What we need to know

- All living things are made of Cells
  - ***Prokaryote (single cell)***
  - ***Eukaryote (multiple cells)***
- ***Chromosomes***
- ***Cell Signaling***
- ***What is Inside the cell: From DNA, to RNA, to Proteins***

Cells

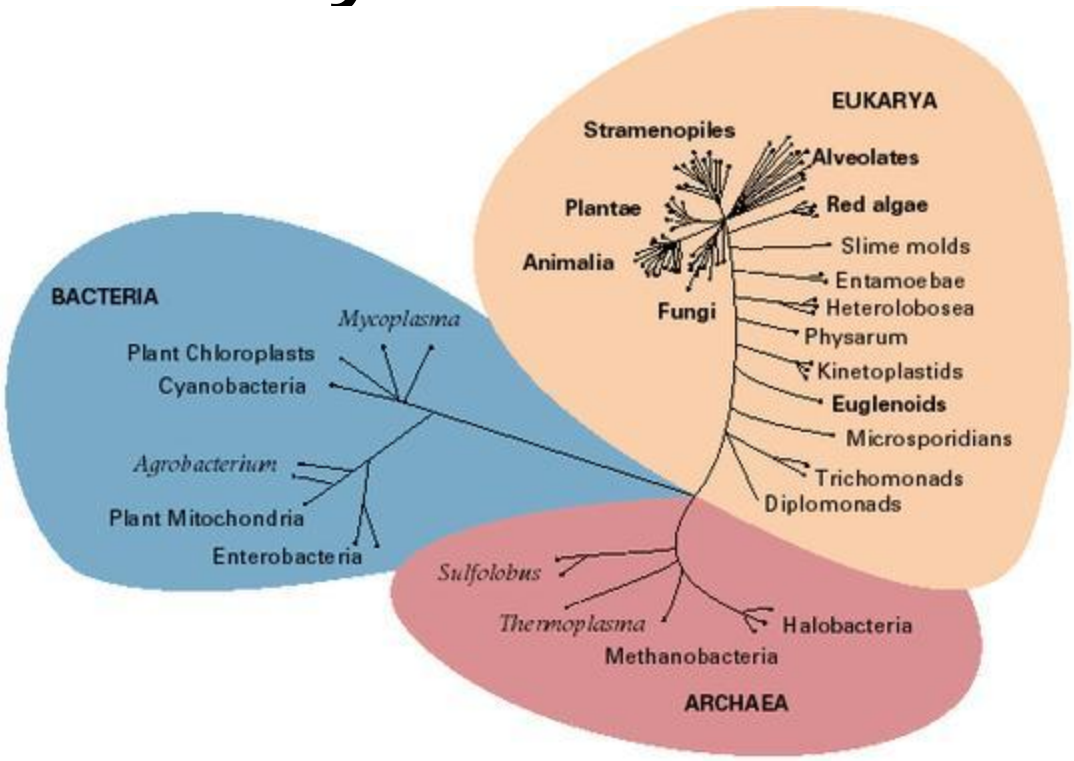
- **Fundamental working units** of every living system. The basic unit of any living organism that carries the biochemical processes of life.
- Every organism is composed of one of two

  radically different types of cells:

  prokaryotic cells or

  eukaryotic cells.
- **Prokaryotes** and **Eukaryotes** are descended from the same primitive cell.
  - All extant prokaryotic and eukaryotic cells are the result of a total of 3.5 billion years of evolution.

Prokaryotes and Eukaryotes



•According to the most recent evidence, there are three main branches to the tree of life.
•Prokaryotes include Archaea ("ancient ones") and bacteria.
•Eukaryotes are the kingdom Eukarya and includes plants, animals, fungi and certain algae.

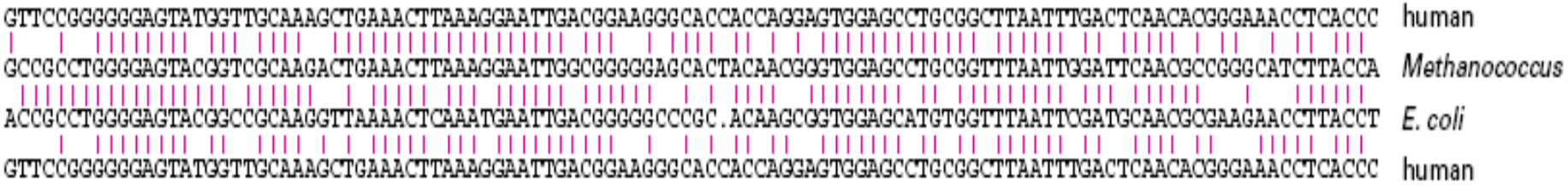


Figure 1–22 Genetic information conserved since the beginnings of life. A part of the gene for the smaller of the two main RNA components of the ribosome is shown. Corresponding segments of nucleotide sequence from an archaean *(Methanococcus jannaschii),* a eubacterium *(Escherichia coli)* and a eucaryote *(Homo sapiens)* are aligned in parallel. Sites where the nucleotides are identical between species are indicated by a vertical line; the human sequence is repeated at the bottom of the alignment so that all three two-way comparisons can be seen. A dot halfway along the *E. coli* sequence denotes a site where a nucleotide has been either deleted from the eubacterial lineage in the course of evolution, or inserted in the other two lineages. Note that the sequences from these three organisms, representative of the three domains of the living world, all differ from one another to a roughly similar degree, while still retaining unmistakable similarities.

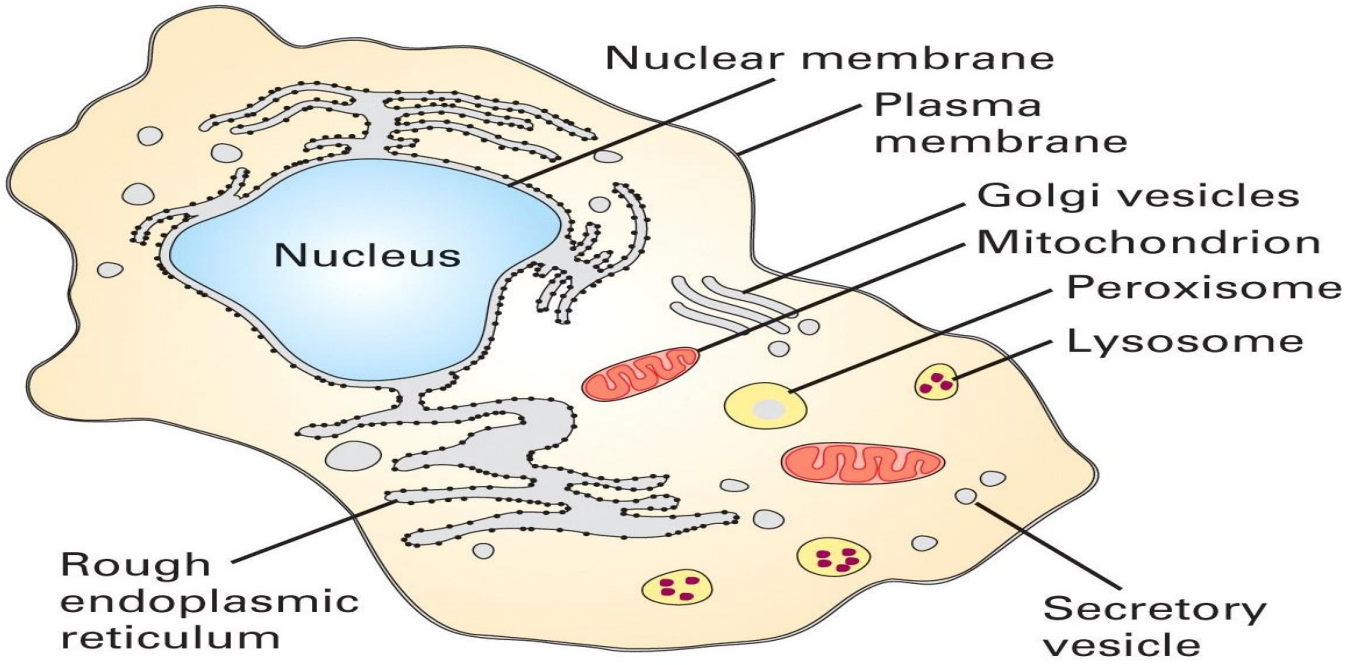
Cells

- *Chemical composition*-by weight
  - 70% water
  - 7% small molecules
    - salts
    - amino acids
    - nucleotides
  - 23% macromolecules
    - Proteins
    - Polysaccharides
    - Lipids
    - Abundant O,C,N. Smaller amounts: Ca, Cl, Mg,P, Na, K,S. Trace:Co,Cu,Fe,Mn,Zn.

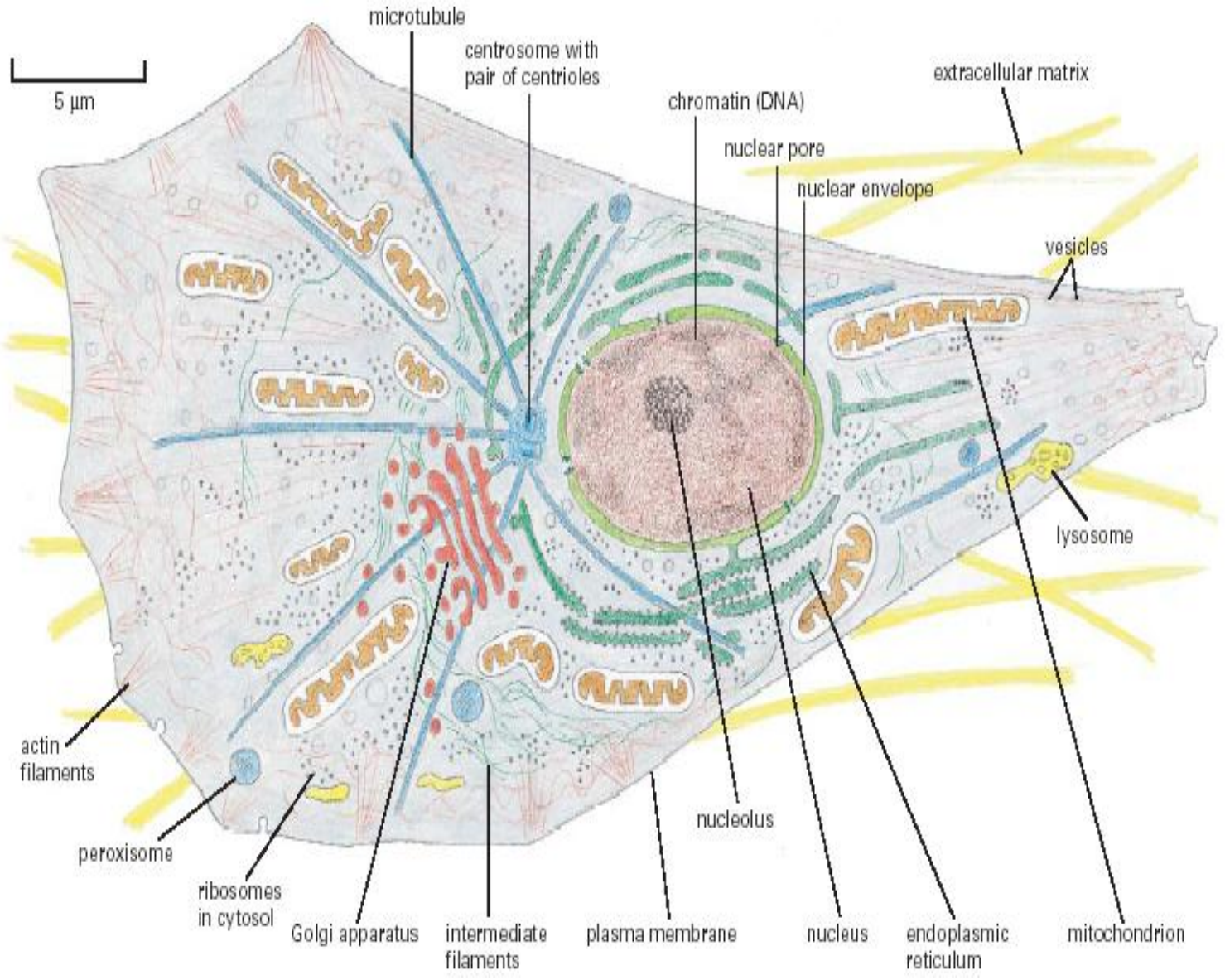
Cell website

http://www.cellsalive.com

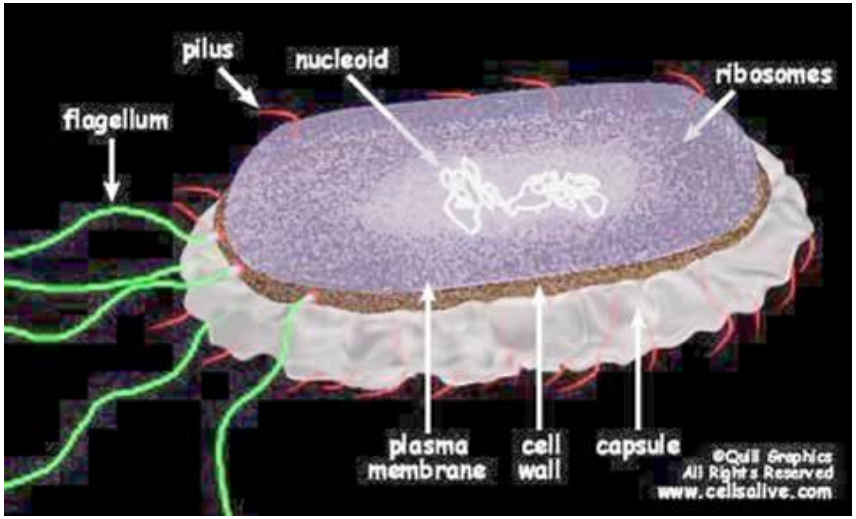
Life begins with Cell

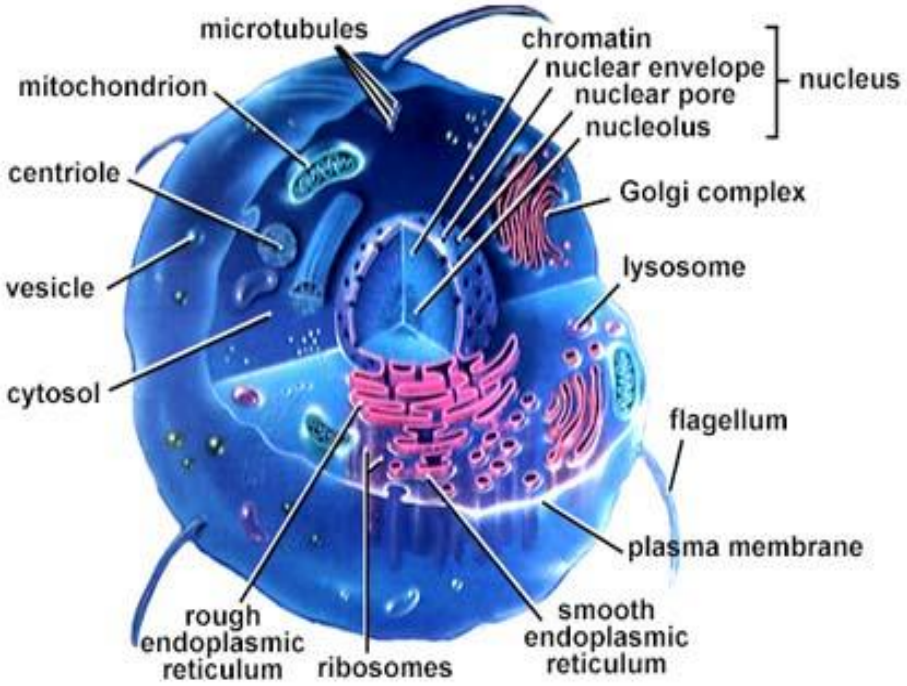


- A cell is a smallest structural unit of an organism that is capable of independent functioning
- All cells have some common features

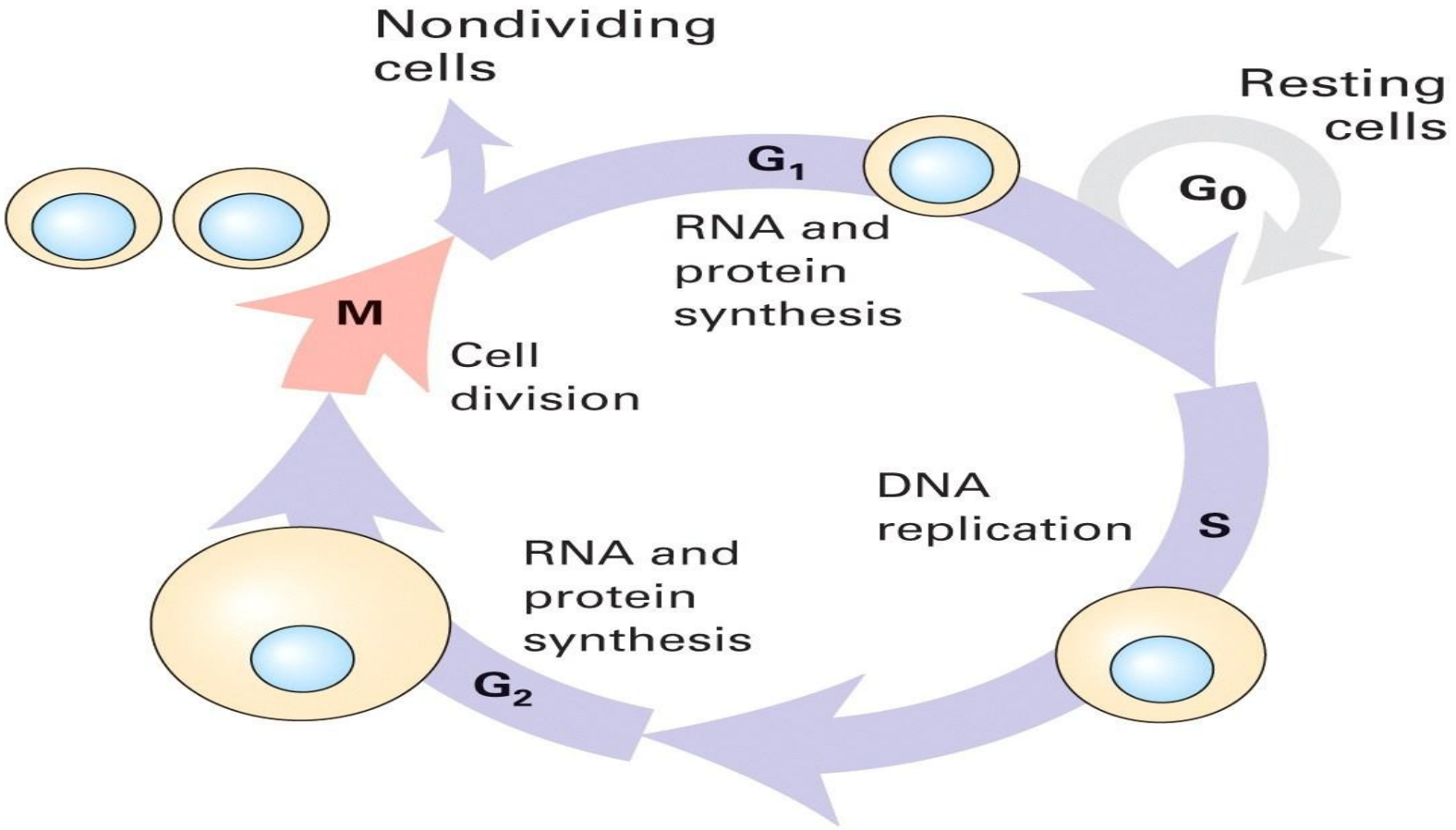

5 µm
microtubule
centrosome with pair of centrioles
chromatin (DNA)
extracellular matrix
nuclear pore
nuclear envelope
vesicles
lysosome
actin filaments
peroxisome
ribosomes in cytosol
Golgi apparatus
intermediate filaments
plasma membrane
nucleolus
nucleus
endoplasmic reticulum
mitochondrion

Cells: Prokaryotes v.s.Eukaryotes



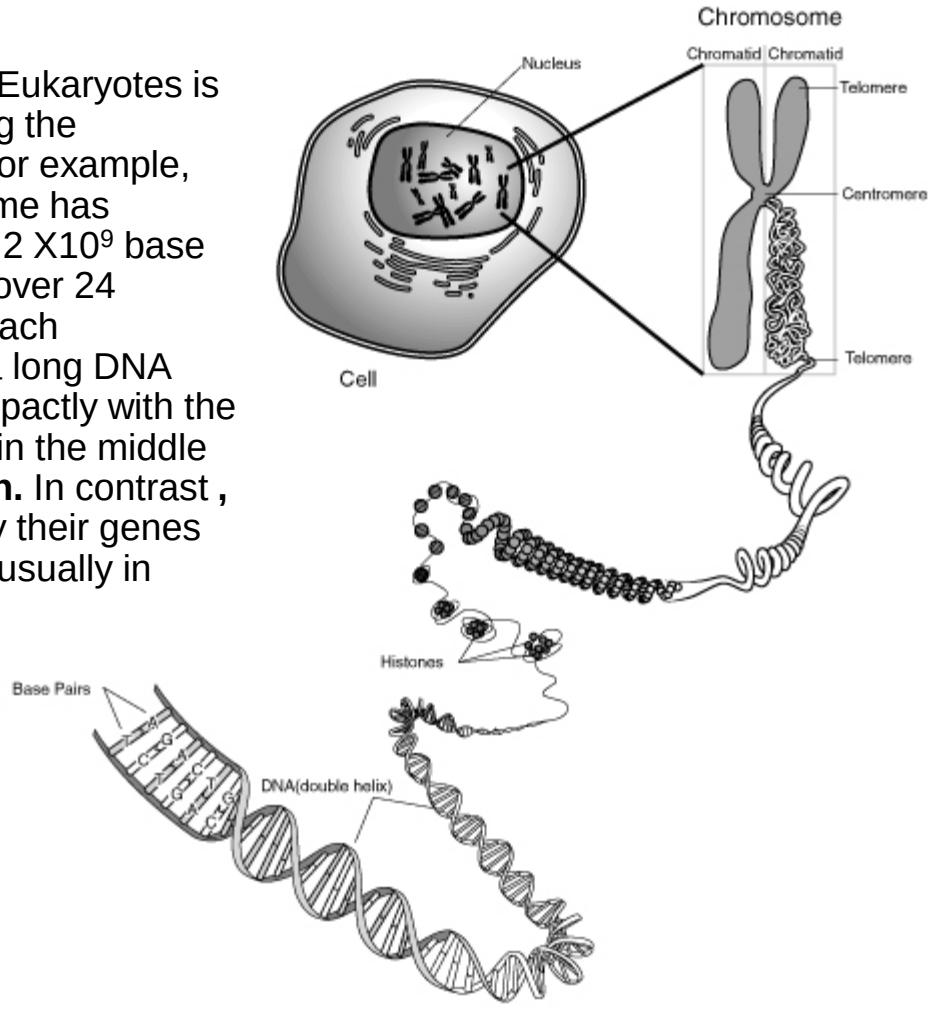


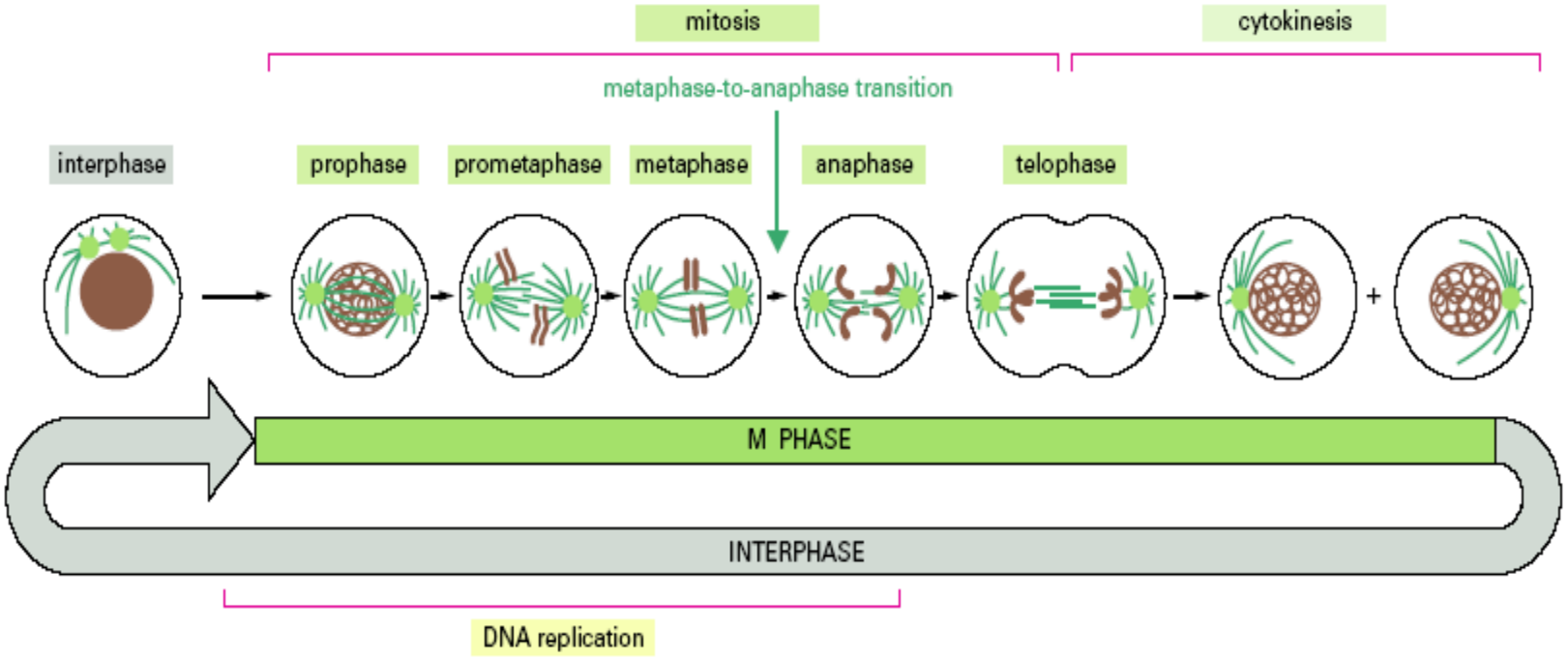
All Cells have common Cycles



- Born, eat, replicate, and die

The DNA for the Eukaryotes is distributed among the chromosomes. For example, the human genome has approximately 3.2 X10^9 base pairs distributed over 24 chromosomes. Each chromosome is a long DNA packed very compactly with the help of a protein in the middle called **Chromatin.** In contrast **,** the bacteria carry their genes on a single DNA usually in circular form.

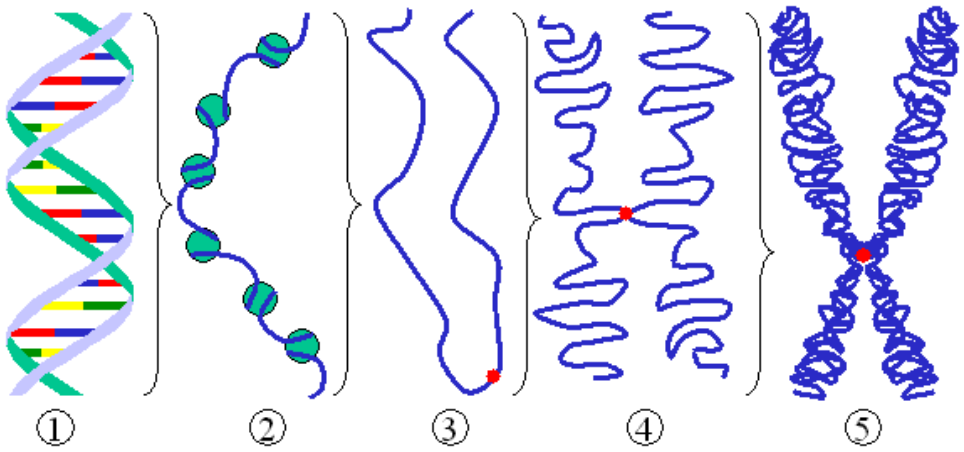




Eukaryotic Cell Division

1. The chromosomes duplicate themselves and get themselves attached to spot called *centromere*.
2. They thicken and shorten (becomes visible under microscope now).
3. The nuclear membrane dissolves and a fibrous spindle is formed, on the chromosomes lined up.
4. The centromeres divide, the spindle fibers tug the chromosome pairs apart.
5. The chromosomes gather at opposite poles, the spindle disappears.
6. The nuclear membrane re-formed, chromosomes, unwind, becomes invisible again and the two cells are formed.

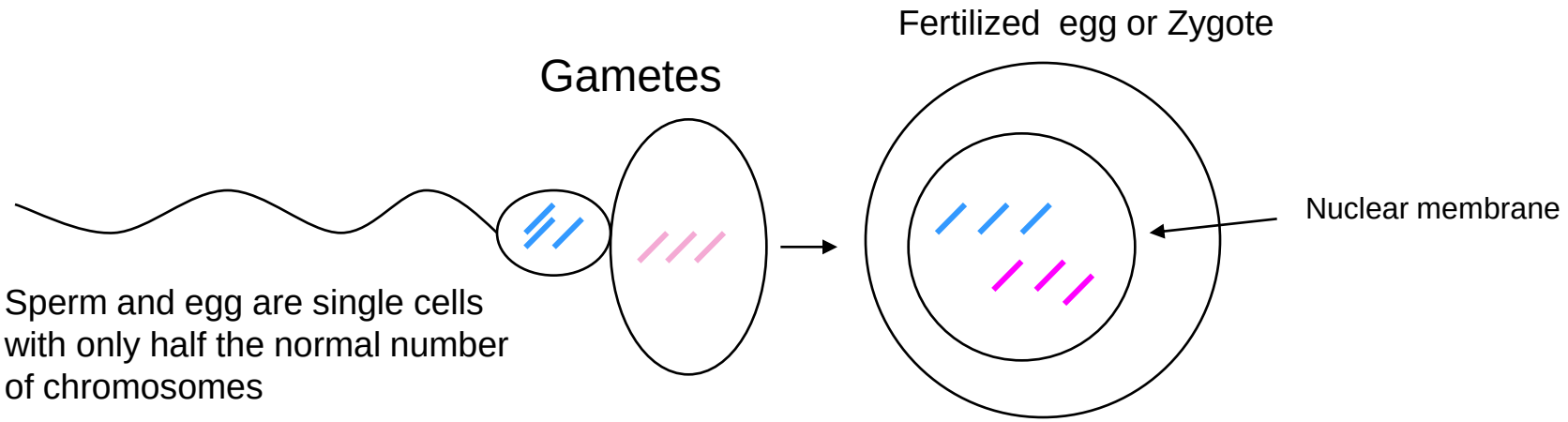
Genetic Information: Chromosomes



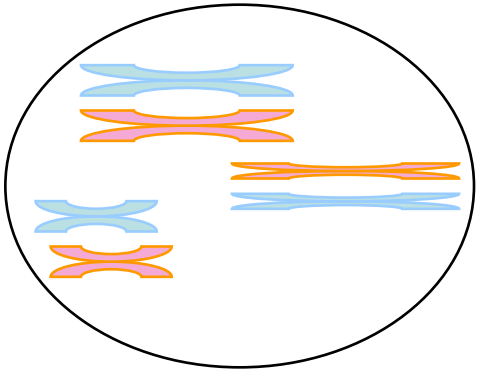
- (1) Double helix DNA strand.
- (2) Chromatin strand (**DNA** with **histones**)
- (3) Condensed chromatin during interphase with **centromere**.
- (4) Condensed chromatin during prophase
- (5) Chromosome during metaphase

Homologs

For higher organisms with sex discrimination, each cell contains two copies of each chromosome, one inherited from mother and the other inherited from father. This pair is called **homologous chromosomes or homologs.** Homologs are DNA sequences with a high degree of similarity. The only non-homologous chromosomes are the sex chromosomes in males, where father contributes a Y Chromosome and the mother contributes a X chromosome. Each human cells contain a total of 46 chromosomes- 22 pairs common to both male and female, X and Y in males and two X's in female.

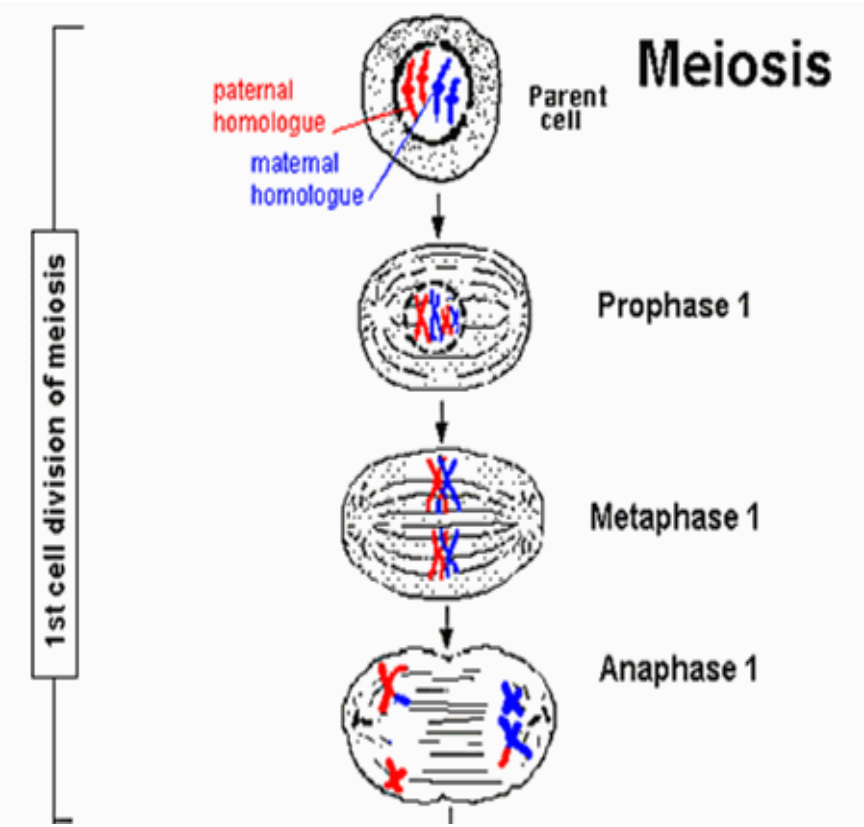


Each chromosome from the sperm can be matched with virtually identical one from the egg. Thus , there are two copies of each chromosome. These are called **homologs** Or homolog pairs.



Gamates are produced by a process called Meiosis

Meiosis



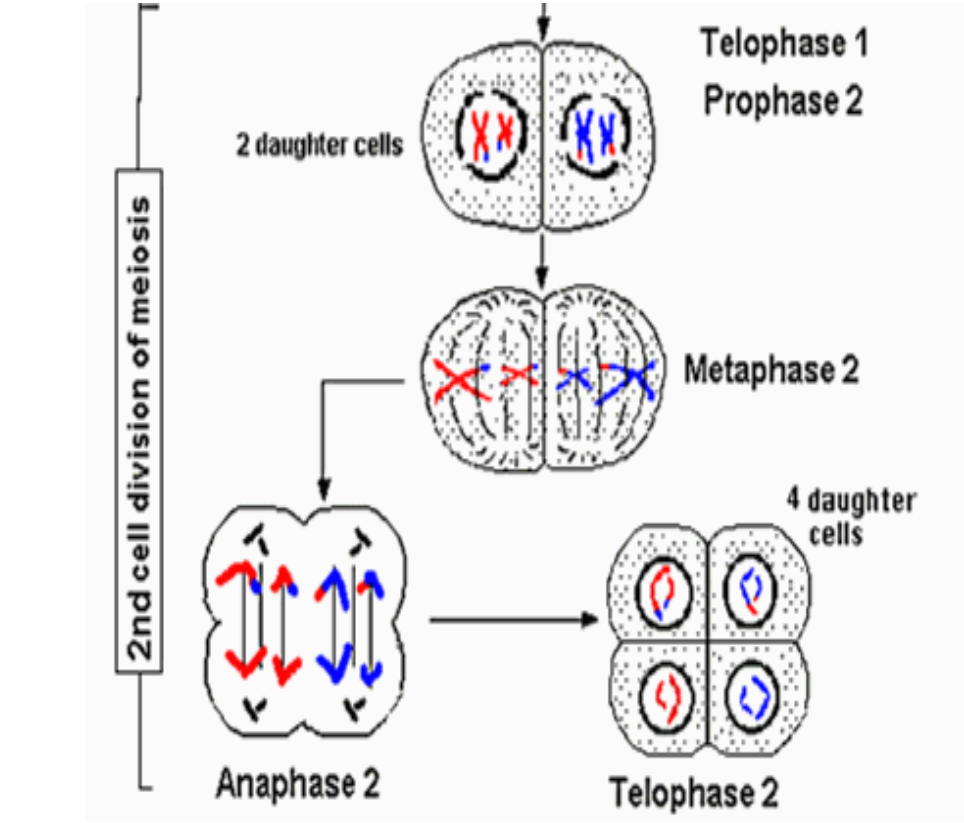


Diagram 1.

Meiosis (Short Description)

1. As in mitosis, the chromosome doubles and thickens
2. The homologs are paired off.
3. The spindle is formed (say, in vertical direction) and the chromosome “tetrads” gather at opposite poles.
4. The pairs are separeted and reach the opposite poles.
5. The spindle vanishes and a new spindle is formed in opposite direction (say in horizontal direction.
6. The chromosomes then separate as in Mitosis.

Thus, meiosis results in four cells , each with half the number of chromosomes. Which of the homolog of each chromosome goes to which cell is completely random. This variability is significant in evolution and heredity.

Meiosis (Long Description)

- Meiosis comprises two successive nuclear divisions with only one round of DNA replication.

- First division of meiosis
  - **Prophase 1:** Each chromosome duplicates and remains closely associated. These are called sister chromatids. Crossing-over can occur during the latter part of this stage.
  - **Metaphase 1**: Homologous chromosomes align at the equatorial plate.
  - **Anaphase 1**: Homologous pairs separate with sister chromatids remaining together.
  - **Telophase 1**: Two daughter cells are formed with each daughter containing only one chromosome of the homologous pair.

Meiosis (contd.)

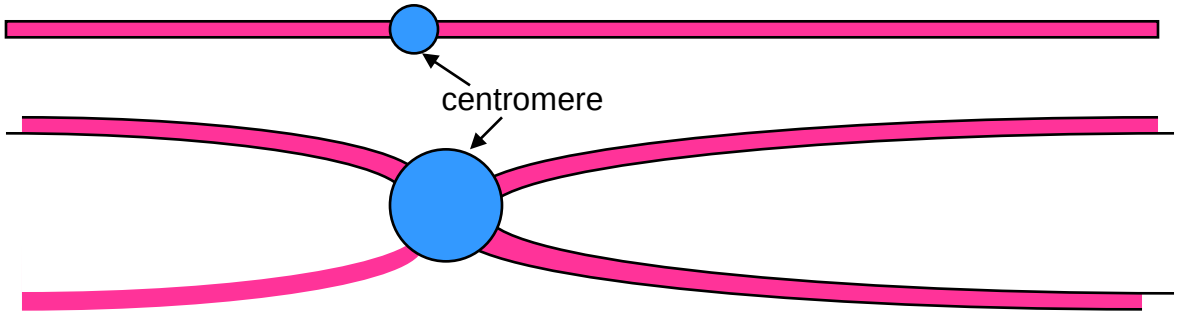
- Second division of meiosis: Gamete formation
  - **Prophase 2**: DNA does not replicate.
  - **Metaphase 2**: Chromosomes align at the equatorial plate.
  - **Anaphase 2**: Centromeres divide and sister chromatids migrate separately to each pole.
  - **Telophase 2**: Cell division is complete. Four haploid daughter cells are obtained.
- One parent cell produces **four** daughter cells.

Daughter cells:

  - half the number of chromosomes found in the original parent cell
  - crossing over cause genetically difference.

Diploid and Haploid

We explained mitotic division in the previous slide. In higher organisms, ***haploid cells***, each carrying one set of chromosomes, combine to produce ***diploid cells*** each carrying a double set of chromosomes. A chromosome is a single long double helix of DNA. At the beginning, its long and short 'arms' are joined by a **centromere**. At the end of 'metaphase', it is duplicated and condensed consisting of two identical sister double helix chain called **chromatids** joined at the centromere**.**

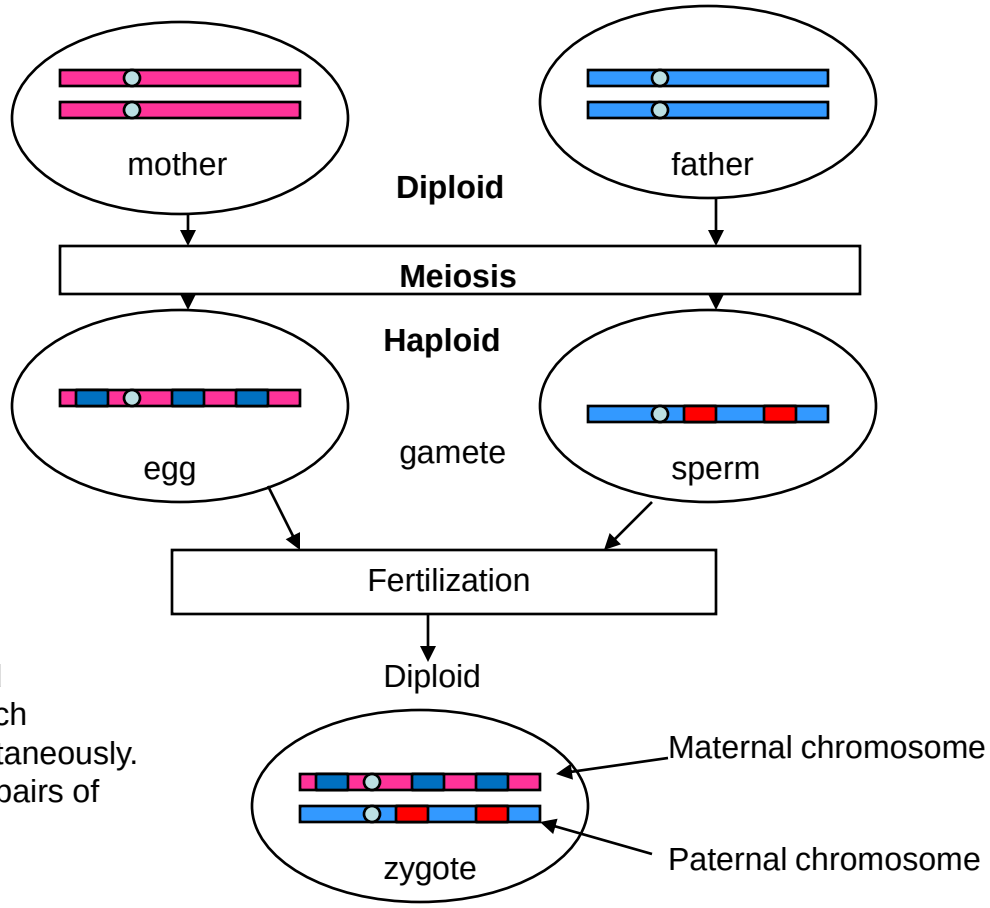


Reproduction

- Formation of new individual by a combination of two haploid sex cells (gametes).
- Fertilization- combination of genetic information from two separate cells that have one half the original genetic information
- Gametes for fertilization usually come from separate parents

  1. Female- produces an egg

  2. Male produces sperm
- Both gametes are haploid, with a single set of chromosomes
- The new individual is called a zygote, with two sets of chromosomes (diploid).
- **Meiosis** is a process to convert a diploid cell to a haploid gamete, and cause a change in the genetic information to increase the diversity of the offspring.



This diploid-haploid cycle occurs for each chromosome simultaneously. Humans have 23 pairs of Chromosomes.

Prokaryotes and Eukaryotes, continued

Prokaryotes	**Eukaryotes**
Single cell	Single or multi cell
No nucleus	Nucleus
No organelles	Organelles
One piece of circular DNA	Chromosomes
No mRNA post transcriptional modification	Exons/Introns splicing

Prokaryotes v.s. Eukaryotes
Structural differences

Prokaryotes

- Eubacterial (blue green algae) and archaebacteria
- only one type of membrane-- plasma membrane forms
  - the **boundary** of the cell proper
- The smallest cells known are bacteria
  - Ecoli cell
  - $3x10^6$ protein molecules
  - 1000-2000 polypeptide species.

Eukaryotes

- plants, animals, Protista, and fungi
- complex systems of internal membranes forms
  - ***organelle*** and ***compartments***
- The volume of the cell is several hundred times larger
  - $5x10^9$ protein molecules
  - 5000-10,000 polypeptide species

Prokaryotic and Eukaryotic Cells
Chromosomal differences

Prokaryotes

- The genome of E.coli contains amount of $4X10^6$ base pairs
- > 90% of DNA encode protein
- Lacks a membrane-bound nucleus.
  - Circular DNA and supercoiled domain
- Histones are unknown

Eukaryotes

- The genome of yeast cells contains $1.35x10^7$ base pairs
- A small fraction of the total DNA encodes protein.
  - Many repeats of non-coding sequences
- All chromosomes are contained in a membrane bound nucleus
  - DNA is divided between two or more chromosomes
- A set of five histones
  - DNA packaging and gene expression regulation

Chromosomes

One of the threadlike "packages" of genes and other DNA in the nucleus of a cell. Different kinds of organisms have different numbers of chromosomes. Humans have 23 pairs of chromosomes, 46 in all: 44 autosomes and two sex chromosomes. Each parent contributes one chromosome to each pair, so children get half of their chromosomes from their mothers and half from their fathers

We know now that DNA in chromosome carries the hereditary Information**.**

The are also protein components in Chromosomes to package an enormously large string of DNA into a compact shape that can fit inside of a cell.

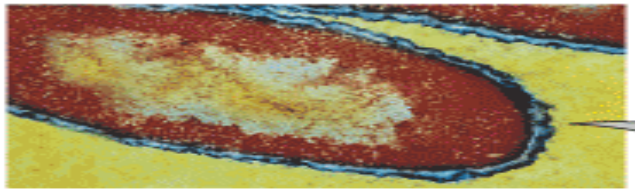
Chromosomes

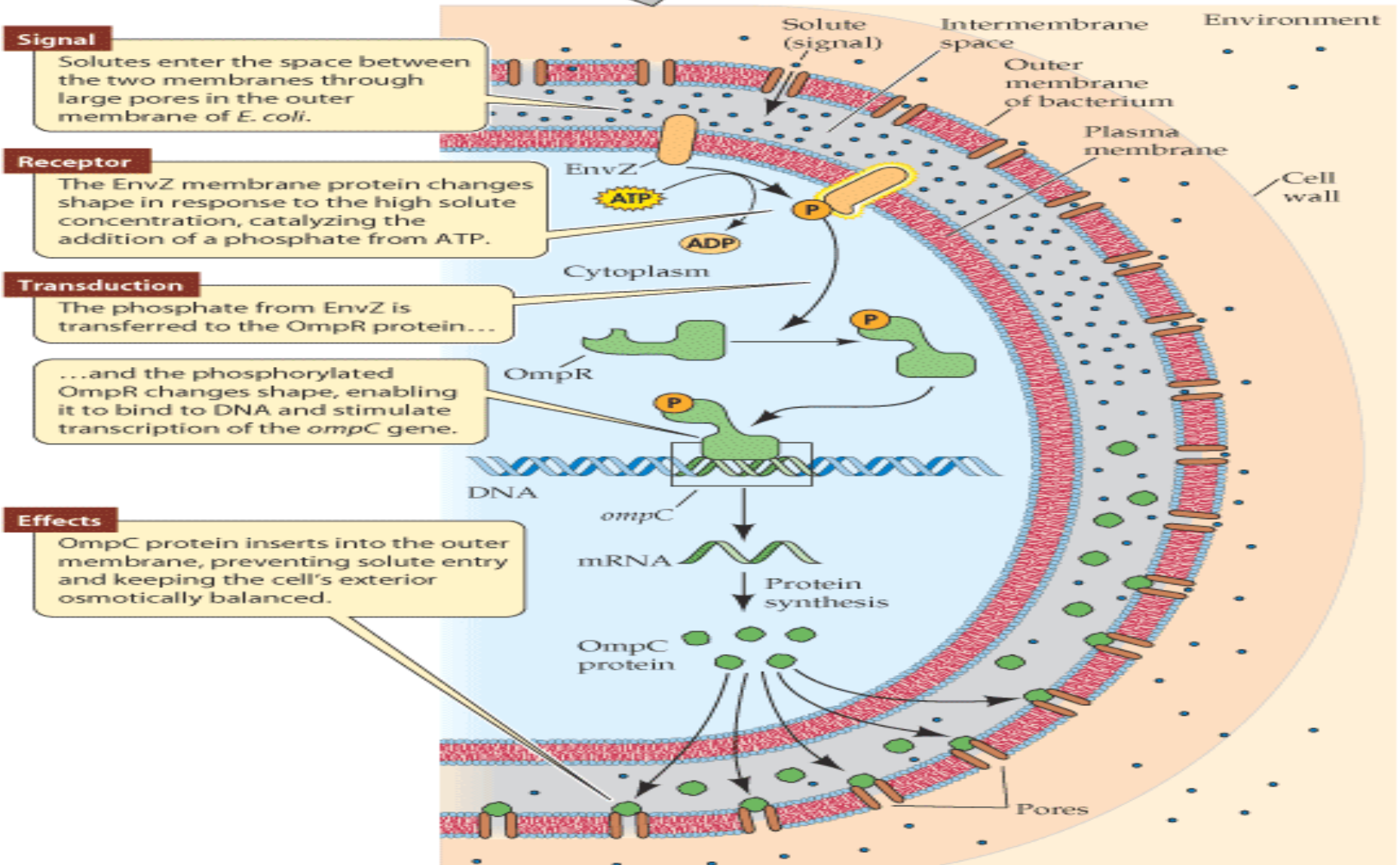
Organism	Number of base pair	number of Chromosomes
Prokayotic		
Escherichia coli (bacterium)	$4x10^6$	1
Eukaryotic		
Saccharomyces cerevisiae (yeast)	$1.35x10^7$	17
Drosophila melanogaster(insect)	$1.65x10^8$	4
Homo sapiens(human)	$2.9x10^9$	23
Zea mays(corn)	$5.0x10^9$	10

Signaling Pathways: Control Gene Activity

- Instead of having brains, cells make decision through complex networks of chemical reactions, called pathways
  - Synthesize new materials
  - Break other materials down for spare parts
  - Signal to eat or die

Example of cell signaling





Cells Information and Machinery

- Cells store all information to replicate itself
  - Human genome is around 3 billions base pair long
  - Almost every cell in human body contains same set of genes
  - But not all genes are used or expressed by those cells
- Machinery:
  - Collect and manufacture components
  - Carry out replication
  - Kick-start its new offspring

  (A cell is like a car factory)

Overview of organizations of life

- **Nucleus** = **library**
- **Chromosomes** = **bookshelves**
- **Genes** = **books**
- Almost every cell in an organism contains the same libraries and the same sets of books.
- Books represent all the information (DNA) that every cell in the body needs so it can grow and carry out its vaious functions.

Some Terminology

- **Genome**: an organism's genetic material
- **Gene**: a discrete units of hereditary information located on the chromosomes and consisting of DNA.
- **Genotype**: The genetic makeup of an organism
- **Phenotype**: the physical expressed traits of an organism
- **Nucleic acid**: Biological molecules(RNA and DNA) that allow organisms to reproduce;

More Terminology

- The **genome** is an organism's complete set of DNA.
  - a bacteria contains about 600,000 DNA base pairs
  - human and mouse genomes have some 3 billion.
- human genome has 24 distinct chromosomes.
  - Each chromosome contains many **genes**.
- **Gene**
  - basic physical and functional units of heredity.
  - specific sequences of DNA bases that encode instructions on how to make **proteins**.
- **Proteins**
  - Make up the cellular structure
  - large, complex molecules made up of smaller subunits called **amino acids.**

All Life depends on 3 critical molecules

- DNAs
  - Hold information on how cell works
- RNAs
  - Act to transfer short pieces of information to different parts of cell
  - Provide templates to synthesize into protein
- Proteins
  - Form enzymes that send signals to other cells and regulate gene activity
  - Form body's major components (e.g. hair, skin, etc.)