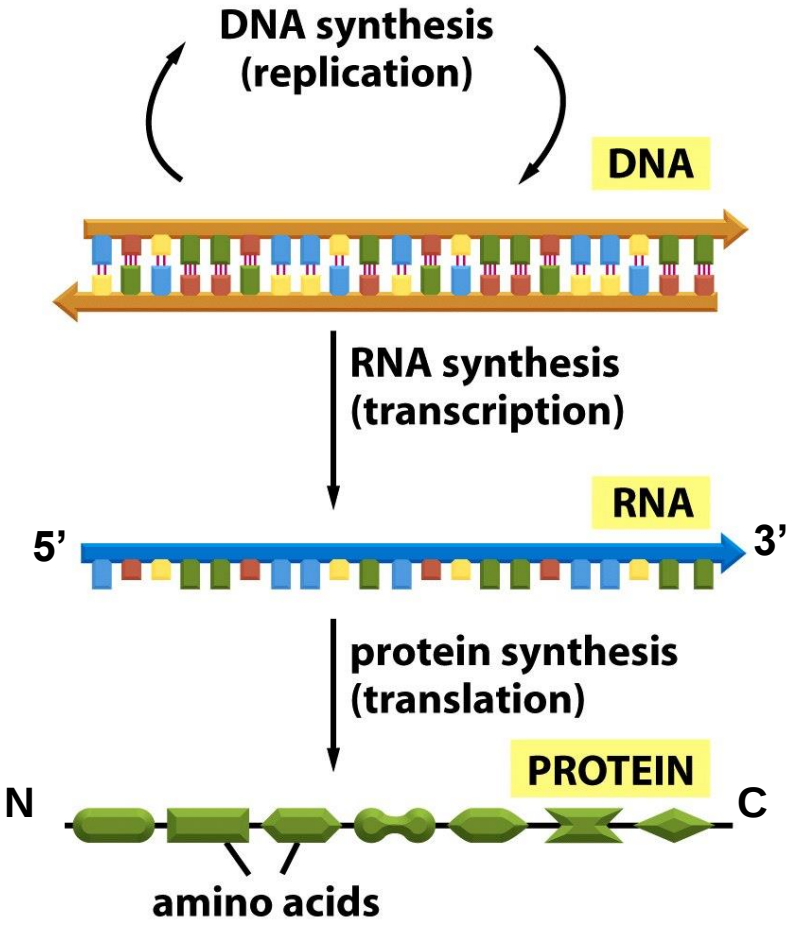
1). Are cells use DNA to store genetic information.
Genetic information are passed on by DNA replication, the templated polymerization



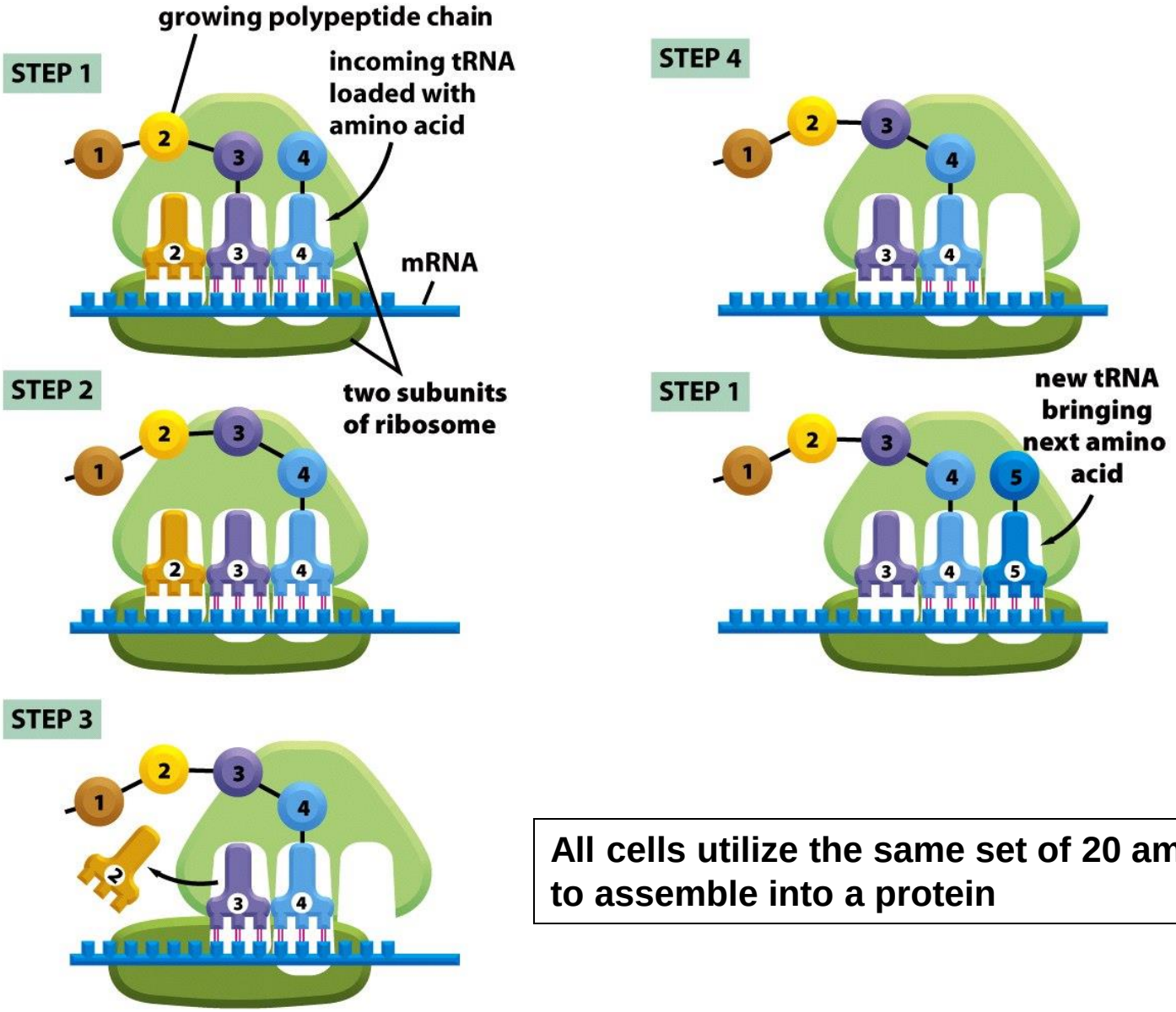
All cells use the same Set of 4 bases in DNA

A
G
C
T

2). All cells transcribe DNA into RNA, and translates RNA into protein, which has various functions in cells



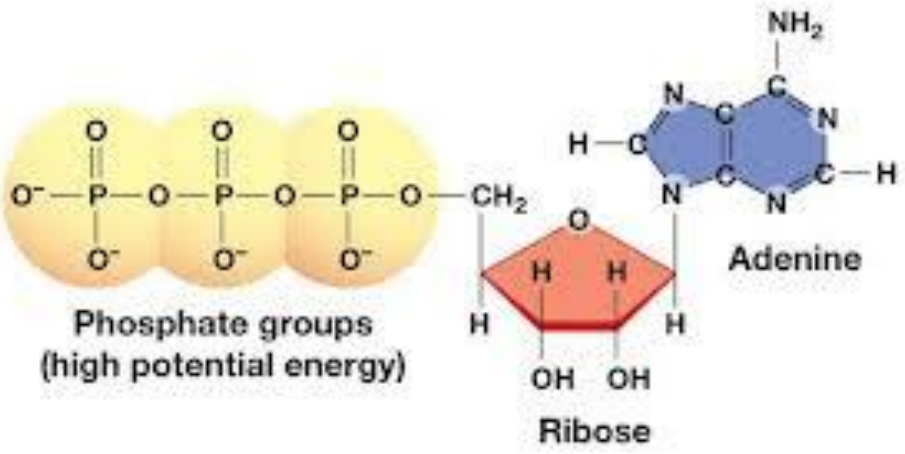
Protein synthesis from messenger RNA by ribosomes



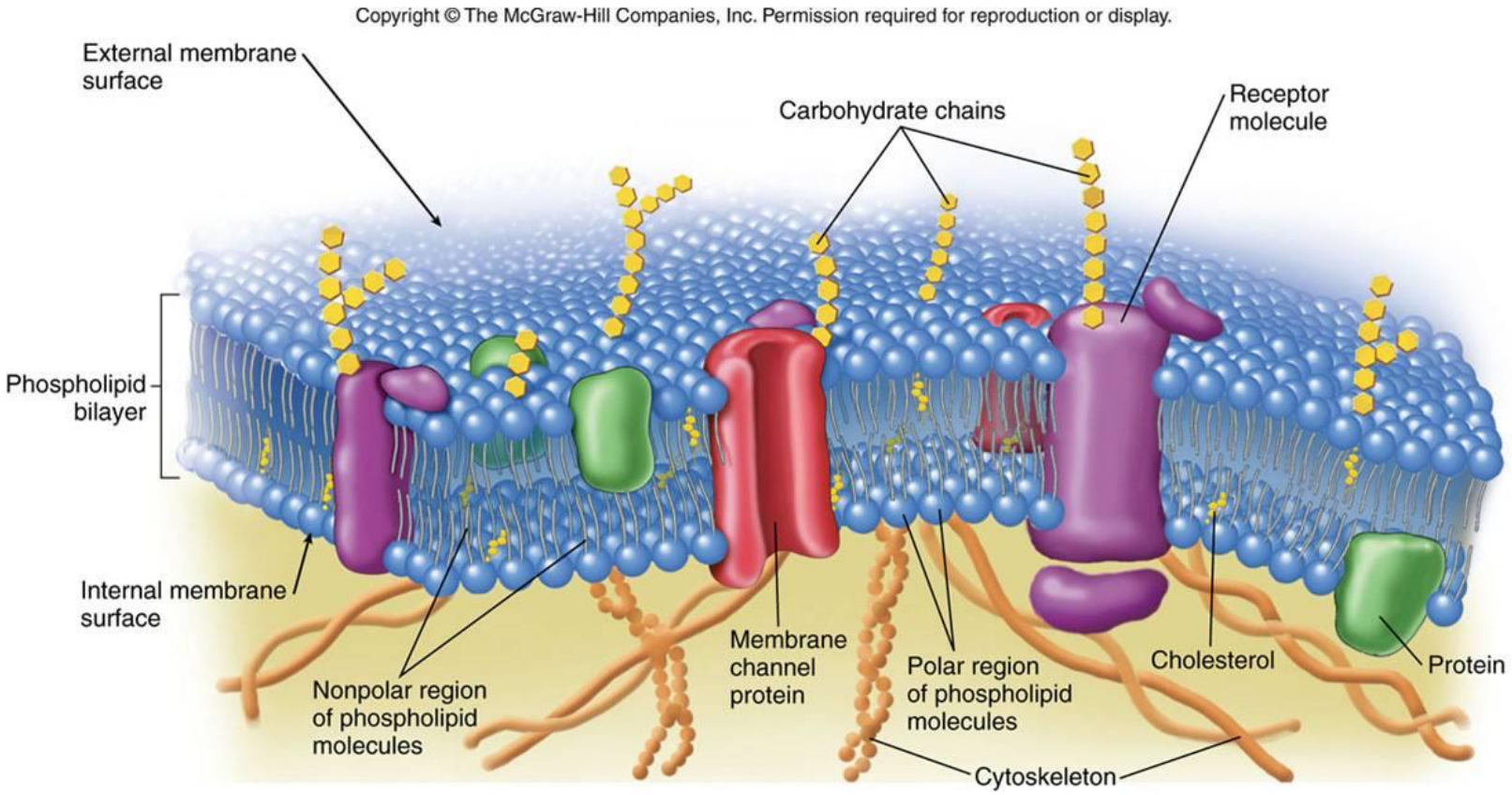
All cells utilize the same set of 20 amino acids to assemble into a protein

3). All cells require free energy, make and consume ATP (adenosine triphosphate) to drive cellular activities

(Cells are highly ordered, to maintain the order, they have to consume energy)



4). All cells are enclosed in a plasma membrane



Functions of the plasma membrane:

1. **Maintain its integrity as a coordinated chemical system**
2. **Retain the nutrients and useful products for its use**
3. **Excreting waste products**
4. **membrane-imbedded proteins act as signaling molecules to sense outside stimuli.**

1.4 How did cells evolve?

Diversity of lives on earth

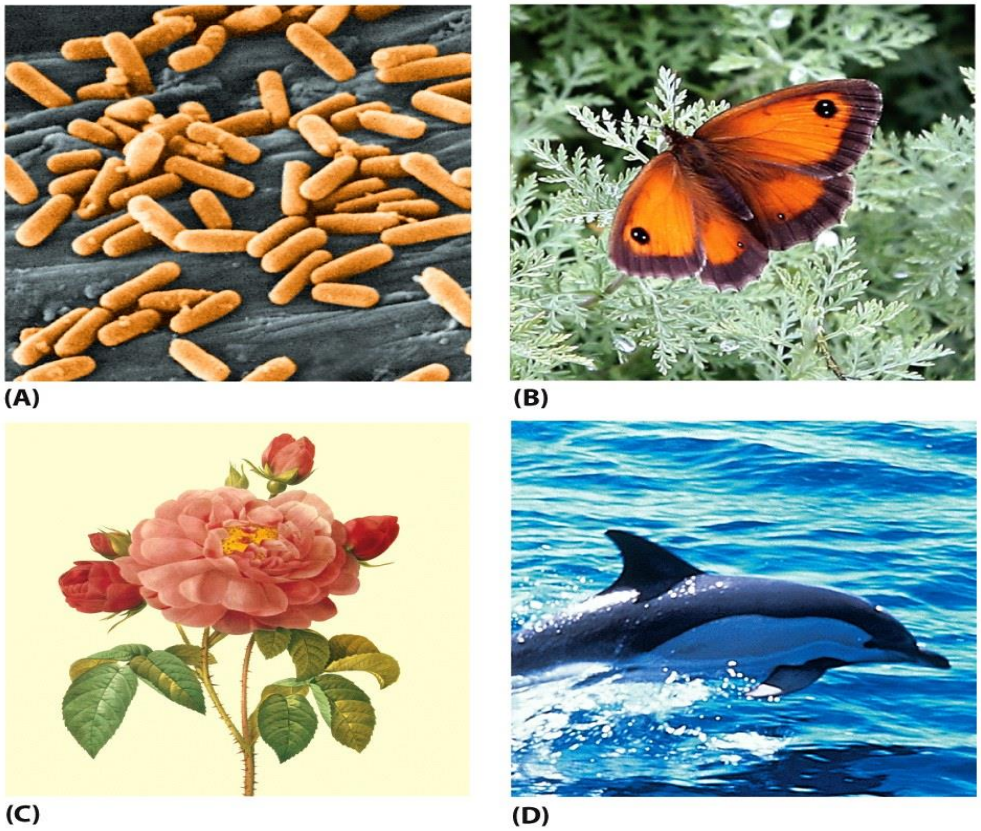


Figure 1-3 Essential Cell Biology 3/e (© Garland Science 2010)

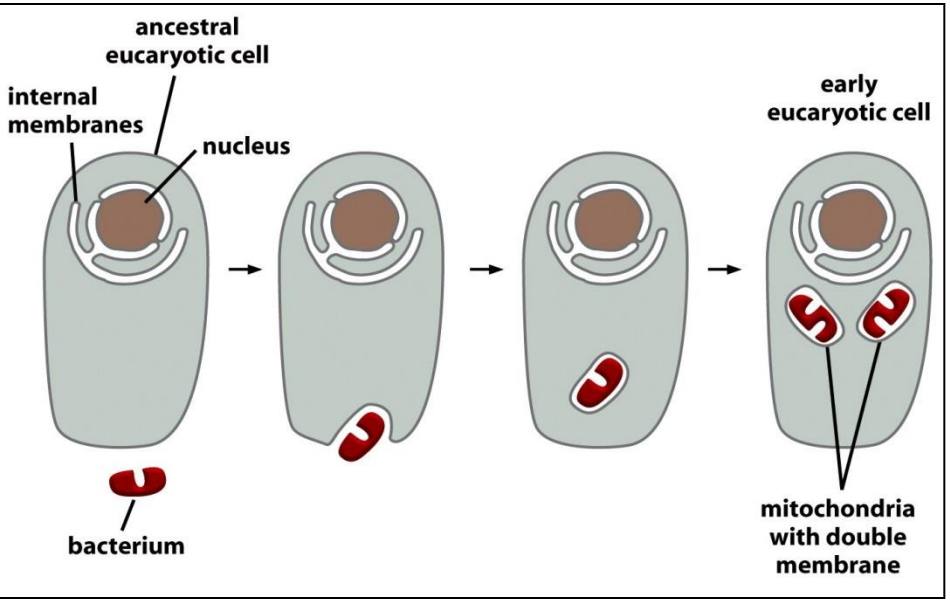
Timeline for Evolution of Life on Earth (from Fossil record)

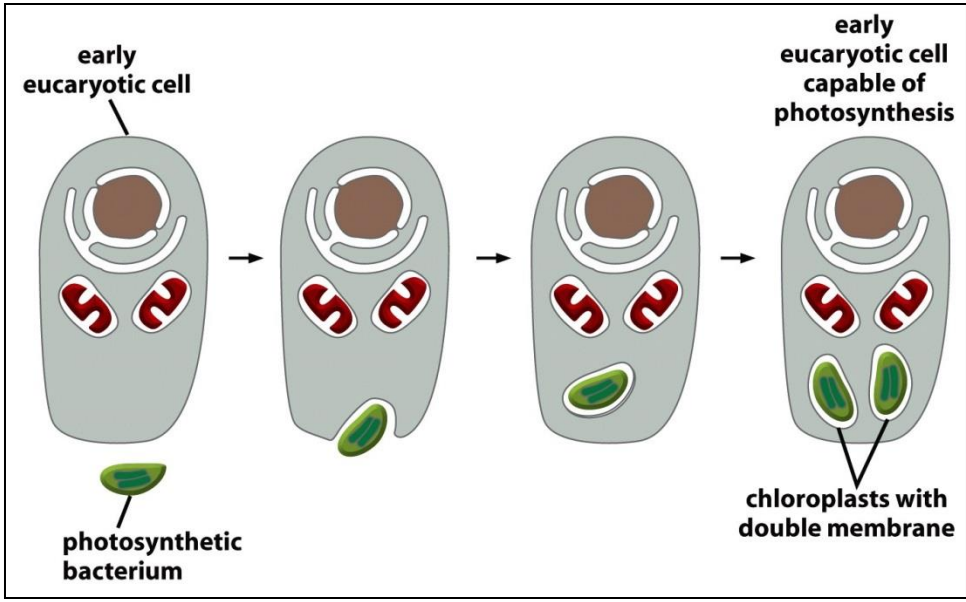
4600 million years ago	The planet earth forms
3900 to 2500 million years ago	Cells resembling prokaryotes appear
3500 million years ago	Split between bacteria and archaea occurs
2700 million years ago	Cyanobacteria evolve
1850 million years ago	Unicellular eukaryotic cell appear
1200 million years ago	Simple multicellular organisms evolve
580-500 million years ago	Most modern phyla of animals begin to appear
485 million years ago	First vertebrates with true bones evolve
434 million years ago	First primitive plants arise on land.
225 million years ago	Earliest dinosaurs appear
215 million years ago	First mammal evolve
65.5 million years ago	Extinction of dinosaurs and almost half of all animal species
6.5 million years ago	First hominids evolve
2 million years ago	First members of the genus Homo appear.
200 thousand years ago	Anatomically modern humans appear in Africa

---adapted from *Molecular Cell Biology*, 7th edition

How does an eukaryote evolve?

It is a mystery how the primordial eukaryotic cell evolved. But hypothesis is the ancient eukaryote might be a predator, mitochondria and chloroplast might be the result of engulfing of oxygen-metabolizing bacteria and photosynthesis bacteria, respectively

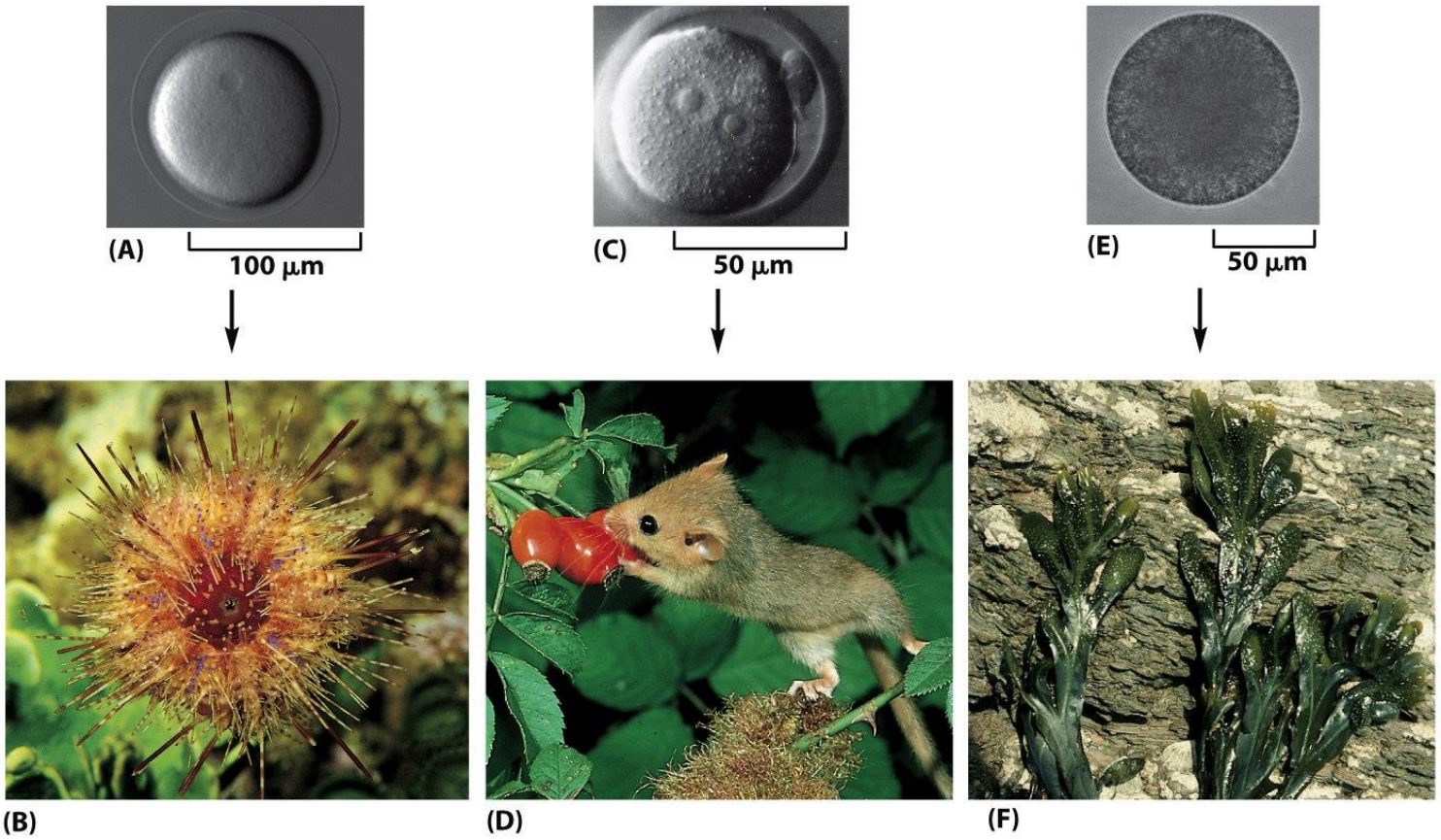




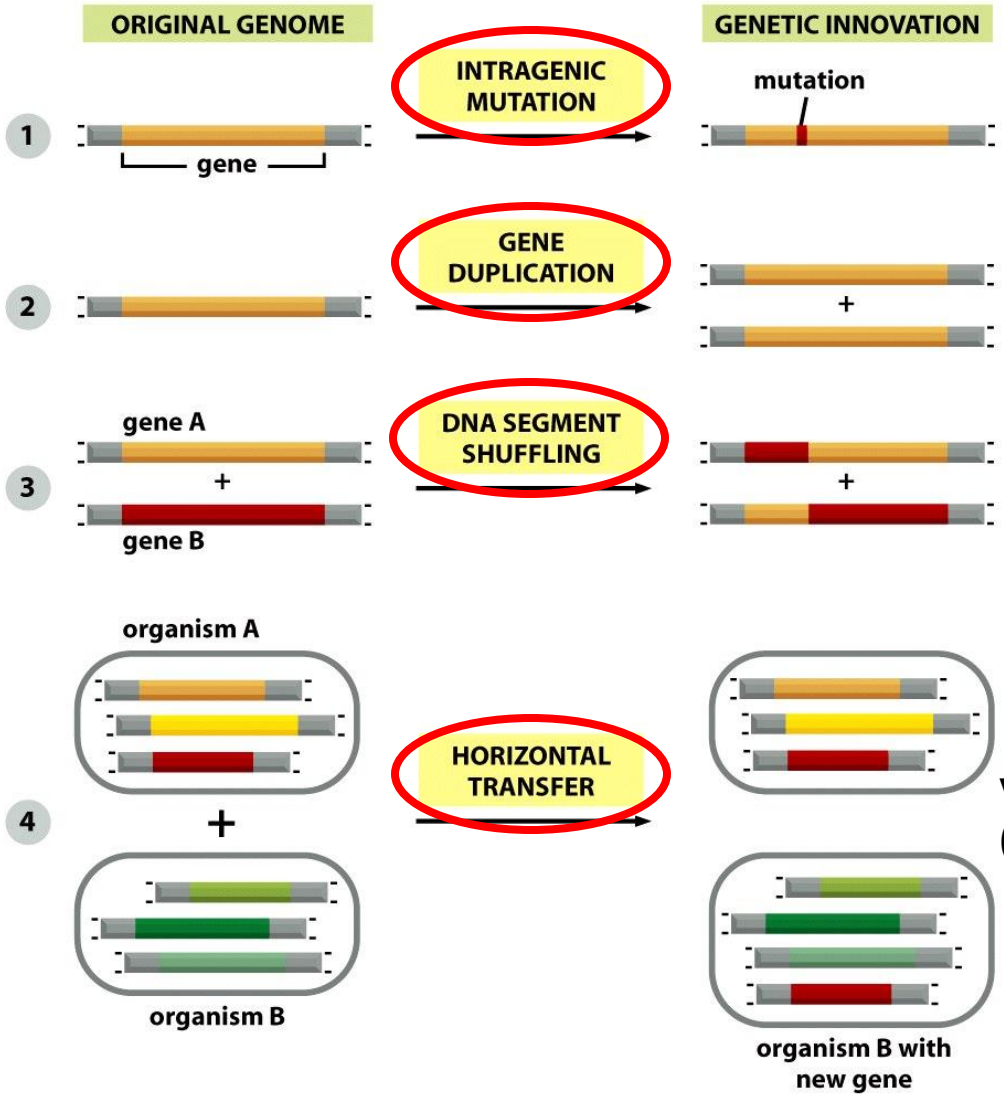
Evidence to support symbiosis

- Mitochondria and chloroplast are the size of a bacterium
- Some different genetic codons are utilized to encode proteins
- Mitochondria and chloroplast have their separate but cut-down versions of genomic DNA, ribosome, tRNA,
  that resemble those of bacteria.

Genetic information determines the nature of whole multicellular organisms



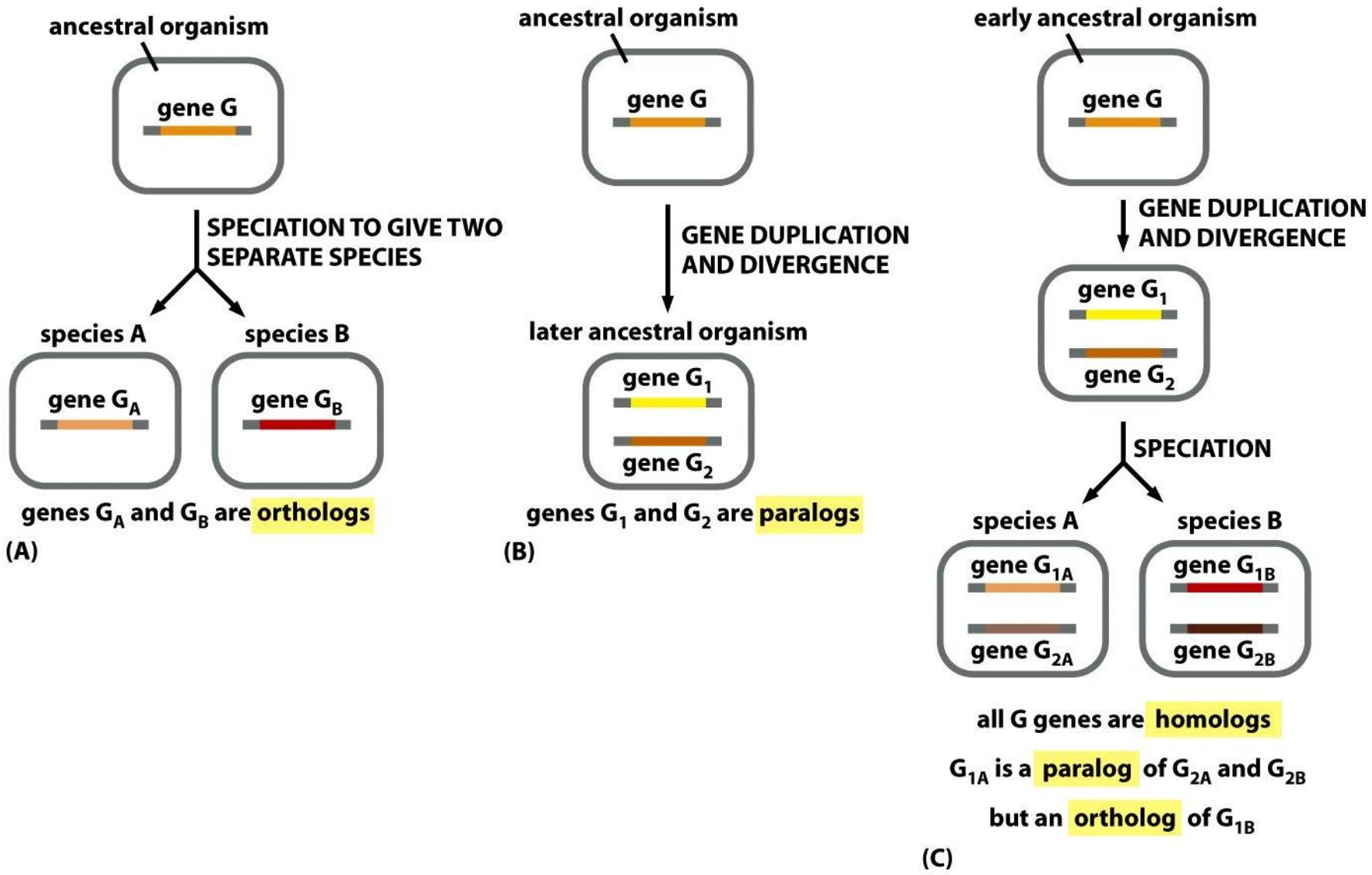
Species evolve from prokaryotic to eukaryotic, from single cell to multicellular cell, the genome size and gene all increase, how do they expand their genes



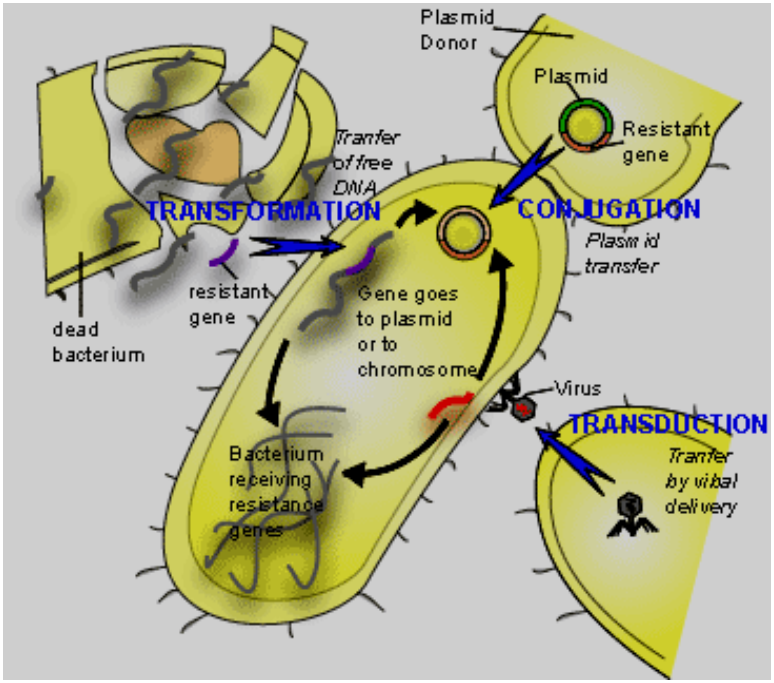
4 ways:
1.Mutations
2.Duplications
3.Shuffling
4.Horizontal transfer

versus vertical transfer (from parent to progeny)

Homologous genes

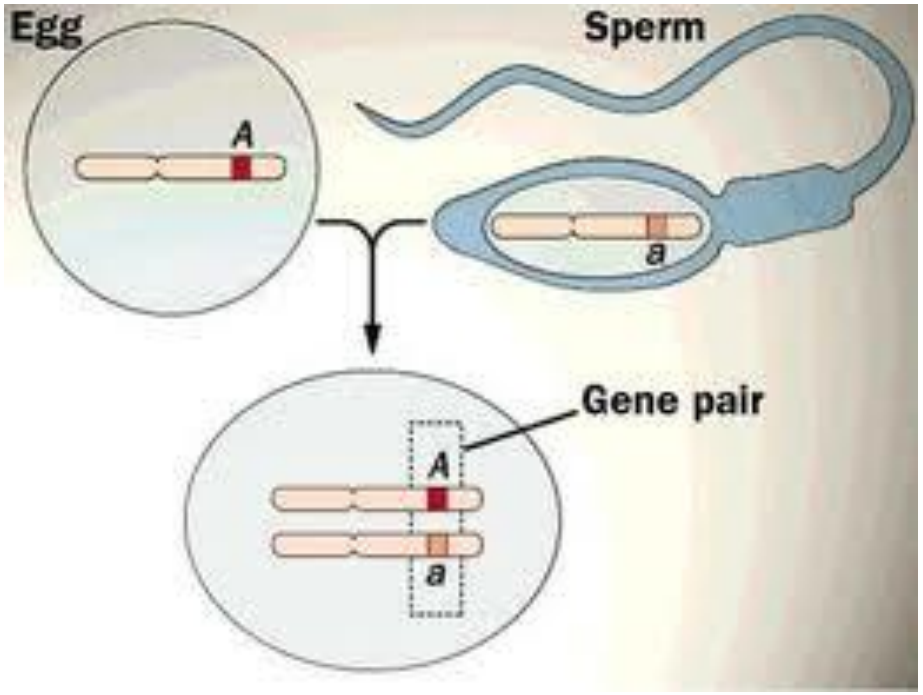


Horizontal gene transfer (HGT) occurs in prokaryotic cells (within the same species or between species)



http://news.ifeng.com/a/20170515/51091274_0.shtml

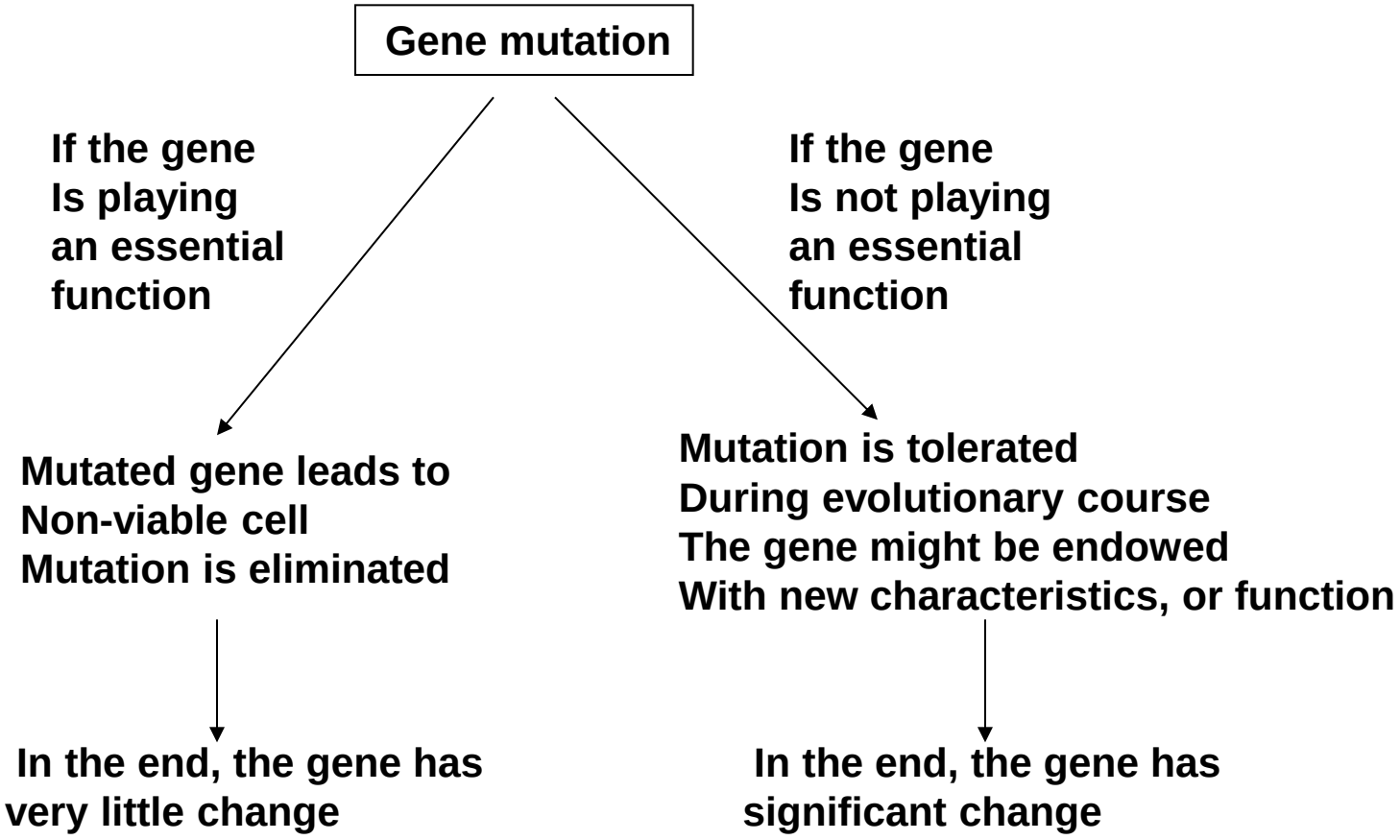
Horizontal gene transfer in higher organisms, by sex



HGT also occurs in human via virus infection.

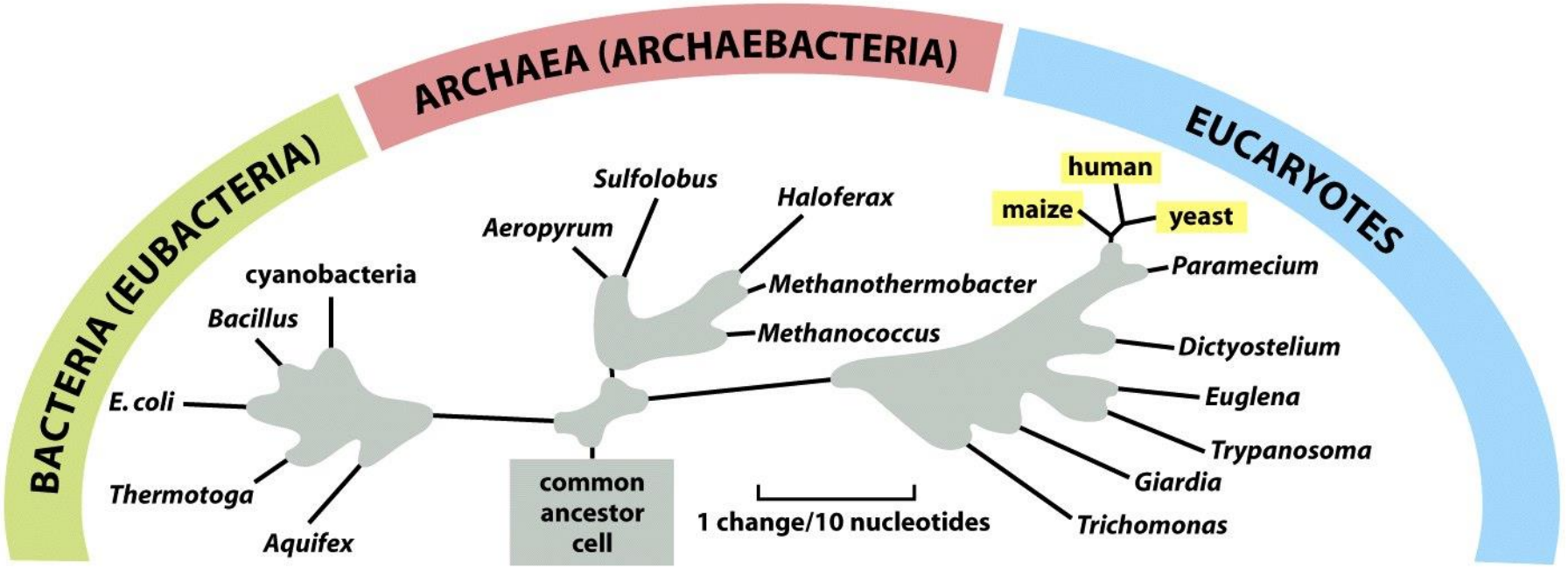
Why are some genes evolve rapidly, while others not?

Random mutation of DNA occurs during DNA replication



Genetic sequence allows simpler and more accurate way to determine evolutionary relationship based on essential genes

Phylogenetic Tree of Life by rRNA sequence



Archaea resembles enkaryotes in DNA replication, transcription and translation but resembles eubacteria in metabolism and energy conversion.

1.5 The application of model systems to study cell biology

- Smaller genome size
- Short life cycle
- Easy manipulation
- Less expensive
- Ethical
- Mutations available

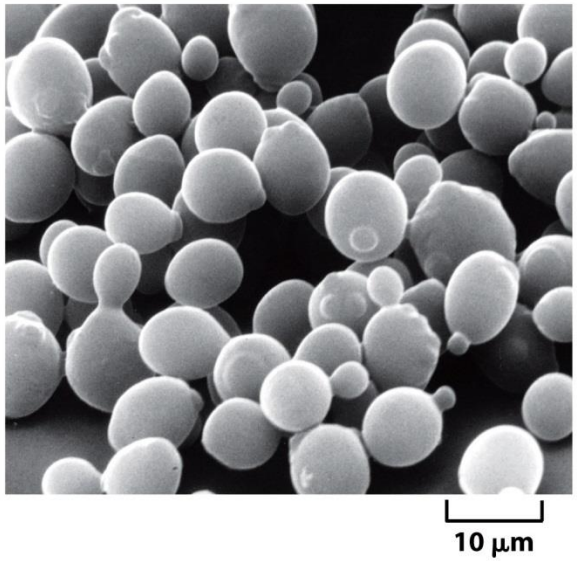


Figure 1-32 Essential Cell Biology 3/e (© Garland Science 2010)

Figure 1-33 Essential Cell Biology 3/e (©

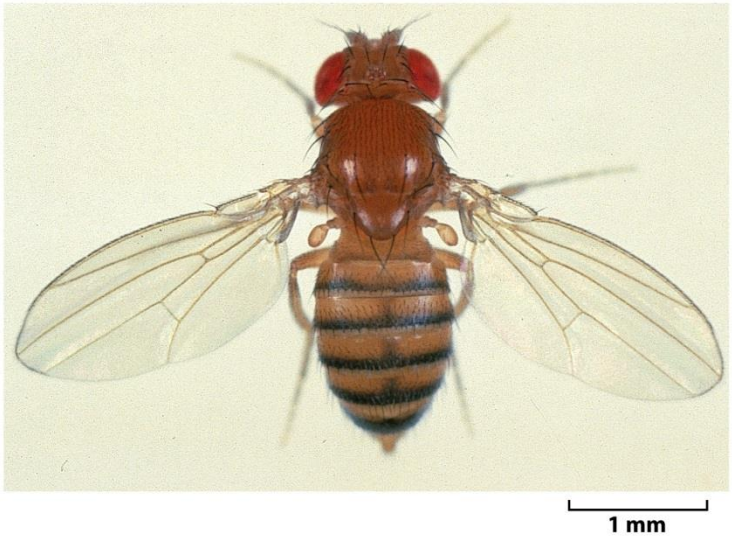


Figure 1-34 Essential Cell Biology 3/e (© Garland Science 2010)

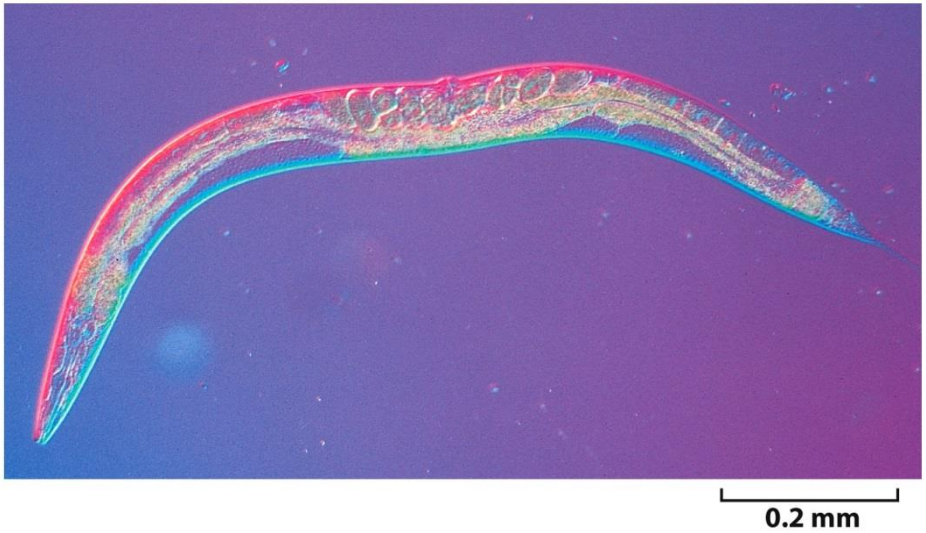


Figure 1-38 Essential Cell Biology 3/e (© Garland Science 2010)

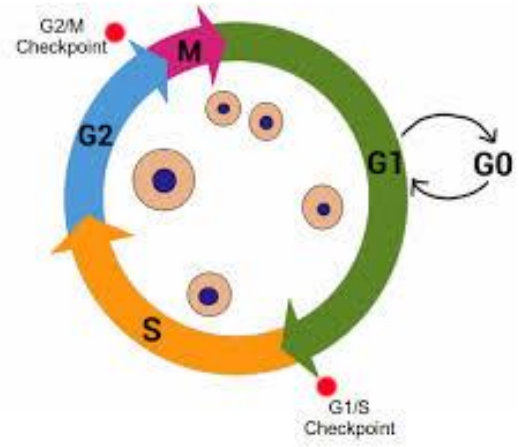
Figure 1-39 Essential Cell Biology 3/e (© Garland Science 2010)

Some commonly used model systems that have been fully sequenced

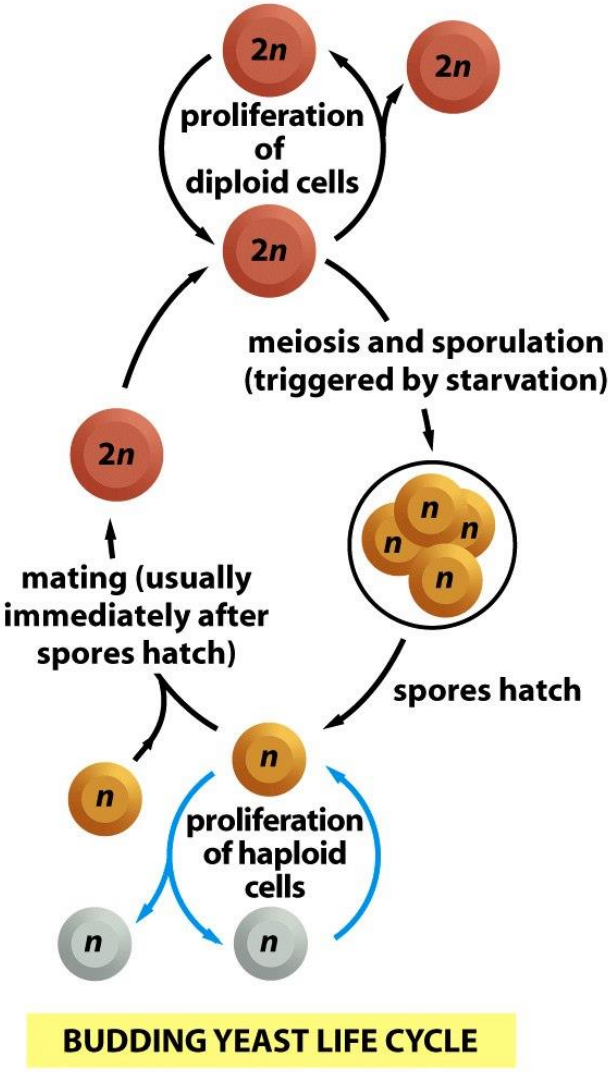
	Base pairs (millions)	encoded protein	chromosomes
• Bacteria (*E.coli*)	4.64	4289	1
• Yeast (*S.cerevisiae*)	12.16	5885	16
• *Worm (C. elegans)*	100	20424	6
• Fruit fly(*D.melanogaster*)	168	13781	4
• Zebrafish (*Danio rerio*)	1505	19929	25
• Mice(*Mus musculus*)	3421	22085	20
• *Arabidospsis thaliana*	135	27416	5
• Homo sapiens	3279	21077	23

Adapted from *Molecular Cell Biology*, 7th edition

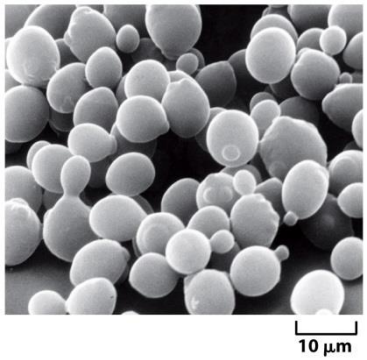
e.g. Use of Yeast as a model system to study cell division



a life cycle for somatic mammalian cell



Mutations in Yeast led to the identification of key cell cycle proteins



Mutagen, UV, IR

Yeast cells with largely random mutation

Isolate temperature-sensitive mutants With altered division of haploid yeast Cells

low temperature- permissive mutated protein fold correctly

high temperature-non-permissive Mutated protein fold wrongly

Isolate those mutation-defined genes and cloned them, study their biochemistry

Use sequence alignment to search Their human homologs, usually Human homologs can rescue the Phenotype caused by these mutants.

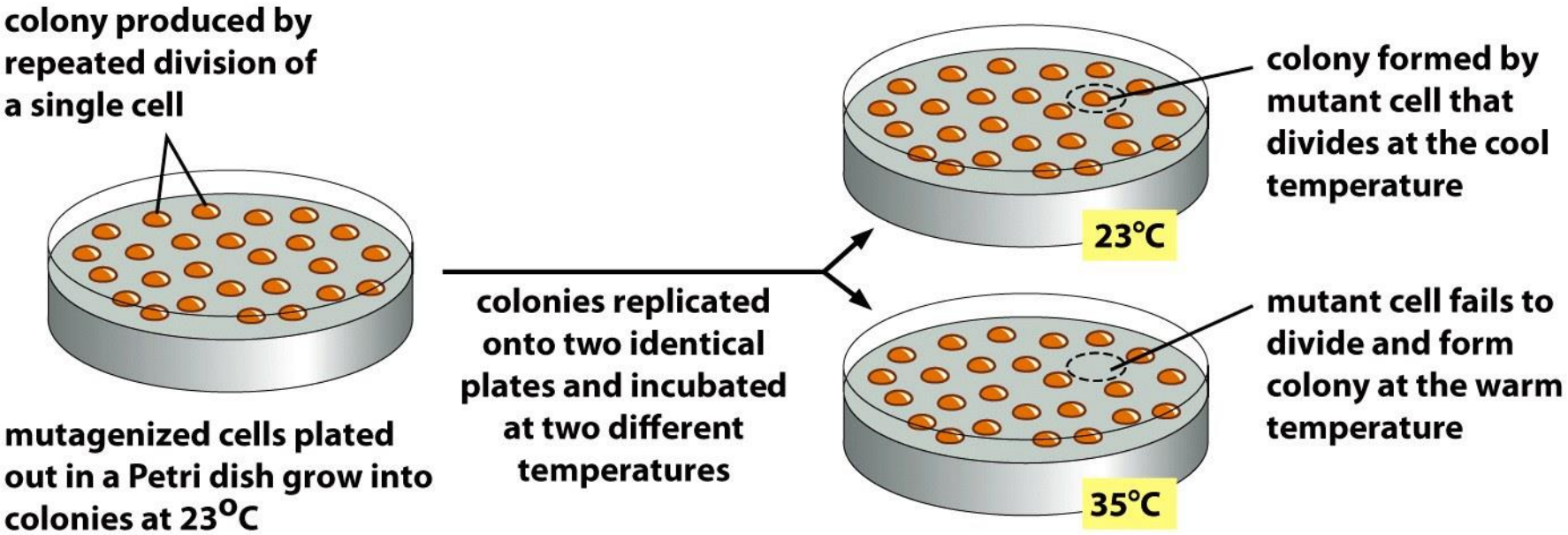
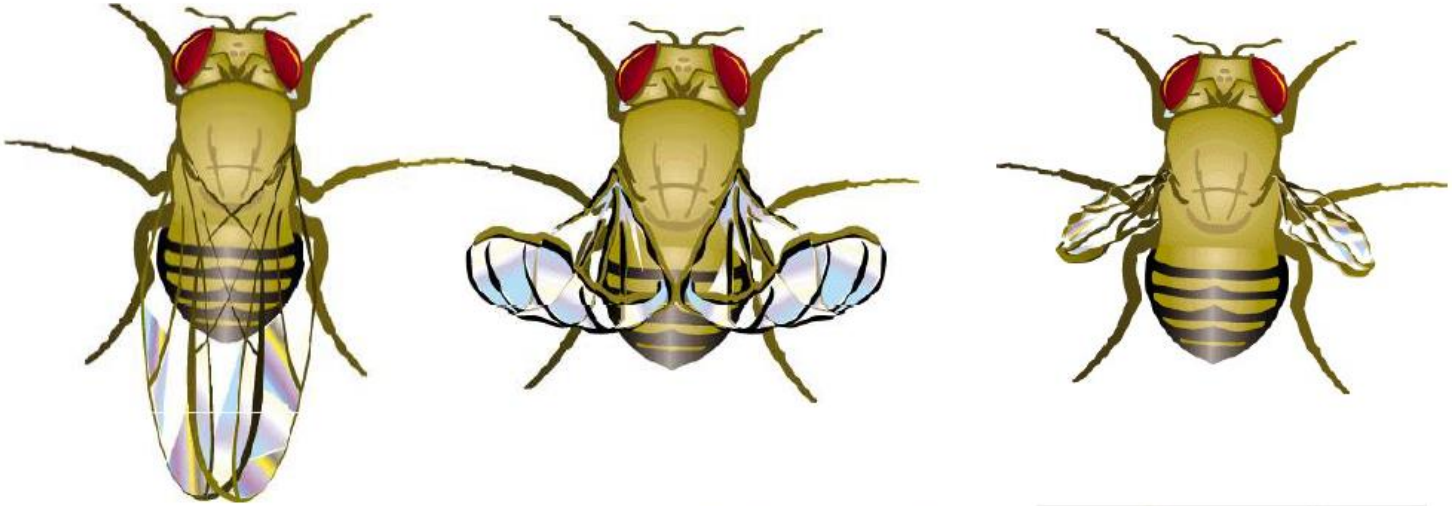
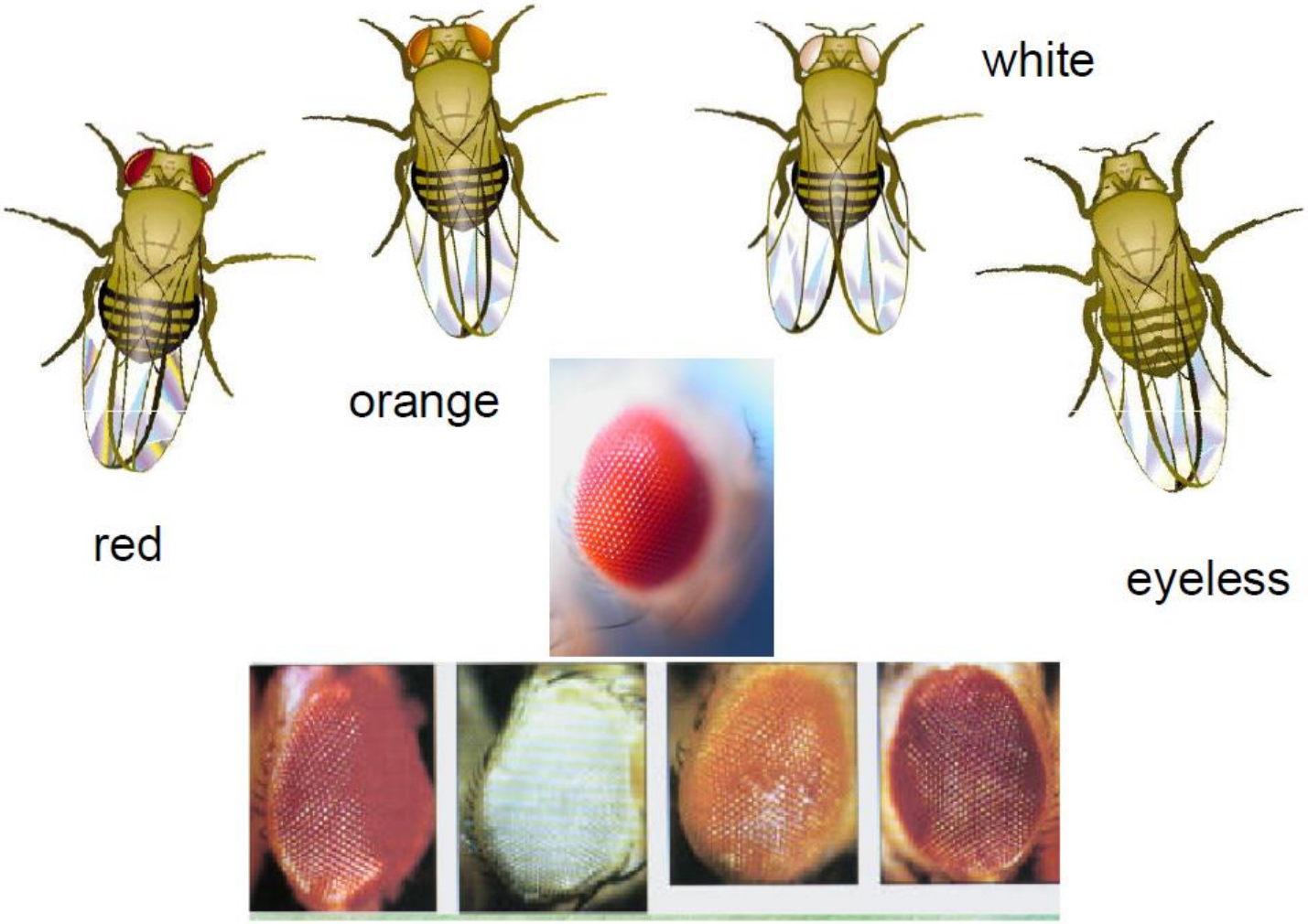


Figure 1-35 Essential Cell Biology 3/e (© Garland Science 2010)

Drosophilae Wing mutations



Drosophilae eye color mutations



Summary for Lecture 1:

1. Think about why you want to study Cell Biology.
2. Understand the theory of cell and the history of cell theory.
3. What are the general differences between eukaryotic cells and prokaryotic cells?
4. Understand all cells have constancy in four remarkable aspects.
5. Think about the evolution of life.
6. Understand the common ways of gene evolution.
7. What are the common model systems used in cell biology?