Molecular and Cell Biology

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2014 GT Superworkshop

Molecular and Cell Biology

- Cell Cycle
  - Mitosis
  - Meiosis
- Plant Cell Structure and Function
- Central Dogma

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Cell Cycle

Actively dividing eukaryote cells pass through a series of stages known collectively as the cell cycle:

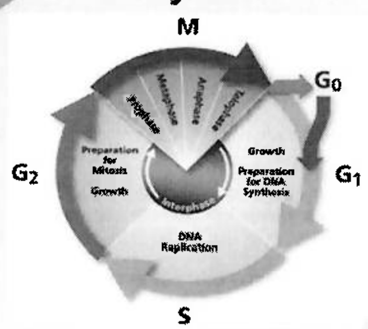
two gap phases (G1 and G2)

S (for synthesis) phase, in which the genetic material is duplicated

M phase, in which mitosis partitions the genetic material and the cell divides.

G1- growth and prep
S- DNA copied
M- cell divides

Cell Cycle



http://vcell.ndsu.nodak.edu/animations/

M- 4 stages
S- DNA replication

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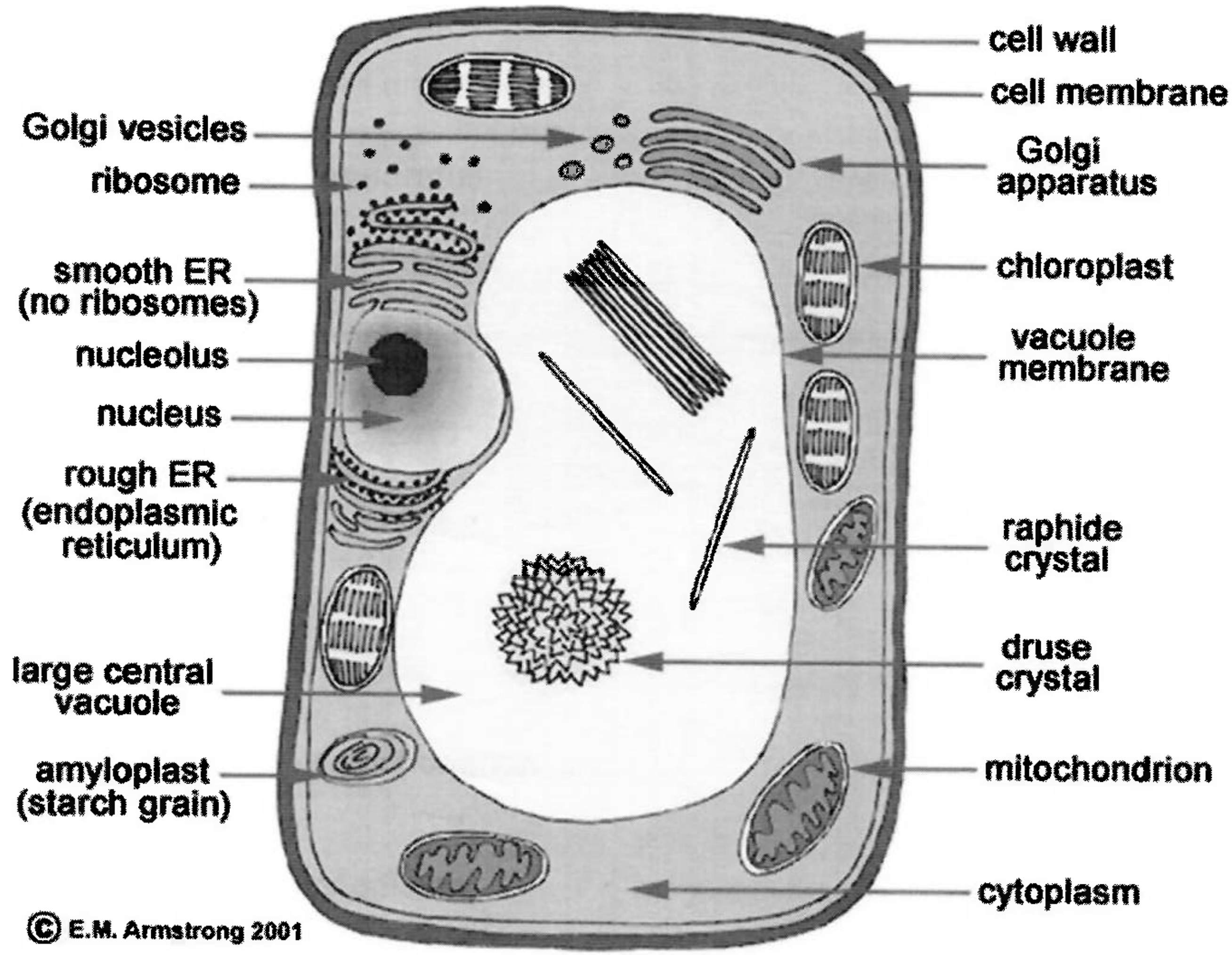
The Plant Cell



http://www.cellsalive.com/cells/cell_model.htm

Mitosis-- Movie Narrative (Advanced Look)

Cell division is required for an organism to grow, mature, and maintain tissues. During the mitotic phase, a cell will undergo mitosis to form two new nuclei and then divide to form two new individual cells during cytokinesis.

Mitosis is the process of dividing the duplicated DNA of a cell into two new nuclei. Mitosis is split into distinct stages. The first stage is prophase; the DNA condenses, organizes, and the classic chromosome structure appears. Next comes prometaphase where microtubules attach to the chromosomes. This step is followed by metaphase where the chromosomes align. Metaphase is followed by anaphase where the chromosomes separate. Finally, during telophase nuclear membranes reappear around the two sets of chromosomes. Mitosis is now complete. After mitosis two new cells are formed by a process called cytokinesis.

Mitosis is only one part of what is called the cell cycle. For many eukaryotic cells, a cell is duplicated every 24 hours. Most of the life of a cell is spent in interphase. Interphase consists of three stages called G1, S, and G2.

G1 (or Gap 1) is the first growth stage of interphase. In G1, the cell grows to nearly its full size and performs many of its specific biochemical functions that aid the organism.

Next is the S (or synthesis) phase. This is an important stage, because it is during the S phase that DNA in the nucleus is replicated.

The cell next enters another growth stage called G2 (or Gap 2). It is during G2 that the cell finishes growing. Once the cell has duplicated DNA in the nucleus, and two centrosomes have appeared in the cytoplasm, mitosis can begin. For a typical eukaryotic cell this will last about 80 minutes.

During the first stage of mitosis, called prophase, we first see the classic chromosome structure. This occurs through a condensation process. At the same time, protein strands called microtubules appear from the centrosomes in animals. Finally, a structure found within the nucleus, the nucleolus, disappears.

Next, prometaphase begins when the nuclear membrane is broken down. At the same time, microtubule strands, or spindle fibers, are growing from the centrosomes. These strands attach to a protein structure called the kinetochore. One kinetochore is attached to the centromere of each sister chromatid.

Next comes metaphase. During this stage the sister chromatids align along the center of the cell so that both chromatids face toward opposite poles of the cell.

Now the sister chromatids are ready to be separated. This occurs during anaphase through a shortening of the microtubules attached to the kinetochores. Additionally, the poles of the cell move farther apart and cause increased separation of sister chromatids. At the end of anaphase, the sister chromatids have moved to the two ends of the cell.

Telophase is the final stage of mitosis. It is here the components of the new cells begin to appear. At this point the spindle fibers are broken up. A new nuclear membrane surrounds the chromosomes at the end of each cell. And the chromosomes uncoil and return to an uncondensed state. Mitosis is now complete. The formation of two cells is all that remains.

Following mitosis, the cell undergoes a process called cytokinesis. First the cell is compressed by a contractile ring that divides the cell in nearly equal halves. By now the organelles in the cell have been replicated, and are now divided between the two halves of the cell. This includes mitochondria, golgi bodies, and the rough ER. Plant cells also have chloroplasts. Once split, the two new cells are now fully in the G1 stage of interphase and ready again to begin their growth.

Let's watch the process one more time. Mitosis begins with prophase. Notice the DNA condensing into chromosomes during this stage. Microtubules appear during prometaphase, and the nuclear membrane breaks down. Metaphase occurs when the chromosomes are aligned at the center of the cell. During anaphase the chromosomes are moving apart. The telophase stage is marked by the appearance of new nuclear membranes. This is the end of mitosis.

Finally, the splitting of the cell occurs during cytokinesis. The two new cells are now ready to grow and perform their specialized functions.

Meiosis-- Movie Narrative (Advanced Look)

Many organisms pass their genes to their offspring through sexual reproduction. This begins when two gametes unite to form an embryo that is genetically unique from the parent organisms. The embryo then grows into an adult who in turn passes their genetic information on to their offspring.

Gametes are formed through a process called meiosis. The cells that undergo meiosis to produce the gametes are called germ-line cells.

In diploid organisms, germ-line cells have two copies of each chromosome. Germ-line cells undergo meiosis to produce haploid gametes which have only one copy of each chromosome. These haploid gametes fuse to form a diploid embryo that grows into the adult.

Meiosis is just one step in the life cycle of a germ-line cell. Similar to mitosis, the cells also pass through the interphase, G1, S, and G2 stages before they enter meiosis. The DNA inside a germ-line cell is duplicated before meiosis begins during the S phase. The duplicated germ-line chromosomes are called sister chromatids. These chromatids remain attached to each other until the second cell division event in meiosis.

There are two cell division events during meiosis. The first division, meiosis I, results in two unique daughter cells that have half the amount of DNA as the parent germ-line cell. The second division, meiosis II, results in four unique haploid cells that only have one copy of each chromosome. These haploid cells are the gametes that could go on to produce an offspring through sexual reproduction.

Let's look more closely at each of the division events. Meiosis begins with prophase I. In this stage, the DNA condenses to form chromosomes. Here we see the duplicated sister chromatids joined together at the centromere. They stay fused at the centromere throughout Meiosis I. Next, each pair of homologous chromosomes undergoes synapsis to form a complex involving two pairs of sister chromatids. Chromosomal material is exchanged between the two pairs of sister chromatids. This event is called recombination or more commonly, crossing over. After crossing over, the sister chromatids for each chromosome are no longer identical to one another. This is one of the reasons why no two siblings (aside from twins) are genetically identical.

There are several more key steps in prophase I. The nuclear membrane begins to break down. Then the two centrosomes migrate to opposite ends of the cell and microtubules appear. The microtubules then attach to the chromosomes.

The next phase of meiosis I is called metaphase I. Here the synapsed chromosomes align at the equator of the cell. The chromosomes align randomly which results in different combinations each time meiosis occurs.

The next phase is anaphase I. During this phase, homologous chromosomes separate and migrate to the two poles of the cell. Importantly, the sister chromatids remain attached at their centromeres.

The final steps of meiosis I are telophase I and cytokinesis. Here the cell divides into two daughter cells.

Each of these two cells now undergo meiosis II. Meiosis II is similar to mitosis.

The first stage of meiosis II is prophase II. Again, chromosomes condense, the nuclear envelop breaks down, and the spindle apparatus forms. The major difference between prophase II and prophase I is the fact that the daughter cells have only one copy of each homologous chromosome. So, in prophase II, there is no synapsis of homologous chromosomes or crossing over.

In metaphase II, the chromosomes align at the equator of the cell. Again, the alignment is random. Since the sister chromatids are no longer identical, there will be many different possible ways for these chromosomes to align.

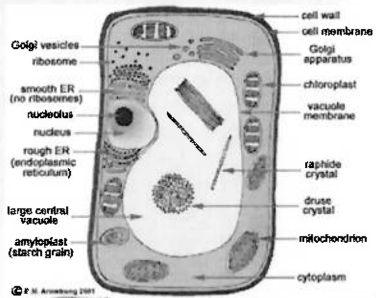
In anaphase II, the sister chromatids are pulled apart as the microtubules shorten. Also, the ends of the cell are pushed further apart as microtubules elongate.

In telophase II, the nuclear membrane reforms, and the cytoplasm is divided into the two haploid daughter cells. This division is called cytokinesis. Since meiosis II began with two cells, and each of those cells were split into two cells, we now have 4 unique haploid cells at the end of meiosis. These cells are gametes.

Two gametes, one from the father and one from the mother, may fuse to produce a diploid embryo. The resulting embryo then grows through many cycles of mitosis.

Mitosis twice, but the second time the DNA doesn't replicate.

The Plant Cell



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TO HELP STUDY

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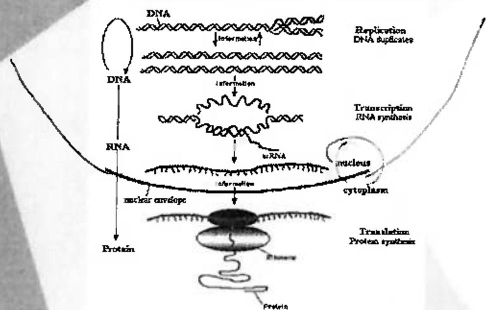
- Central Dogma

Central Dogma

- **Transcription of DNA to RNA to protein: This dogma forms the backbone of molecular biology and is represented by four major stages.**
  - **DNA REPLICATION**
  - **TRANSCRIPTION**
  - **PROCESSING**
  - **TRANSLATION**

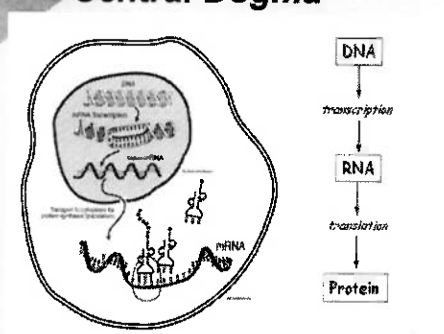
Central Dogma



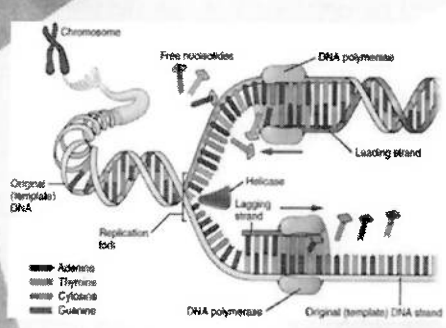
The Central Dogma of Molecular Biology

BE ABLE TO DRAW THIS

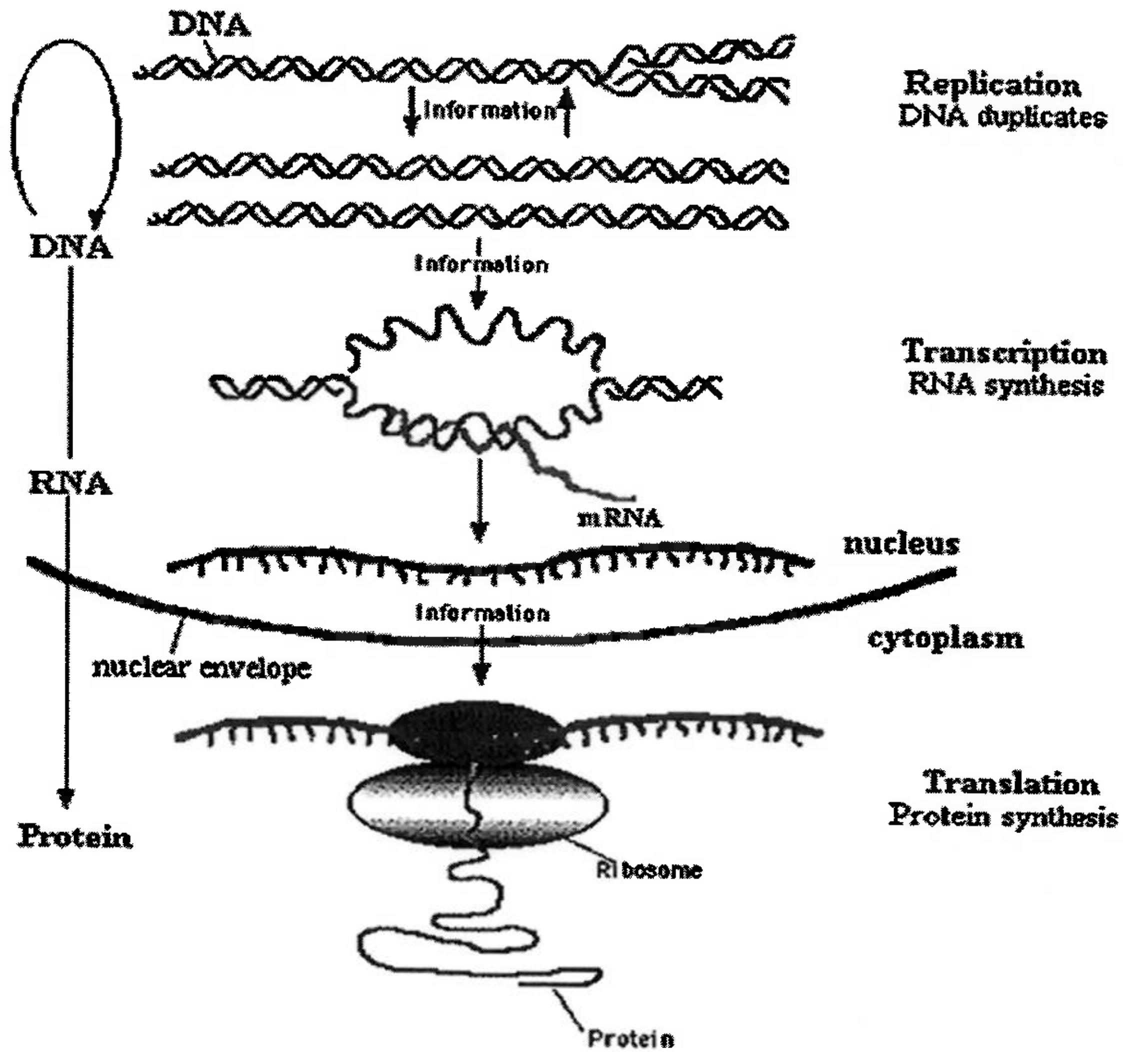
Central Dogma



DNA

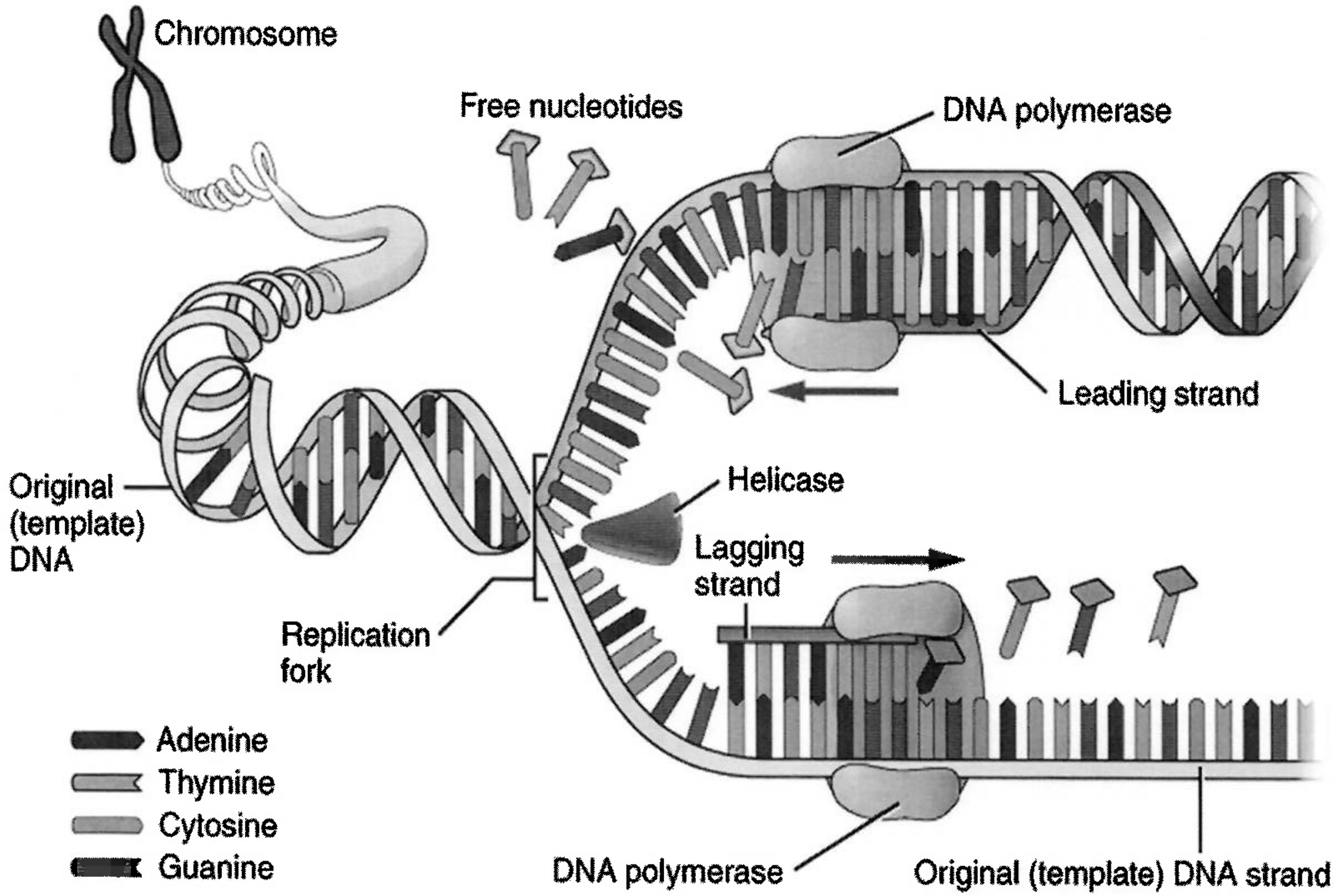


Central Dogma

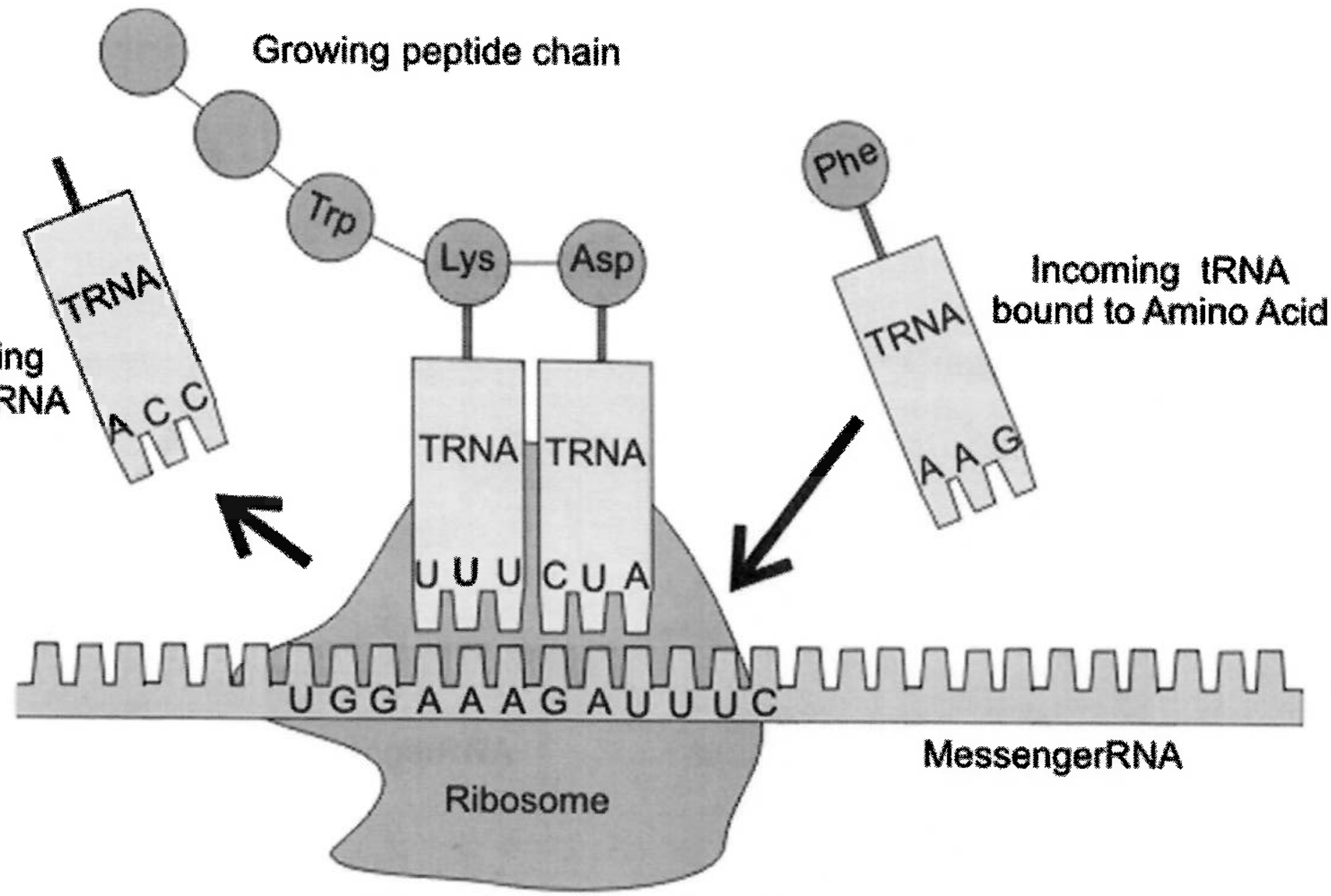


The Central Dogma of Molecular Biology

DNA


Chromosome
Free nucleotides
DNA polymerase
Leading strand
Helicase
Lagging strand
Original (template) DNA
Replication fork
Adenine
Thymine
Cytosine
Guanine
DNA polymerase
Original (template) DNA strand

Messenger RNA, Transfer RNA and Protein Synthesis



Peptide Synthesis

Transcription -- Movie Narrative (Advanced Look)

Transcription is the process of making RNA from a DNA template. Several key factors are involved in this process. Including, DNA, transcription factors, RNA polymerase, and ATP.

Transcription begins with a strand of DNA. It is divided into several important regions. The largest of these is the transcription unit. This portion of the DNA will be used to produce RNA. Upstream of the transcription unit is the TATA box. An enhancer region may also be involved.

Several complexes, known as transcription factors, are required for successful transcription. The first is TFIID, the largest of the general factors. A component of this factor, TBP, binds to the DNA using the TATA box to position TFIID near the transcription initiation site. Other transcription factors, including TFIIA and TFIIB, then attach.

These complexes prepare the DNA for the successful binding of RNA polymerase. One RNA polymerase is bound, other transcription factors complete the mature transcription complex.

Now, energy must be added to the system for transcription to begin. This energy is provided by the reduction of ATP into ADP and Pi.

RNA polymerase then synthesizes an RNA template from the strand of DNA. Most factors are released after transcription begins. When the end of the transcription unit is reached, the RNA polymerase dissociates, and the newly formed strand of RNA is released.

Translation -- Movie Narrative

Translation is the synthesis of a protein from an mRNA template. This process involves several key molecules including mRNA, the small and large subunits of the ribosome, tRNA, and finally, the release factor. The process is broken into three stages: initiation, elongation, and termination. Let's see the process in action...

Eukaryotic mRNA, the substrate for translation, has a unique 3'-end called the poly-A tail. mRNA also contains codons that will encode specific amino acids.

A methylated cap is found at the 5'-end. Translation initiation begins when the small subunit of the ribosome attaches to the cap and moves to the translation initiation site.

tRNA is another key molecule. It contains an anticodon that is complementary to the mRNA codon to which it binds. The first codon is typically AUG. Attached to the end of tRNA is the corresponding amino acid. Methionine corresponds to the AUG codon.

The large subunit now binds to create the peptidyl (or P) site and the aminoacyl (or A) site. The first tRNA occupies the P-site. The second tRNA enters the A-site and is complementary to the second codon.

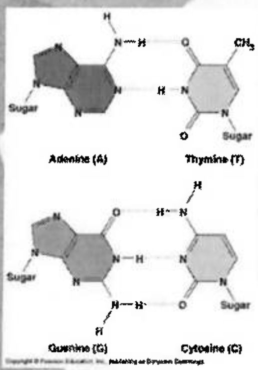
The methionine is transferred to the A-site amino acid, the first tRNA exits, the ribosome moves along the mRNA, and the next tRNA enters. These are the basic steps of elongation.

As elongation continues, the growing peptide is continually transferred to the A-site tRNA, the ribosome moves along the mRNA, and new tRNAs enter.

When a stop codon is encountered in the A-site, a release factor enters the A-site and translation is terminated. When termination is reached, the ribosome dissociates, and the newly formed protein is released.

There are 3 different stop codons.

DNA BASE PAIRS



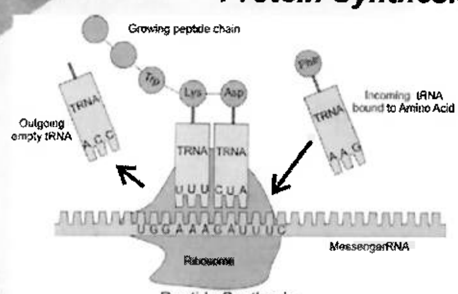
The bases hydrogen bond with each other to form "BASE PAIRS"

A single ring only bonds with a double ring.

A-T has two H bonds, and G-C has three H bonds. G-C base pairs are stronger and more difficult to split

A-T : 2 H bonds
G-C : 3 H bonds

Messenger RNA, Transfer RNA and Protein Synthesis



Peptide Synthesis

A-U : ~~m~~RNA
G-C : RNA

tRNA - 3 base pair codone

DO NOT HAVE TO MATCH AMINO ACIDS TO CODONS

Plant Cell Structure Glossary:

amyloplast - an organelle in some plant cells that stores starch. Amyloplasts are found in starchy plants like tubers and fruits.
ATP - ATP is short for adenosine triphosphate; it is a high-energy molecule used for energy storage by organisms. In plant cells, ATP is produced in the cristae of mitochondria and chloroplasts.
cell membrane - the thin layer of protein and fat that surrounds the cell, but is inside the cell wall. The cell membrane is semipermeable, allowing some substances to pass into the cell and blocking others.
cell wall - a thick, rigid membrane that surrounds a plant cell. This layer of cellulose fiber gives the cell most of its support and structure. The cell wall also bonds with other cell walls to form the structure of the plant.
centrosome - (also called the "microtubule organizing center") a small body located near the nucleus - it has a dense center and radiating tubules. The centrosomes is where microtubules are made. During cell division (mitosis), the centrosome divides and the two parts move to opposite sides of the dividing cell. Unlike the centrosomes in animal cells, plant cell centrosomes do not have centrioles.
chlorophyll - chlorophyll is a molecule that can use light energy from sunlight to turn water and carbon dioxide gas into sugar and oxygen (this process is called photosynthesis). Chlorophyll is magnesium based and is usually green.
chloroplast - an elongated or disc-shaped organelle containing chlorophyll. Photosynthesis (in which energy from sunlight is converted into chemical energy - food) takes place in the chloroplasts.
christae - (singular crista) the multiply-folded inner membrane of a cell's mitochondrion that are finger-like projections. The walls of the cristae are the site of the cell's energy production (it is where ATP is generated).
cytoplasm - the jellylike material outside the cell nucleus in which the organelles are located.
Golgi body - (also called the golgi apparatus or golgi complex) a flattened, layered, sac-like organelle that looks like a stack of pancakes and is located near the nucleus. The golgi body packages proteins and carbohydrates into membrane-bound vesicles for "export" from the cell.
granum - (plural grana) A stack of thylakoid disks within the chloroplast is called a granum.
mitochondrion - spherical to rod-shaped organelles with a double membrane. The inner membrane is infolded many times, forming a series of projections (called cristae). The mitochondrion converts the energy stored in glucose into ATP (adenosine triphosphate) for the cell.
nuclear membrane - the membrane that surrounds the nucleus.
nucleolus - an organelle within the nucleus - it is where ribosomal RNA is produced.
nucleus - spherical body containing many organelles, including the nucleolus. The

nucleus controls many of the functions of the cell (by controlling protein synthesis) and contains DNA (in chromosomes). The nucleus is surrounded by the nuclear membrane

photosynthesis - a process in which plants convert sunlight, water, and carbon dioxide into food energy (sugars and starches), oxygen and water. Chlorophyll or closely-related pigments (substances that color the plant) are essential to the photosynthetic process.

ribosome - small organelles composed of RNA-rich cytoplasmic granules that are sites of protein synthesis.

rough endoplasmic reticulum - (rough ER) a vast system of interconnected, membranous, infolded and convoluted sacks that are located in the cell's cytoplasm (the ER is continuous with the outer nuclear membrane). Rough ER is covered with ribosomes that give it a rough appearance. Rough ER transport materials through the cell and produces proteins in sacks called cisternae (which are sent to the Golgi body, or inserted into the cell membrane).

smooth endoplasmic reticulum - (smooth ER) a vast system of interconnected, membranous, infolded and convoluted tubes that are located in the cell's cytoplasm (the ER is continuous with the outer nuclear membrane). The space within the ER is called the ER lumen. Smooth ER transport materials through the cell. It contains enzymes and produces and digests lipids (fats) and membrane proteins; smooth ER buds off from rough ER, moving the newly-made proteins and lipids to the Golgi body and membranes

stroma - part of the chloroplasts in plant cells, located within the inner membrane of chloroplasts, between the grana.

thylakoid disk - thylakoid disks are disk-shaped membrane structures in chloroplasts that contain chlorophyll. Chloroplasts are made up of stacks of thylakoid disks; a stack of thylakoid disks is called a granum. Photosynthesis (the production of ATP molecules from sunlight) takes place on thylakoid disks.

vacuole - a large, membrane-bound space within a plant cell that is filled with fluid. Most plant cells have a single vacuole that takes up much of the cell. It helps maintain the shape of the cell.