BB101
General Introduction to Biology

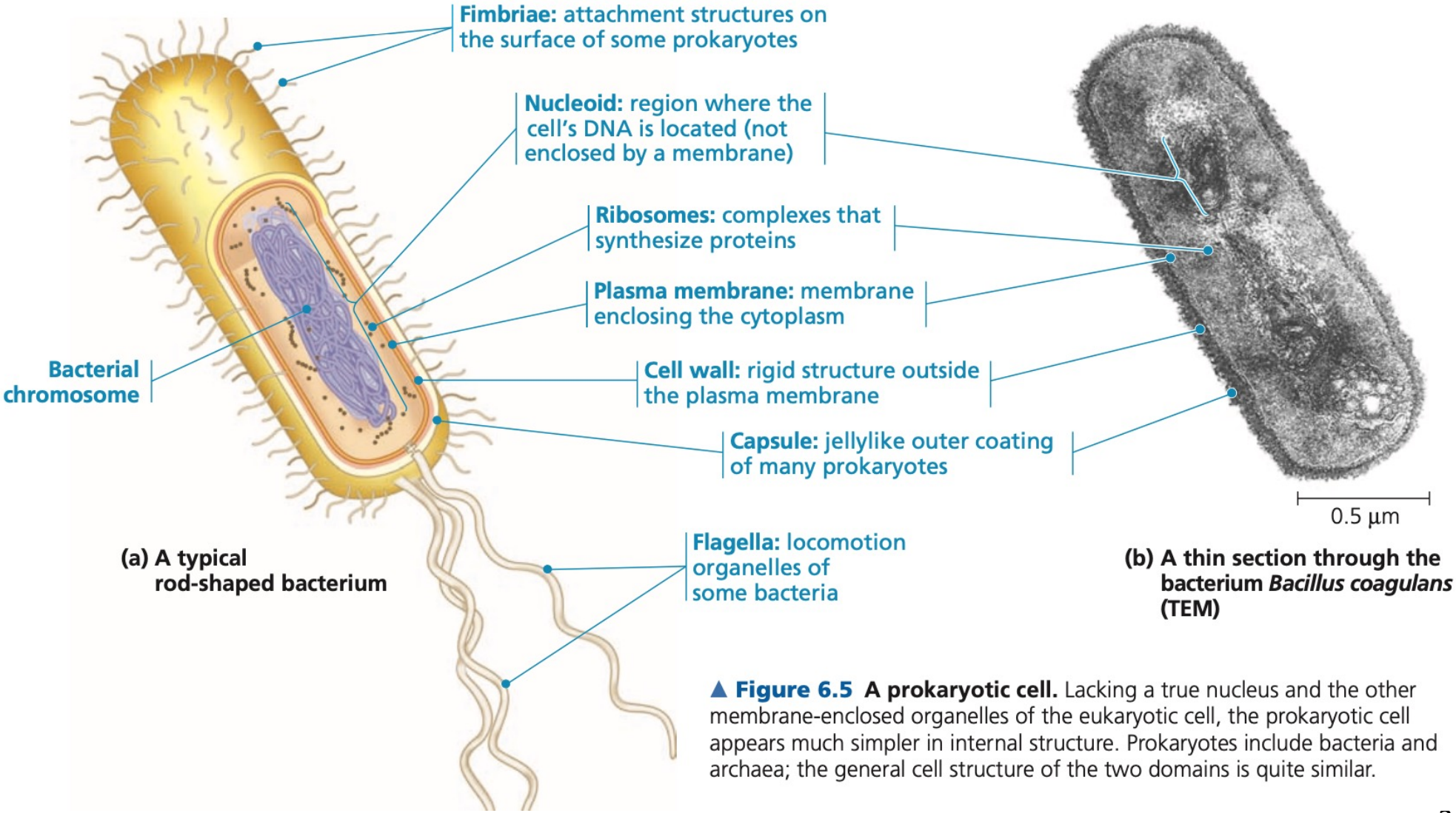
Tutorial 1
(SS-T1)
Introduction

11 January 2024

The functional unit of life: Cell

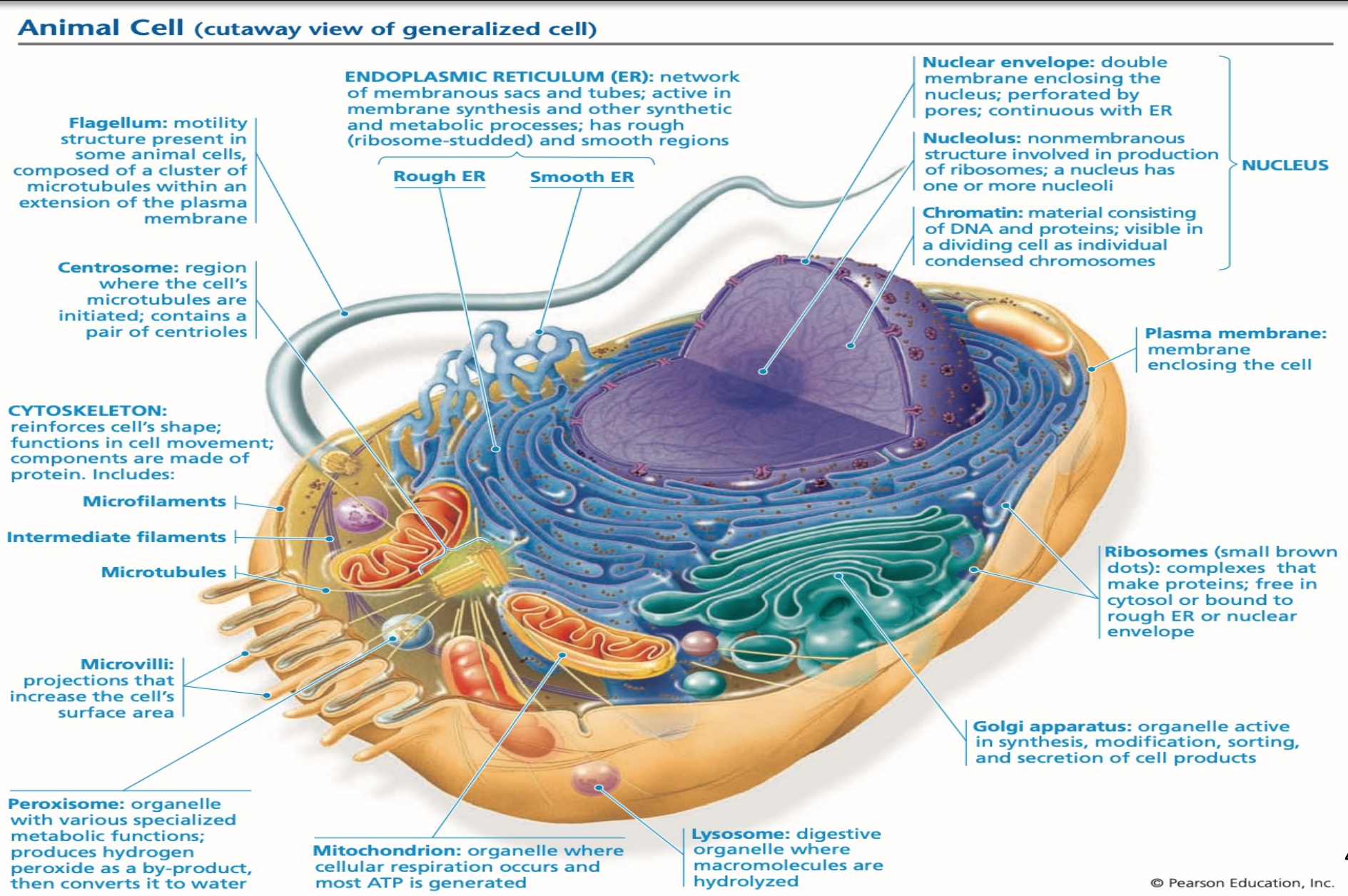
- Prokaryotic cell
- Eukaryotic cell

Prokaryotic Cell

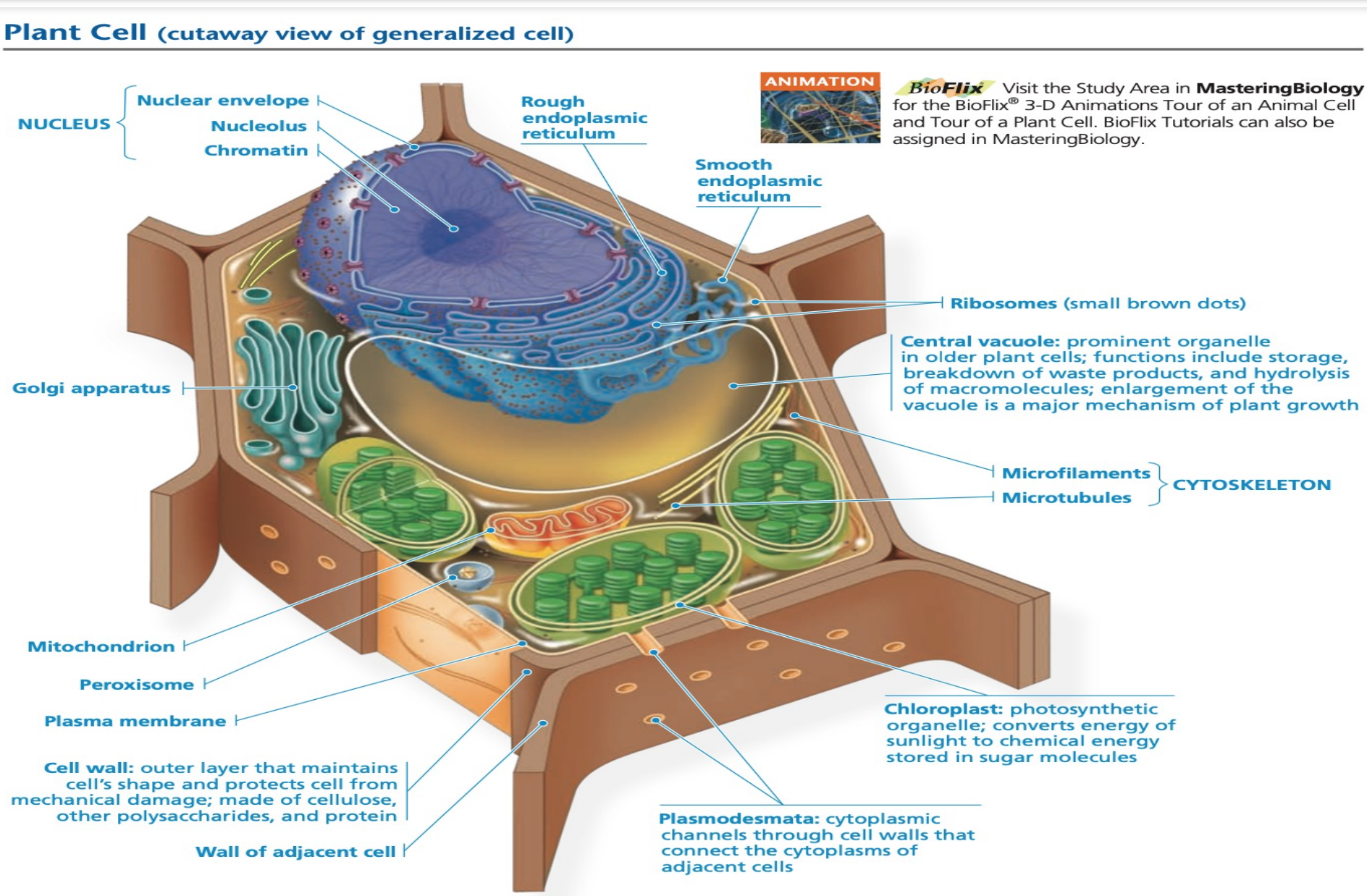


▲ **Figure 6.5 A prokaryotic cell.** Lacking a true nucleus and the other membrane-enclosed organelles of the eukaryotic cell, the prokaryotic cell appears much simpler in internal structure. Prokaryotes include bacteria and archaea; the general cell structure of the two domains is quite similar.

Eukaryotic Cell



Eukaryotic Cell

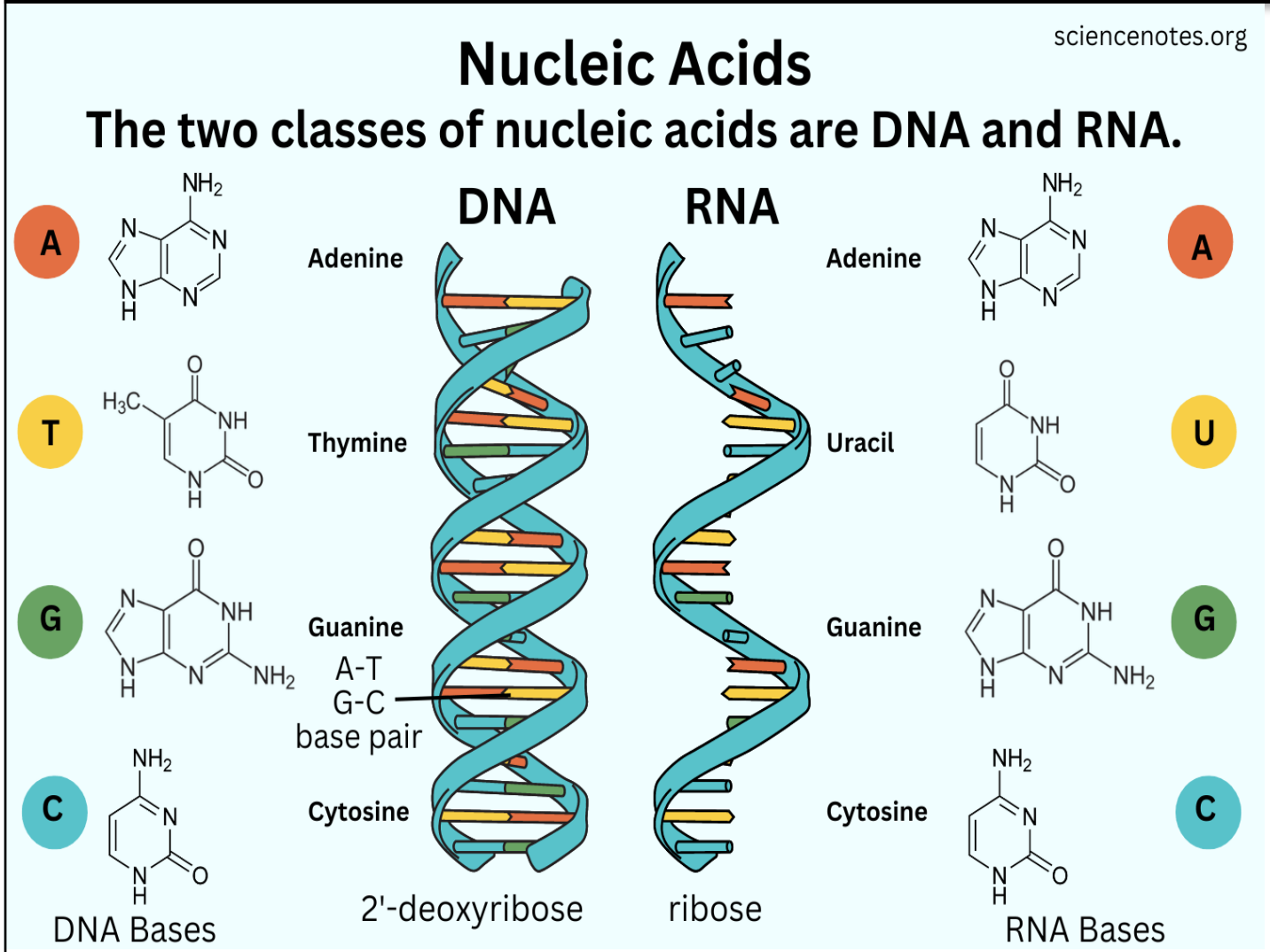


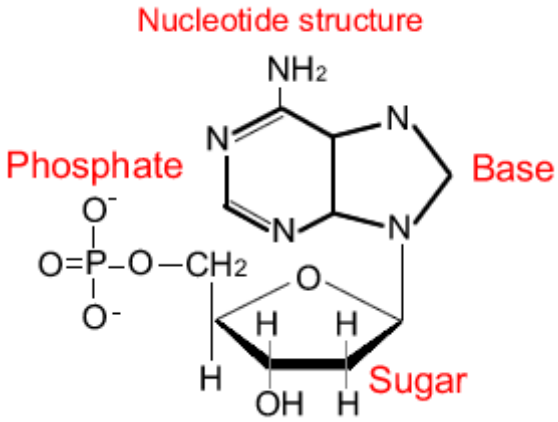
Biological Macromolecules

Life depends on **four** types of organic macromolecules:

1. Nucleic acids
2. Proteins
3. Lipids
4. Carbohydrates

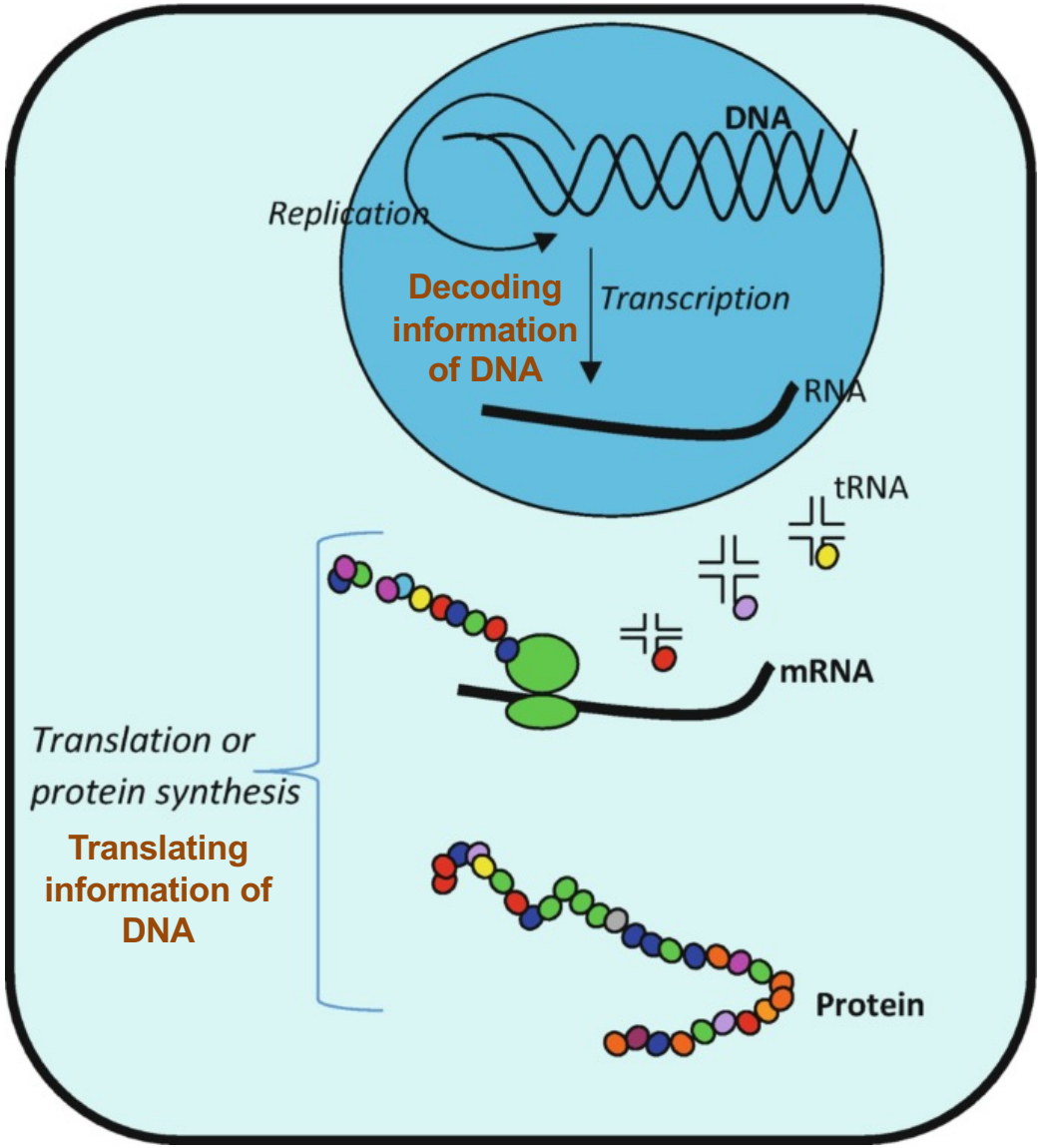
Nucleic Acids





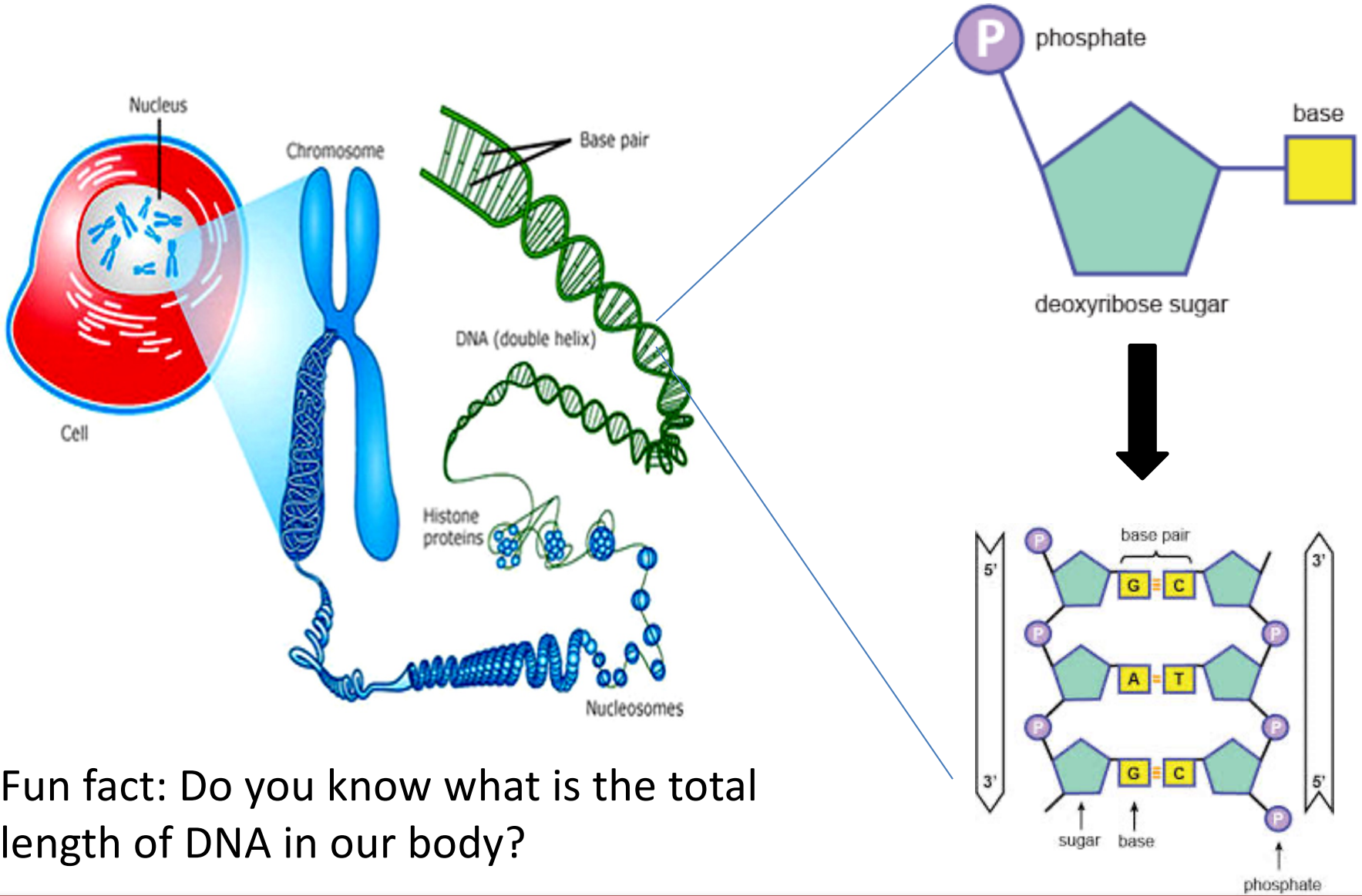
Why named so?

Central Dogma of Cell



https://doi.org/10.1007/978-3-031-37192-9_3

Deoxyribonucleic Acid (DNA)



Fun fact: Do you know what is the total length of DNA in our body?

Interesting Facts about DNA Sequence

Unrelated people

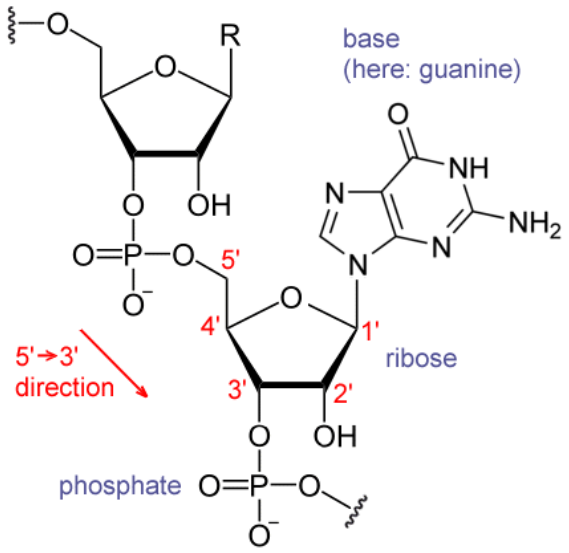
Parent and offspring

Man and chimpanzee (>95%)

Man and cabbage (>50%)

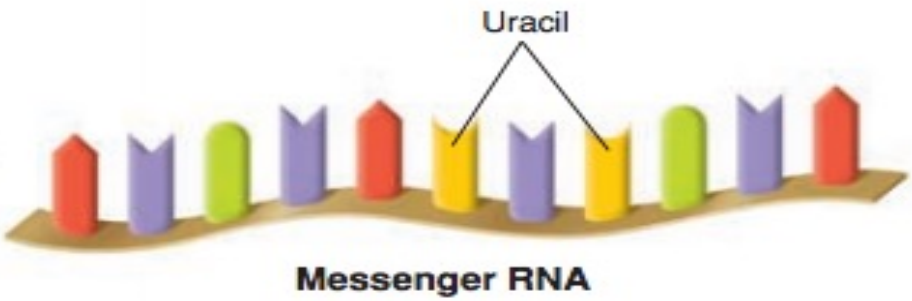
Ribonucleic Acid (RNA)

- Polymer of ribonucleotides
- Usually, single stranded
- Bases: guanine, uracil, adenine, and cytosine
- Synthesized by transcription

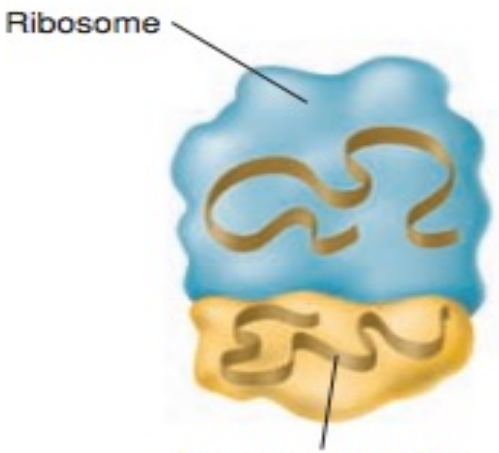


Ribonucleic acid

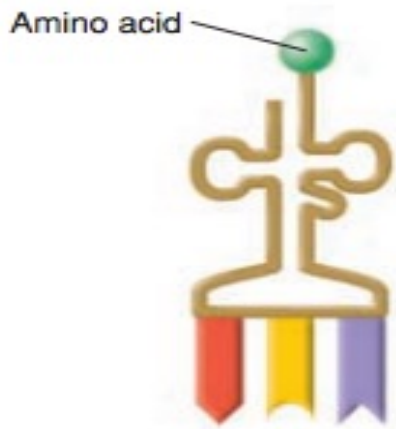
Types of RNA



Messenger RNA



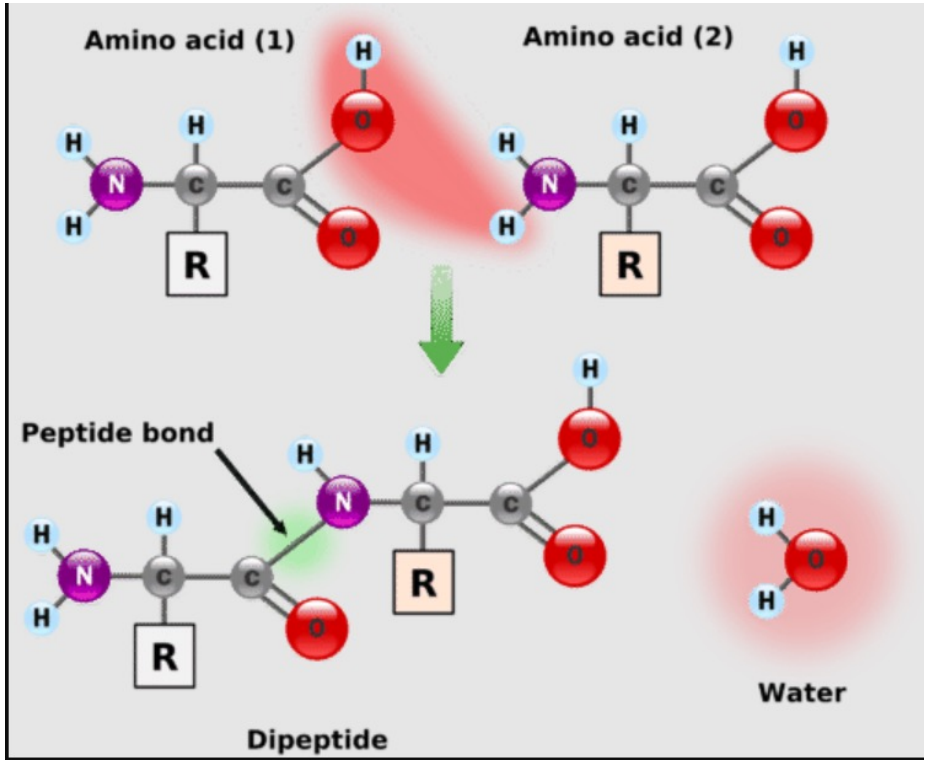
Ribosomal RNA



Transfer RNA

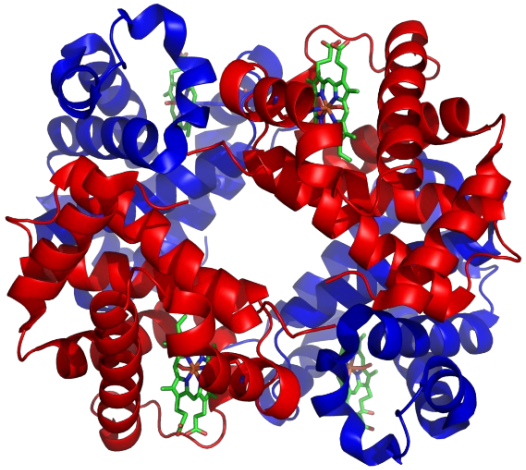
Proteins?

- Large molecules
- Made of amino acids
- Two amino acids are linked by peptide bond
- **Body's functions – workhorses of cell**
- Sequence is determined by DNA
- Structure is crucial for function



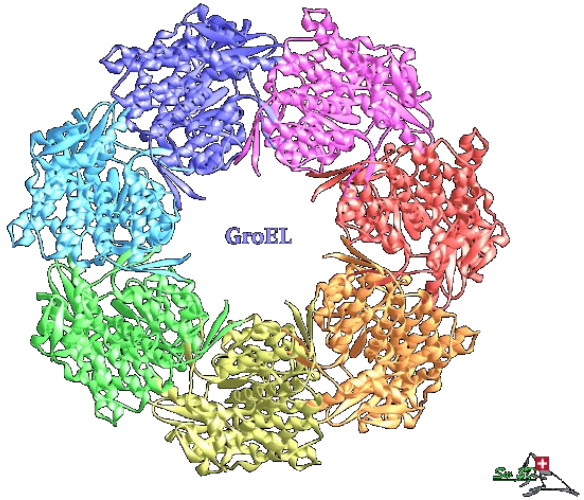
Chemistry Libretext

Protein Structure



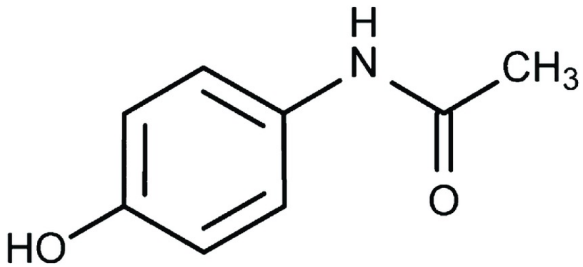
Source – Wikipedia

Source – RCSB PDB

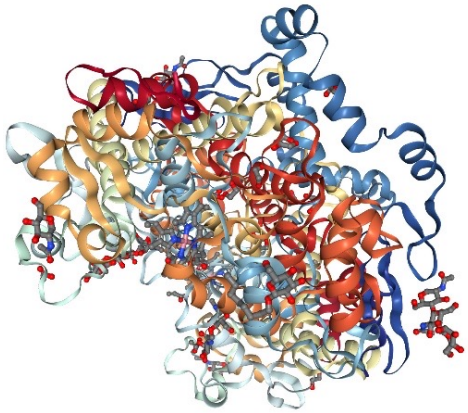


Source – Online Analysis Tools

Drugs – More than 70% of drugs have proteins as their target



Paracetamol



COX2

Source – RCSB PDB

Protein Structure Prediction Using AI

Proteins are complex molecules that are essential to life. Each has its own unique 3D shape that determines how it works and what it does.

Knowing how proteins fold could help scientists understand the biological processes of every living thing. To accelerate progress, we created AlphaFold, a system which accurately predicts the shape of proteins. This research has enormous potential in every field of biology, from helping tackle disease and quickly finding new medicines to unlocking the mysteries of how life itself works.

Carbohydrates

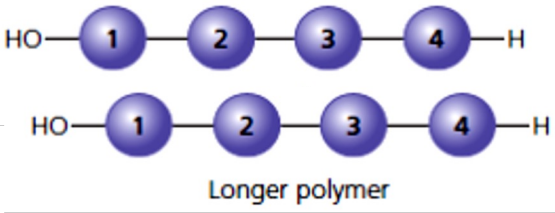
Carbohydrates: Monomers and polymers of sugar

Polymers ↔ **Monomers**

(Energy storage, structural blocks) (Readily available Energy forms)

Primary production (Polymers formation)

Plants

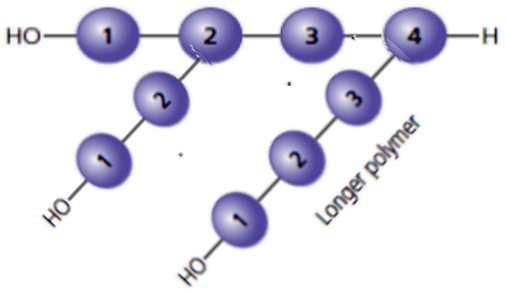


Hydrolysis (Monomerization)

Digestion by animals

Dehydration (polymerization)

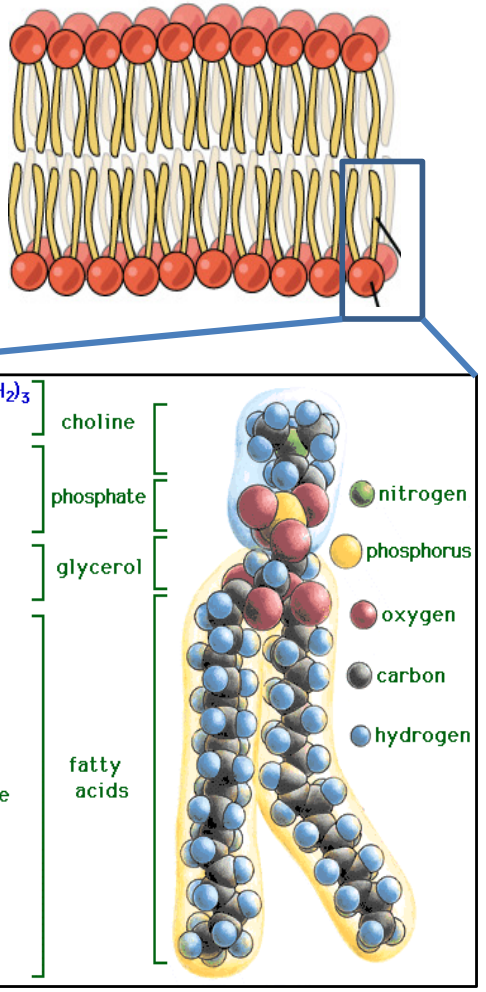
Re-Building structural & functional blocks



Lipids

Lipids: **Organic biomolecules grouped together based on their hydrophobic trait.**

- Energy storage and Structural roles.
- Chains ranging from C_4-C_{36}.



Lipids

Structural roles: eg: Phospholipids

Energy storage: eg: Triglycerides

Why Lipids as Storage?

1 g **Carbohydrates** = **4.0** kcal

1 g **Fat** = **9.0** kcal

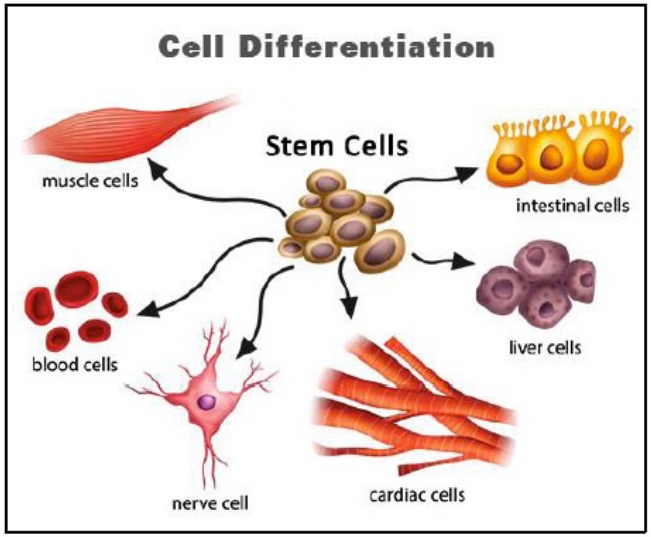
Less weight with more Energy storage

Cell Division

GROWTH

REPAIR

DIFFERENTIATION



Types of Cell Division:

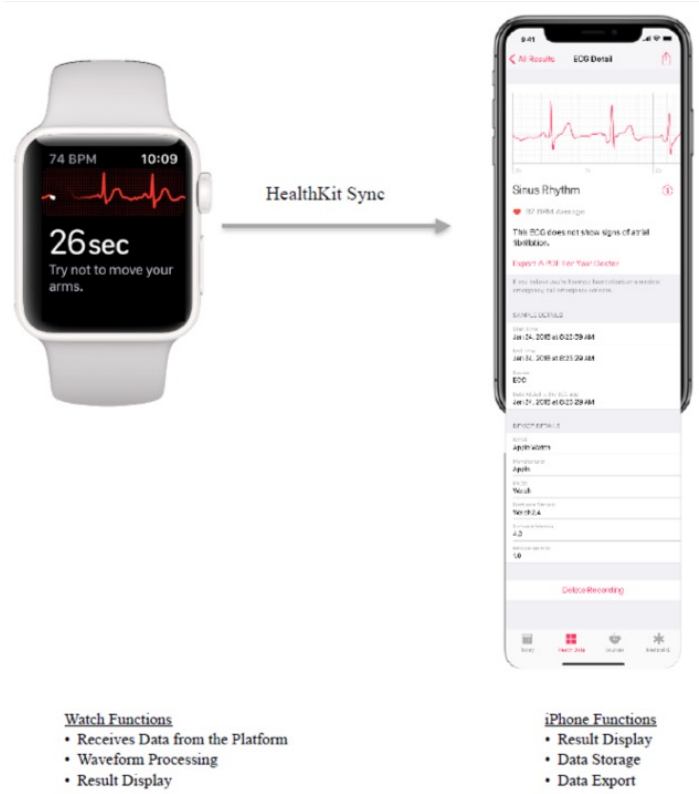
1. Mitosis
2. Meiosis

Real Life Applications of Biology

Biology: Overcoming Health Challenges

Forbes

Apple Watch 4 Is Now An FDA Class 2 Medical Device: Detects Falls, Irregular Heart Rhythm



HEALTHCARE ON YOUR WRIST

cardiogram

Consumer wearables like Android Wear, Fitbit, and Apple Watch will generate two trillion health measurements this year—far too many for any human doctor to review. To help create the future of preventive medicine, we're building DeepHeart, a novel deep neural network tested in multiple rigorous clinical studies.

- Cardiovascular Risk Prediction
- Abnormal heart rhythm – Atrial fibrillation
- Hypertension, Sleep Apnea

What the future looks like?

- Glucose monitoring
- Blood Pressure
- Oxygen Levels
- Parkinson's disease diagnosis and monitoring
- Respiration Rate

Biology: Overcoming Health Challenges

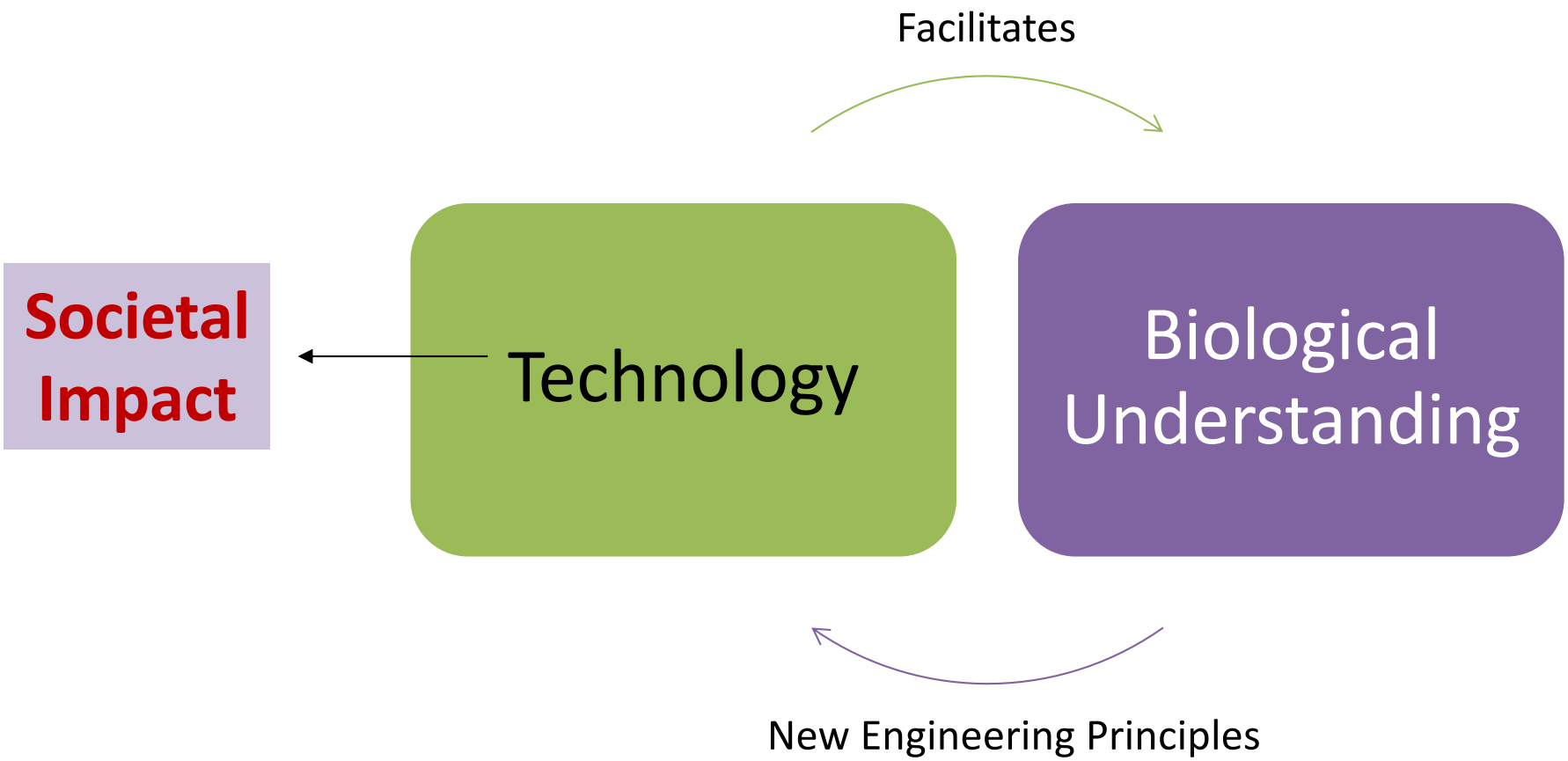
NEURAL ENGINEERING | NEWS

Brain–computer interface that allowed a paralysed man to walk is the *Physics World* 2023 Breakthrough of the Year

- **A digital bridge that restores communication between the brain and spinal cord.**
- When tested on a man with paralysis, the system enabled him to stand and walk naturally

Gert-Jan Oskam is able to walk on his own, thanks to the new technology that interprets messages from his brain | CREDIT: Ecole Polytechnique Federale de Lausanne

Partnership Between Biology and Technology



Take home!

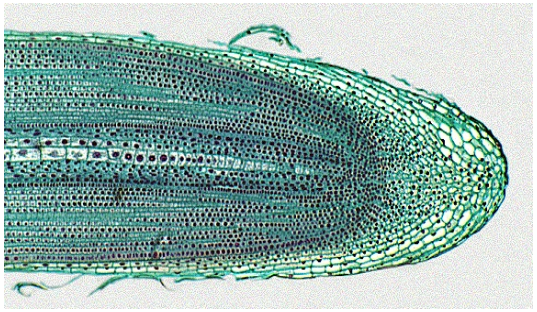
"One of the very few silver linings about me getting sick is that Reed's gotten to spend a lot of time studying with some very good doctors... I think the biggest innovations of the twenty-first century will be the intersection of biology and technology. A new era is beginning, just like the digital one when I was his age."

Steve Jobs

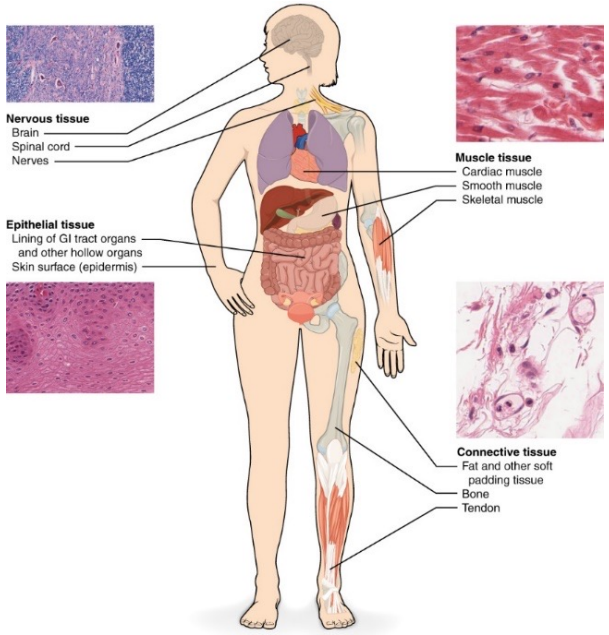
Thank You

Concepts and Queries

Why bother with multi-cellularity? Why not one large cell?

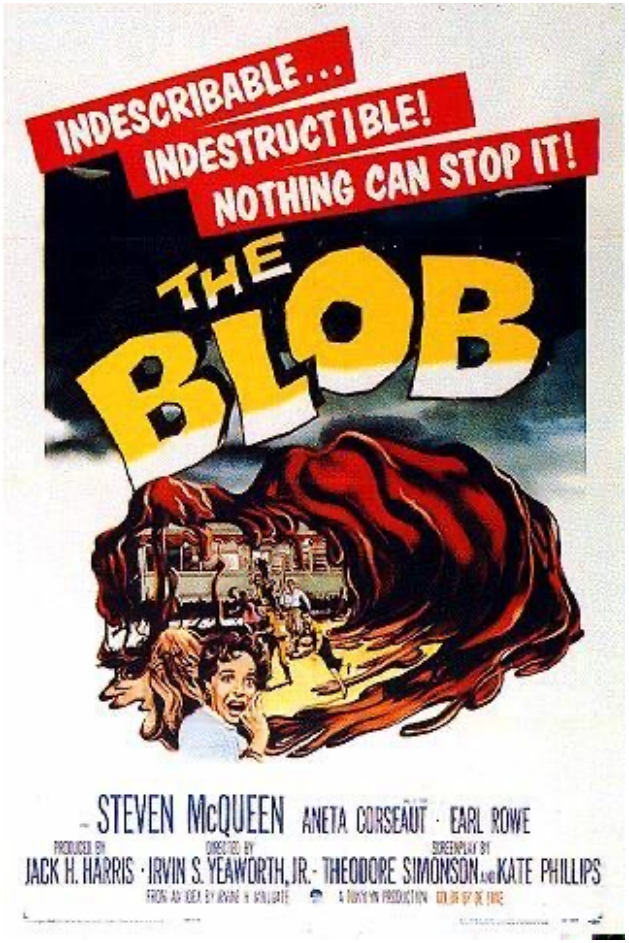


Cross section of a root tip



Human body consisting of organs, tissues and cells

VERSUS



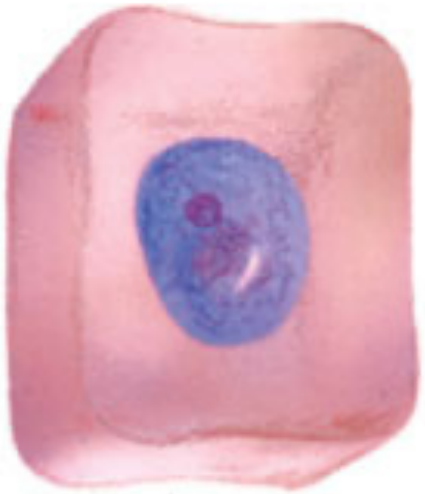
Natural laws limit cell size

At a minimum, a cell must contain enough volume to house the parts it needs to survive and reproduce

The maximum size of a cell is limited by the amount of surface area needed to obtain nutrients from the environment and dispose of wastes

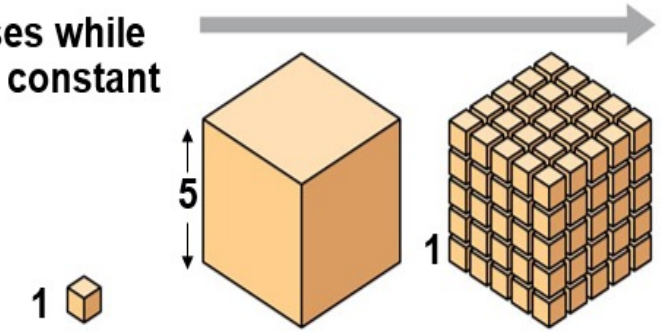
Surface area relative to the volume decreases as the size of a cell increases.

- limits the size of cells



Natural laws limit cell size

Surface area increases while total volume remains constant



Total surface area [sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

Helps in efficient exchange of heat and matter

A larger organism does NOT mean larger cells; just more cells; size of the cell remains pretty much the same

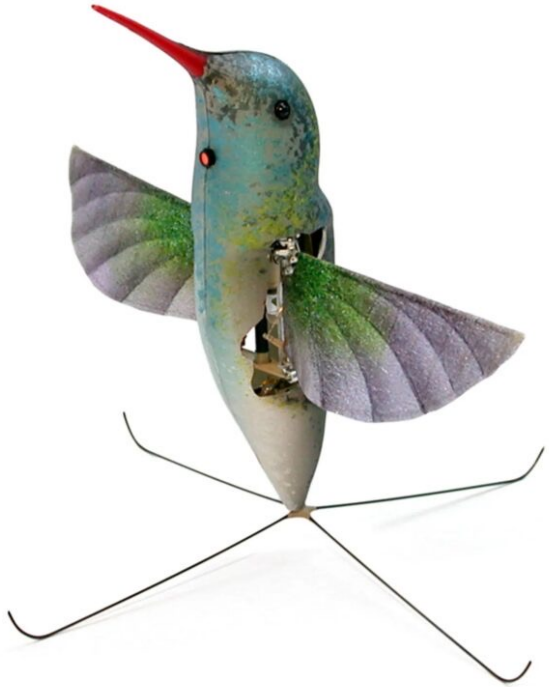
Biomimicry : VELCRO

- Created in the 1940s by Swiss Engineer George de Mestral, VELCRO is one of the best-known examples of biomimicry. While hiking, de Mestral noticed that the hook-like structure of burdock burrs allowed the seed pods to stick to his dog's fur.

- The prickly seed burrs from the plants clung to his clothing and to his dog. While pulling off the burrs he noticed how they were removable yet easily reattached.

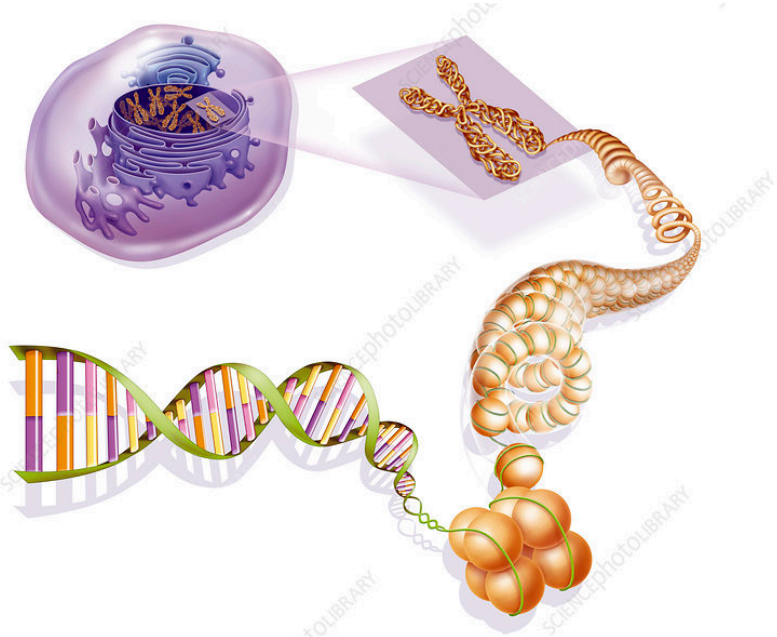
- He studied the burrs under a microscope and discovered a hook system used by the burdock plant to migrate its seeds by attachment. The hooks could grab onto loops of thread or fur. This gave him the idea of creating a hook and loop fastener.

Are bioinspired drones the next big thing in unmanned flight?



- Can you think of animals from which drones can be inspired?
- Can you think of advantages of such bio-inspired drone?

Length of DNA



Calculate the total length of DNA?

The haploid genome contains ~ 3 billion base pairs.

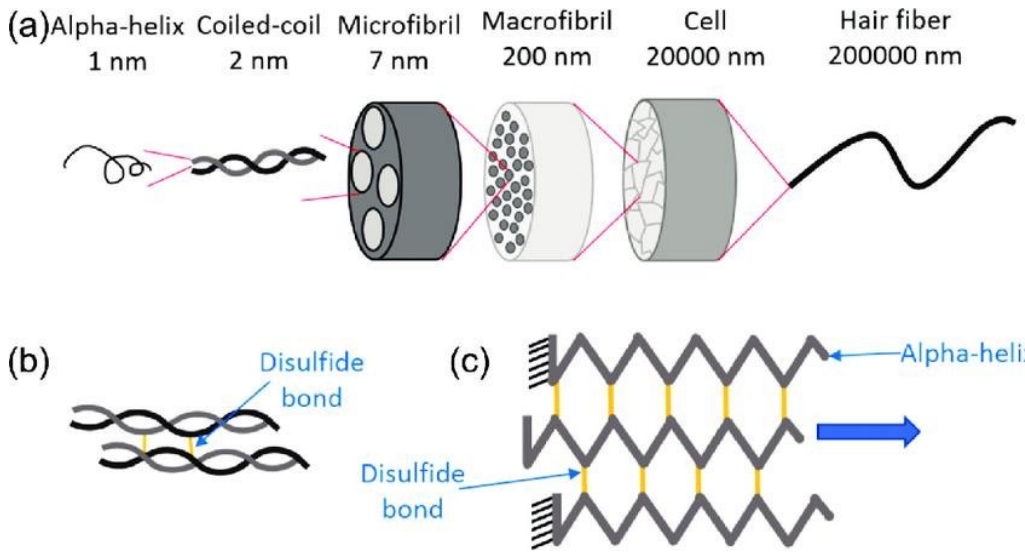
Humans are diploid – i.e., each cell contains two copies of each of the 23 chromosomes.

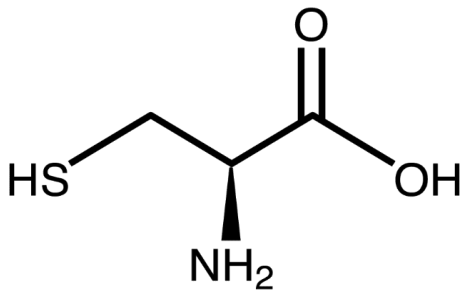
Distance between two adjacent base pairs – 0.34nm.

Total number of cells in human body – More than 30 trillion

The Biochemistry behind Hair Straightening

Hair is made up of protein called **keratin**





Keratin is rich in Sulphur-containing amino acid – cysteine**.**

Texture of the hair is due to disulphide and hydrogen bonds.

Q. How can you make a new hair straightening formulation?

Hint: Disulfide bonds

Scan this for a surprise!!!

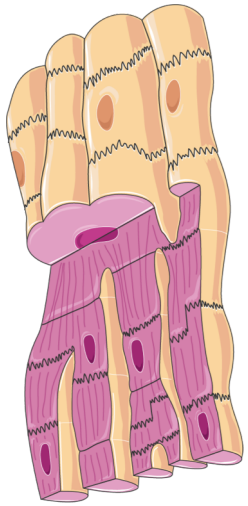
BB 101
Cells and Heredity

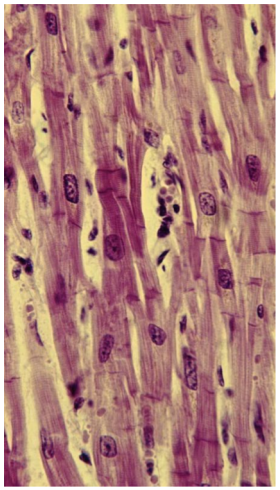
Tutorial 2
18.01.2024

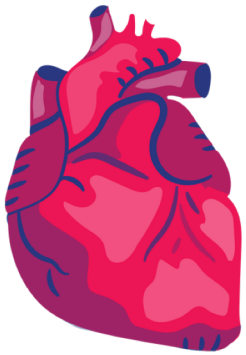
Cell

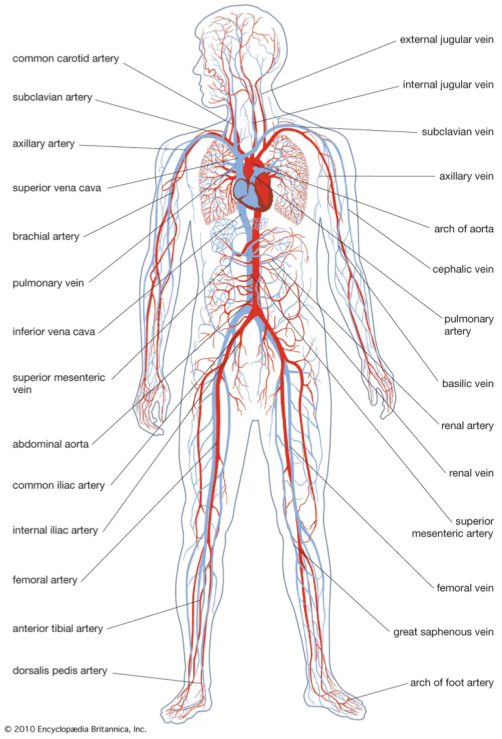
Building block, basic unit of life **Why?**

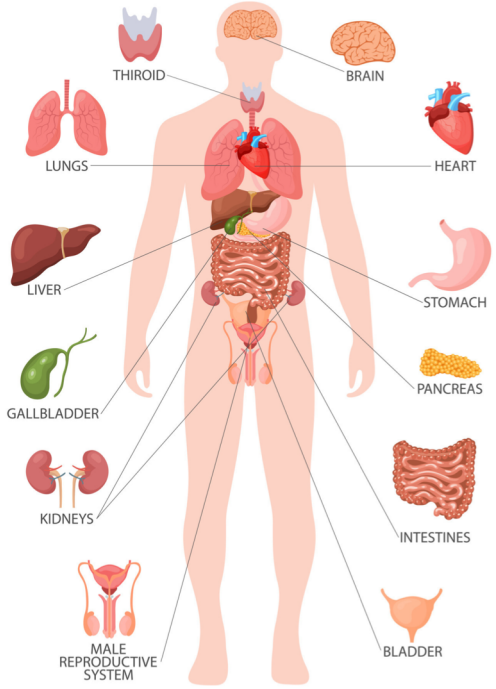
Cell **Tissue** **Organ** **Organ System** **Organism**







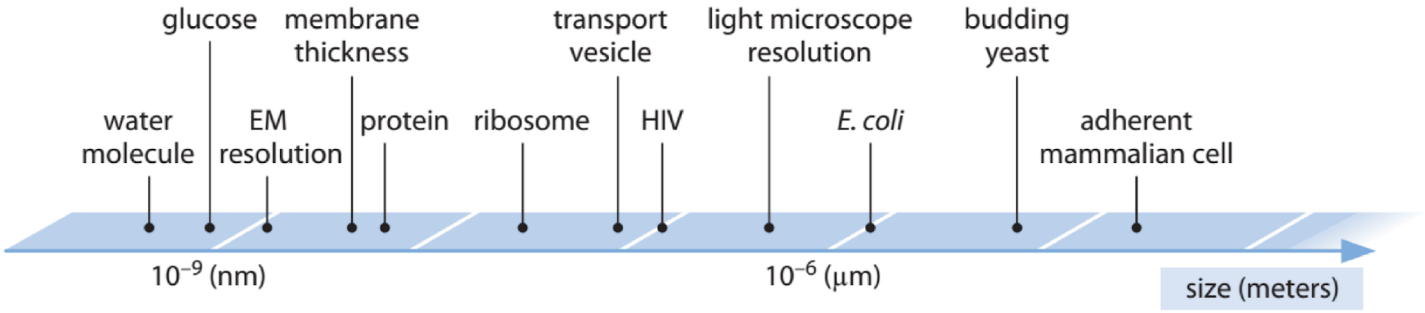




Which system does these form?

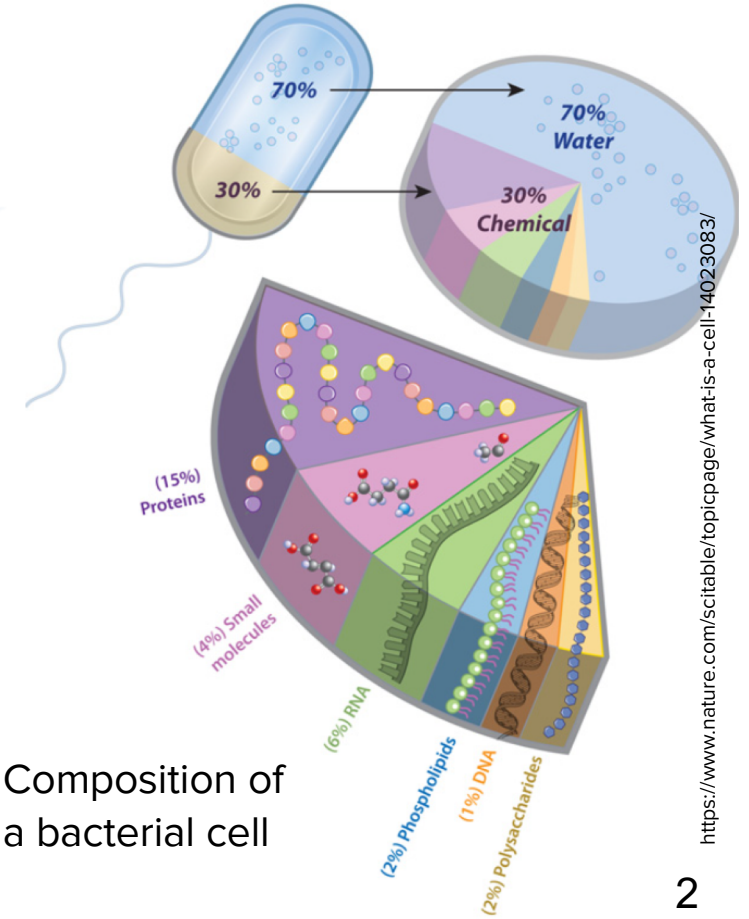
Cardiovascular System

Cell size and composition



https://www.youtube.com/watch?v=fox09v-9gXc

Ovum is the largest cell in humans



https://www.nature.com/scitable/topicpage/what-is-a-cell-14023083/

Composition of a bacterial cell

Organelles: Compartmentalization of cell

https://education.nationalgeographic.org/resource/organelles/

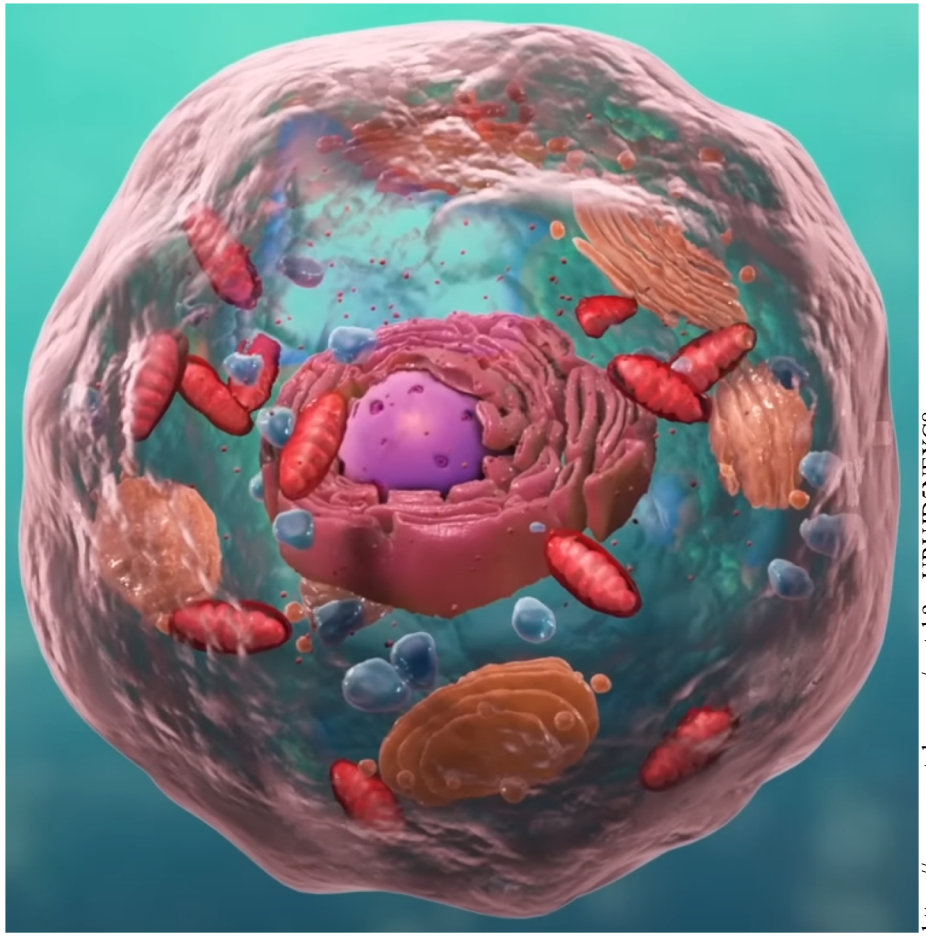
- Increased efficiency
  - Optimize conditions for various reactions to occur at faster rate.
- Enhanced control
  - Regulate interaction of molecule with each other.
- Specialized function
  - Each organelle carry out unique functions.

Origin?

Endosymbiotic theory

3

Organelles

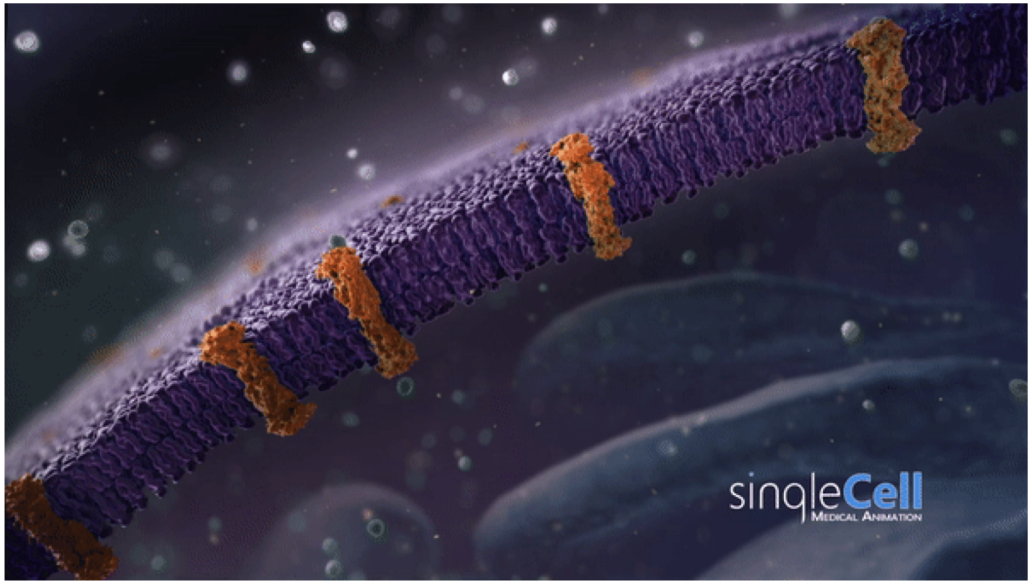


https://www.youtube.com/watch?v=URUJD5NEXC8

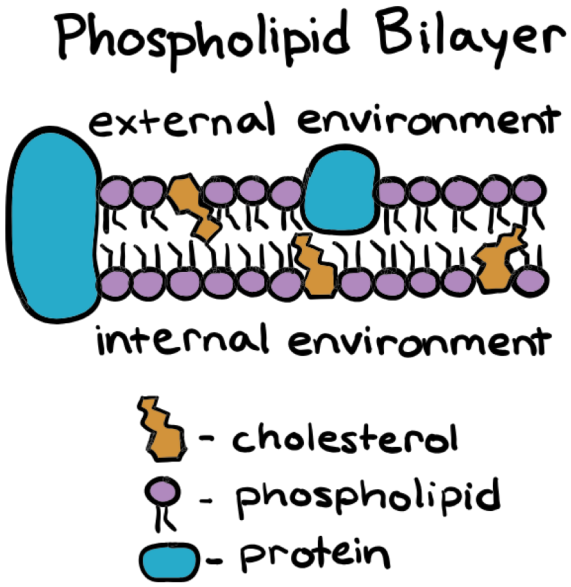
- Nucleus
- Golgi
- Vacuoles
- Mitochondria
- Endoplasmic reticulum
- Cytoskeleton
- Chloroplast

https://www.youtube.com/shorts/0M5-yCKhFhI

Organelles



Plasma membrane

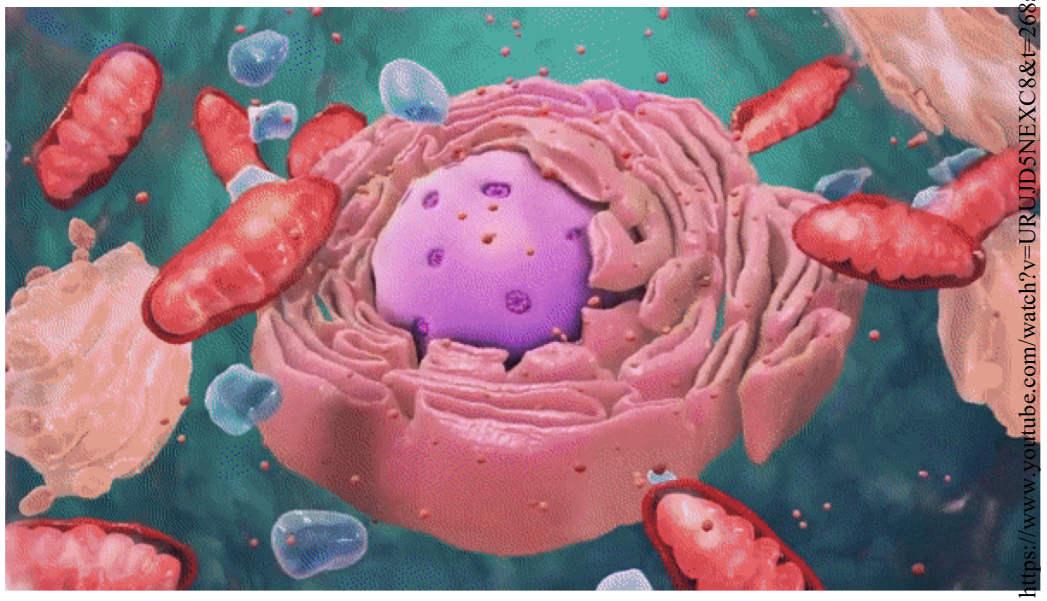


Fluid-mosaic model
Selectively-permeable

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.khanacademy.org%2Fscience%2Fap-biology%2Fcell-structure-and-function%2Fmembrane-permeability%2Fa%2Ffluid-mosaic-model-cell-membranes-article&psig=AOvVaw1IpqGxiCniKx9j86tttYs5&ust=1705042972650000&source=images&cd=vfe&opi=89978449&ved=0CBMQjRxqFwoTCIjV9pri1IMDFQAAAAAdAAAAABAD

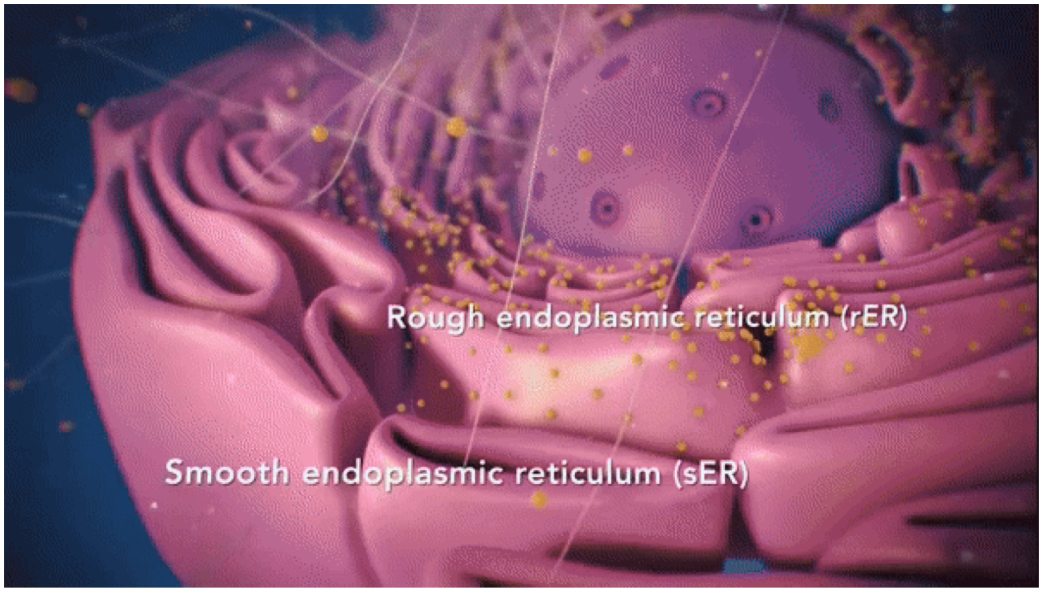
Organelles

Nucleus: Control center of cell



Contains DNA – Genetic material
Regulation of cellular functions
Response to external stimuli
Nucleolus

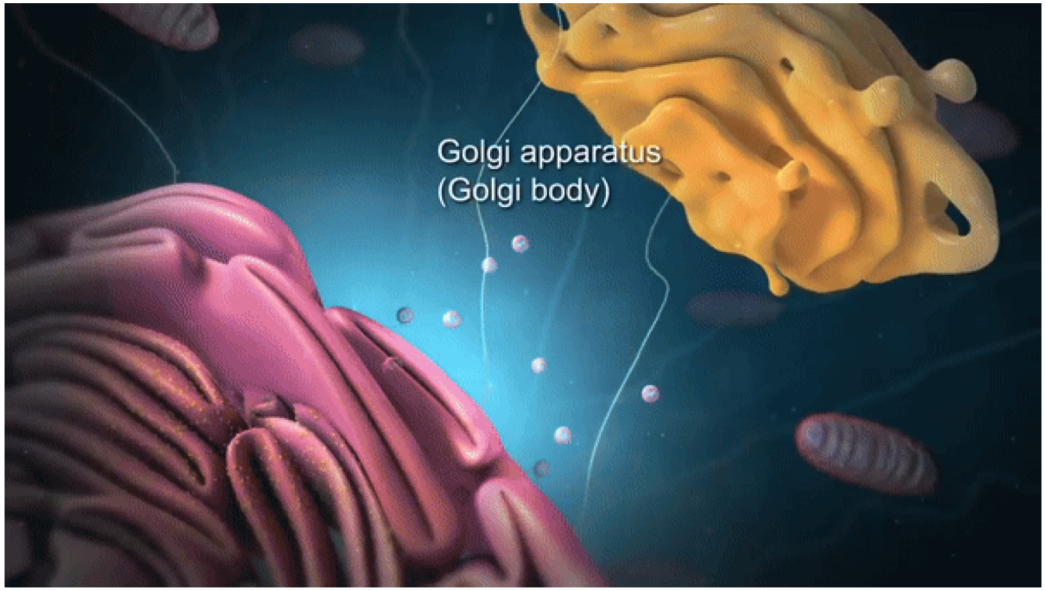
Endoplasmic reticulum: The transporter



Smooth and Rough endoplasmic reticulum
Protein folding and modification
Transport proteins synthesized in the cytoplasm

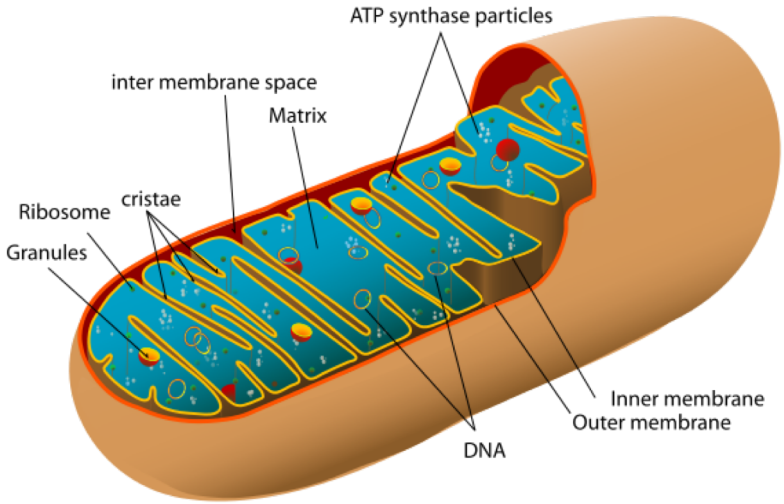
Organelles

Golgi: Post office of the cell



Protein sorting for delivery to various destinations

Mitochondria: Powerhouse



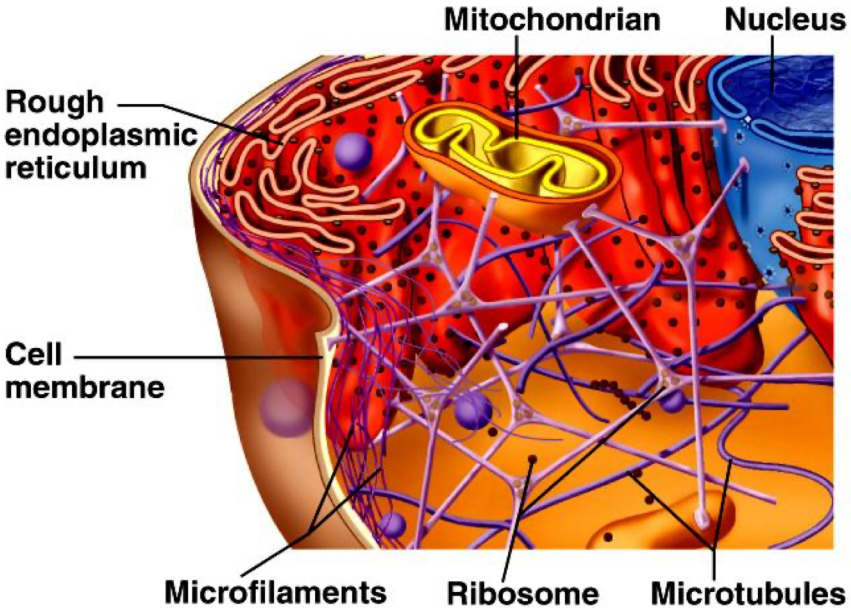
Production of ATP

ATP: Energy currency of the cell

Animation link https://www.youtube.com/watch?v=39HTpUG1MwQ

Cytoskeleton

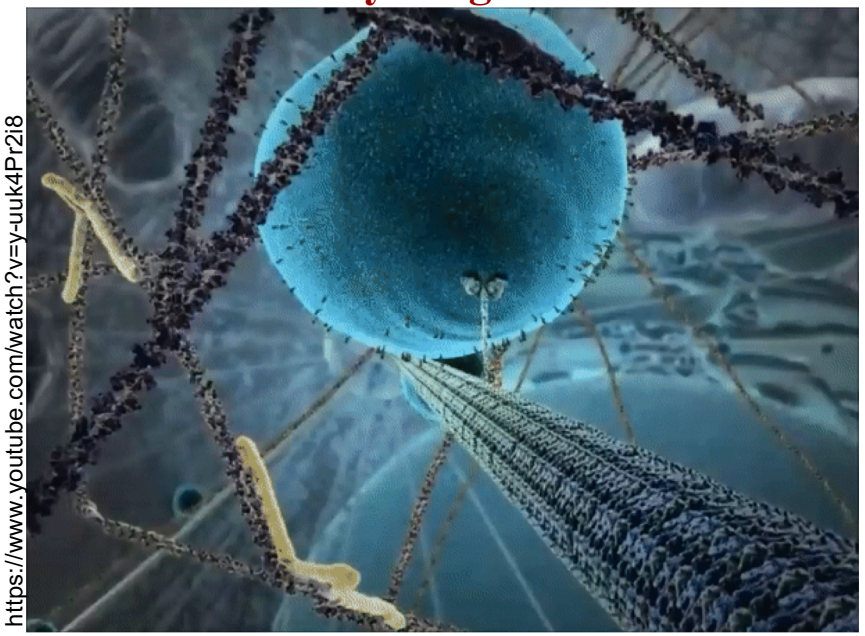
Cytoskeleton: structural support for the cell and provides tracks for movement



Types

- Actin (Microfilament)
- Microtubules
- Intermediate filaments

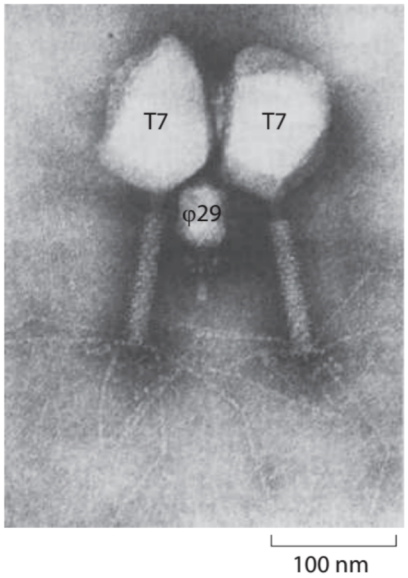
Molecular motors carry cargo on the microtubule tracks

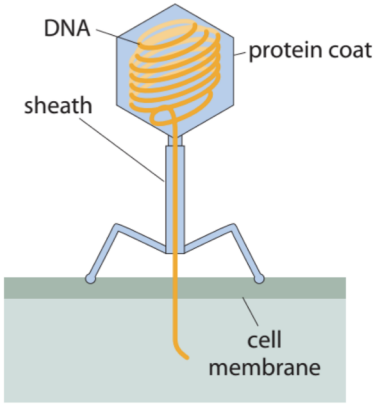


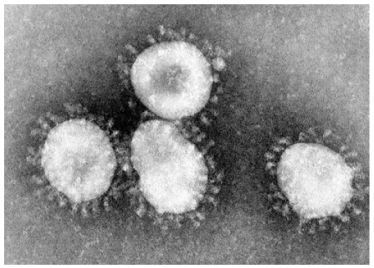
https://www.youtube.com/watch?v=y-uuk4Pr2i8

One end of the protein binds to vesicles and carry them to their destinations.

Viruses



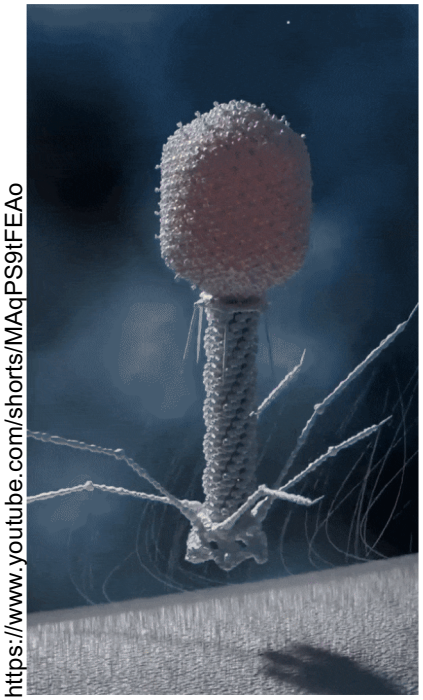




SARS-COV2

Viruses cannot survive without a host cell to infect.

Living?



https://www.youtube.com/shorts/MAqPS9tFEAo

Attachment

Injection of Genetic material

Replication

New viruses

Cell lysis and transmission

BB 101
Heredity

Outline

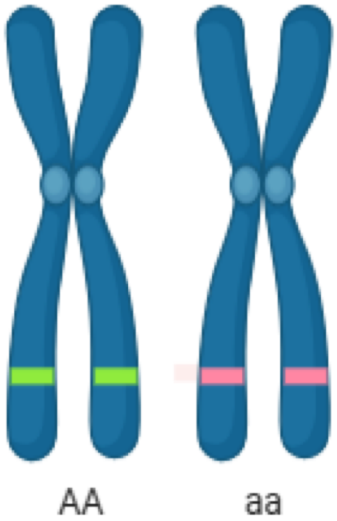
1. Basic Concepts and terminologies of Inheritance

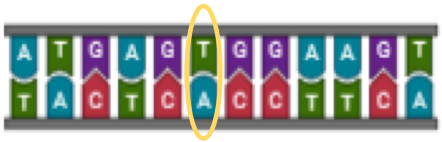
2. Practice of mendelian genetics problems

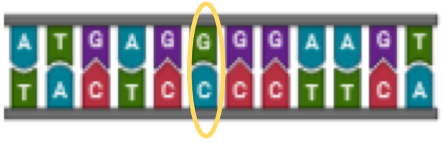
3. Concept of ABO Blood Groups and Practice Problems

Genes vs Alleles

- **Gene** – A region of specific DNA sequence which is responsible for a particular trait
- **Alleles** – Different forms of genes inherited from the parents (alternative variation of the genes)





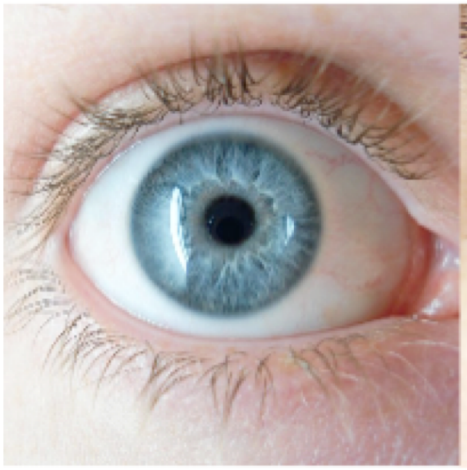


- **Dominant alleles have an effect over the recessive alleles**

What are Genotypes and Phenotypes

- Phenotypes – Actual observed properties
- Genotypes – Full hereditary information

Phenotype= Blue Eyes



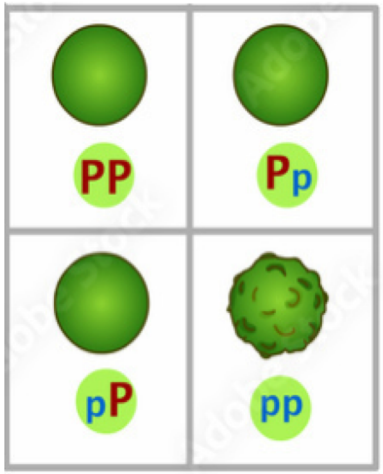
Genotype=bb

Recessive=b

Phenotype=Brown Eyes

Genotype = Bb or BB

Dominant =B

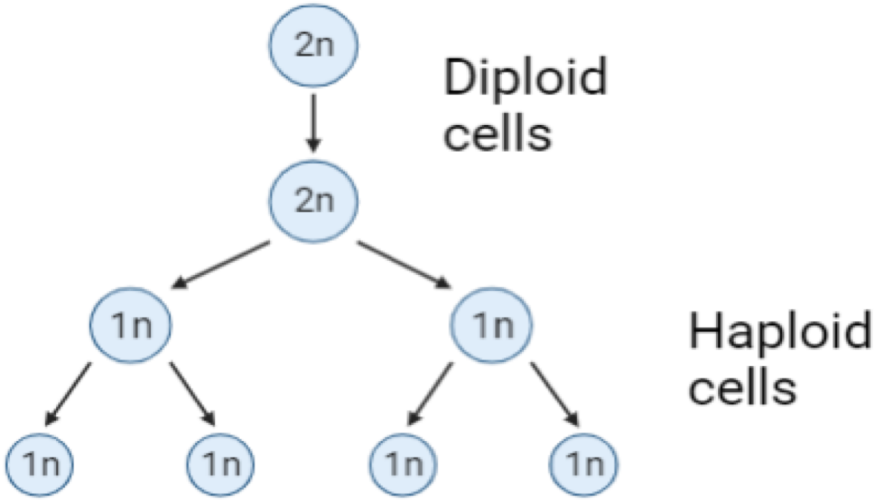


P – round seed

p – wrinkled seed

Haploid and diploid cells

- **Diploid -** A eukaryotic cell with two sets of chromosomes
- **Haploid -** A cell with individual set of chromosomes

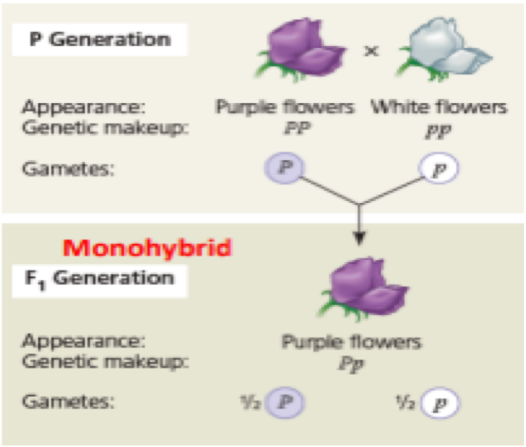


Monohybrid cross and Dihybrid Cross

Law of segregation – Two alleles for a heritable trait separate from each other during gamete formation.

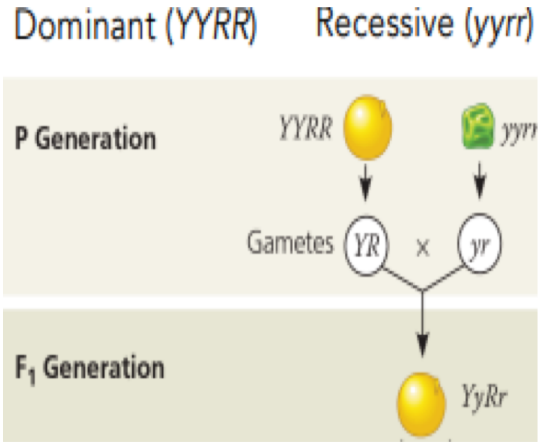
Law of Independent Assortment – Alleles of two (or more) different genes get sorted into two gametes independently of one another.

Monohybrid cross



Phenotypic Ratio – 3:1
Genotypic Ratio – 1:2:1

Dihybrid



Phenotypic Ratio – 9:3:3:1
Genotypic Ratio – 1:2:1:2:4:2:1:2:1

Problems

1. The following two genotypes are crossed: Aa Bb Cc dd Ee *Aa bb Cc Dd Ee. What will the proportion of the following genotypes be among the progeny of this cross?

a. Aa Bb Cc Dd Ee

b. Aa bb Cc dd ee

Ans: a. 1/32

b. 1/64

Problems

Two organisms, with genotypes BbDD and BBDd, are mated. Assuming independent assortment of the B/b and D/d genes, write the genotypes of all possible offspring from this cross and use the rules of probability to calculate the chance of each genotype occurring.

Ans - ¼ BBDD; ¼ BbDD; ¼ BBDd; ¼ BbDd

Number of Genotypic Classes Expected and Number of Phenotypic Classes from Self-Crosses

Number of Segregating Gene Pairs	Number of Phenotypic Classes	Number of Genotypic Classes
1[a]	2	3
2	4	9

Q. What will be the number of phenotypic and genotypic classes if the number of segregating gene pairs is n?

Ans– 2^n, 3^n

Q. If there are 81 genotypic classes, how many segregating gene pairs will there be?

Q. If there are 5 segregating gene pairs, what will be the number of phenotypic classes?

Ans - 4

Ans - 32

Pedigree : Concepts

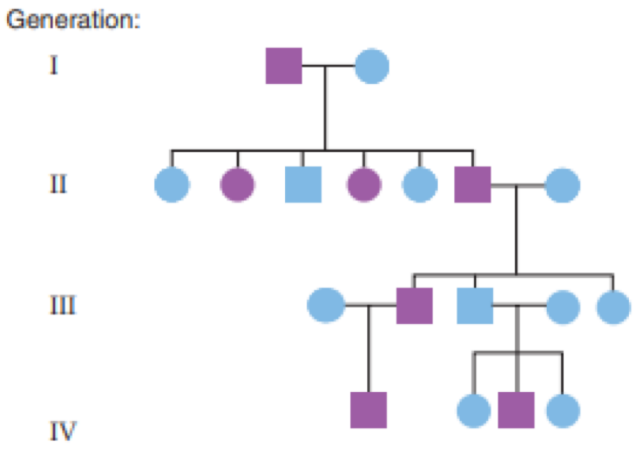
Female

Male

Affected Individuals

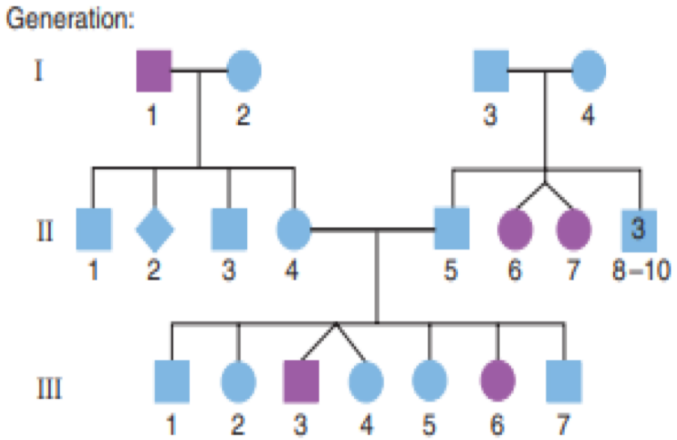
General characteristics of **dominant inheritance** for a trait :

- Every affected person in the pedigree must have at least one affected parent
- The trait usually does not skip generations.



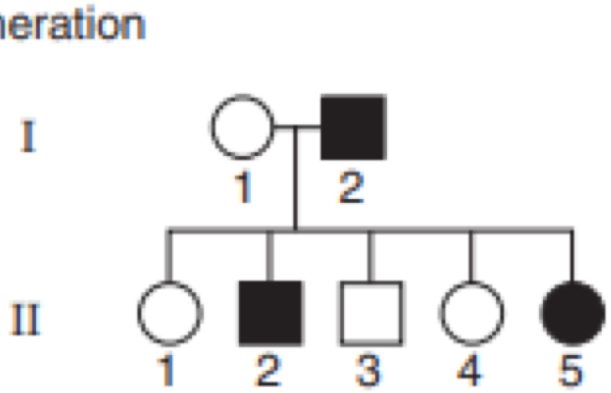
General characteristics of **recessive inheritance** for a trait

- Most affected individuals have two normal parents, both of whom are heterozygous. The trait appears in the F1
- Recessive traits often skip generations.



Problems

Consider the following pedigree, in which the allele responsible for the trait (a) is recessive to the normal allele (A):



a. What is the genotype of the mother? - Aa

b. What is the genotype of the father? - aa

c. What are the genotypes of the children? - aa(II-2, II-V) ; Aa (II-1, II-3, II-4)

Extensions and Deviations of Mendelian Genetics

Genotype	I^AI^A or I^Ai	I^BI^B or I^Bi	I^AI^B	ii
Red blood cell appearance				
Phenotype (blood group)	A	B	AB	O

Phenotype (Blood Group)	Genotype
O	i/i
A	I^A/I^A or I^A/i
B	I^B/I^B or I^B/i
AB	I^A/I^B

ABO blood group

Serum from blood type	Antibodies present in serum	Cells from blood type: O	A	B	AB
O	Anti-A Anti-B				
A	Anti-B				
B	Anti-A				
AB	—				

What transfusions are safe between people with different blood groups in the ABO system?

Problems

A woman of blood group AB marries a man of blood group A whose father was of group O. What is the probability that

a. their two children will both be of group A?

- ¼

a. one child will be of group B, the other of group O?

- 0

c. the first child will be a son of group AB and the second child a son of group B

- 1/64

Thank You

BB 101

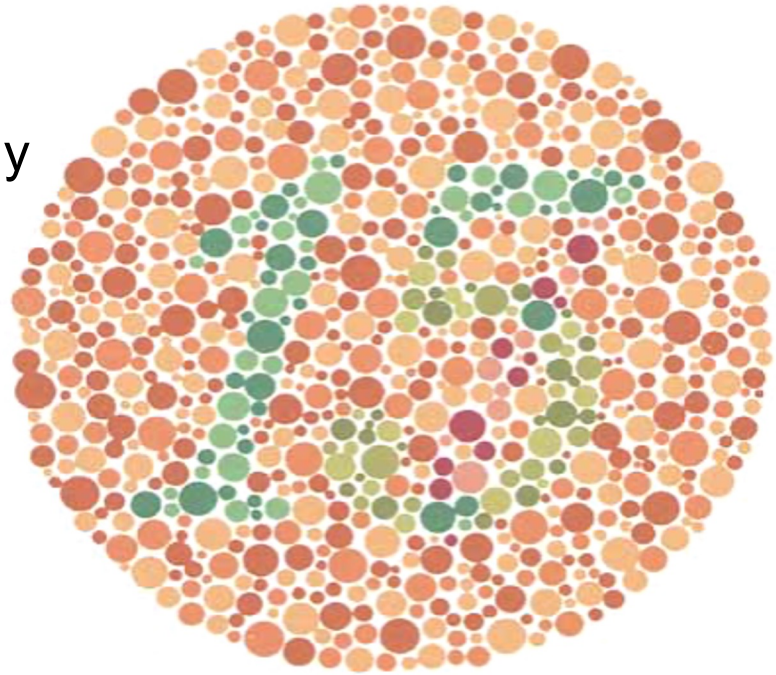
Genetics & DNA as a genetic material

Tutorial 3

25.01.2024

Examples of Sex-linked Traits And Disorders

- Red-green Colour blindness
- Duchenne muscular dystrophy
- Night blindness
- Hemophilia



Transmission of X-linked Recessive Traits: Red-green Color Blindness

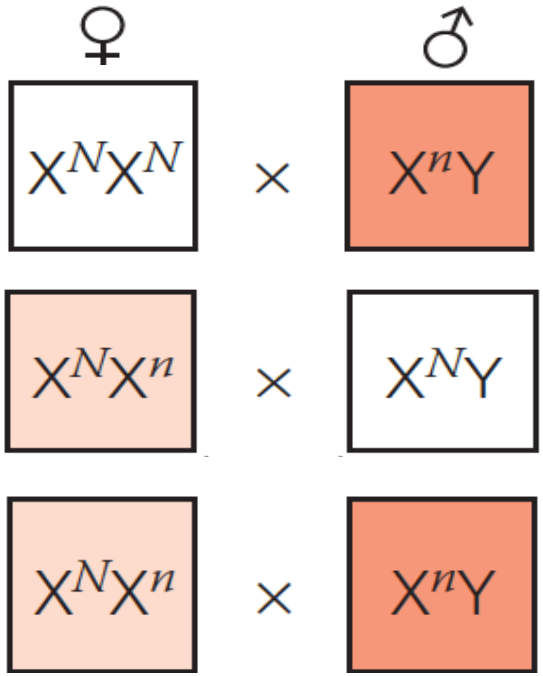
Red-green Color Blindness: X-linked Disorder: A re-cap!

***N** = dominant allele for normal color vision (carried on X chromosome)*
***n** = recessive allele having a mutation for color blindness*

Unaffected individuals

Carriers

Color-blind individuals



Fathers pass X-linked alleles to all of their daughters but to none of their sons.
Mothers can pass X-linked alleles to both sons and daughters.

Any male receiving the recessive allele from his mother will express the trait.
Therefore, far more males than females have X-linked recessive disorders.

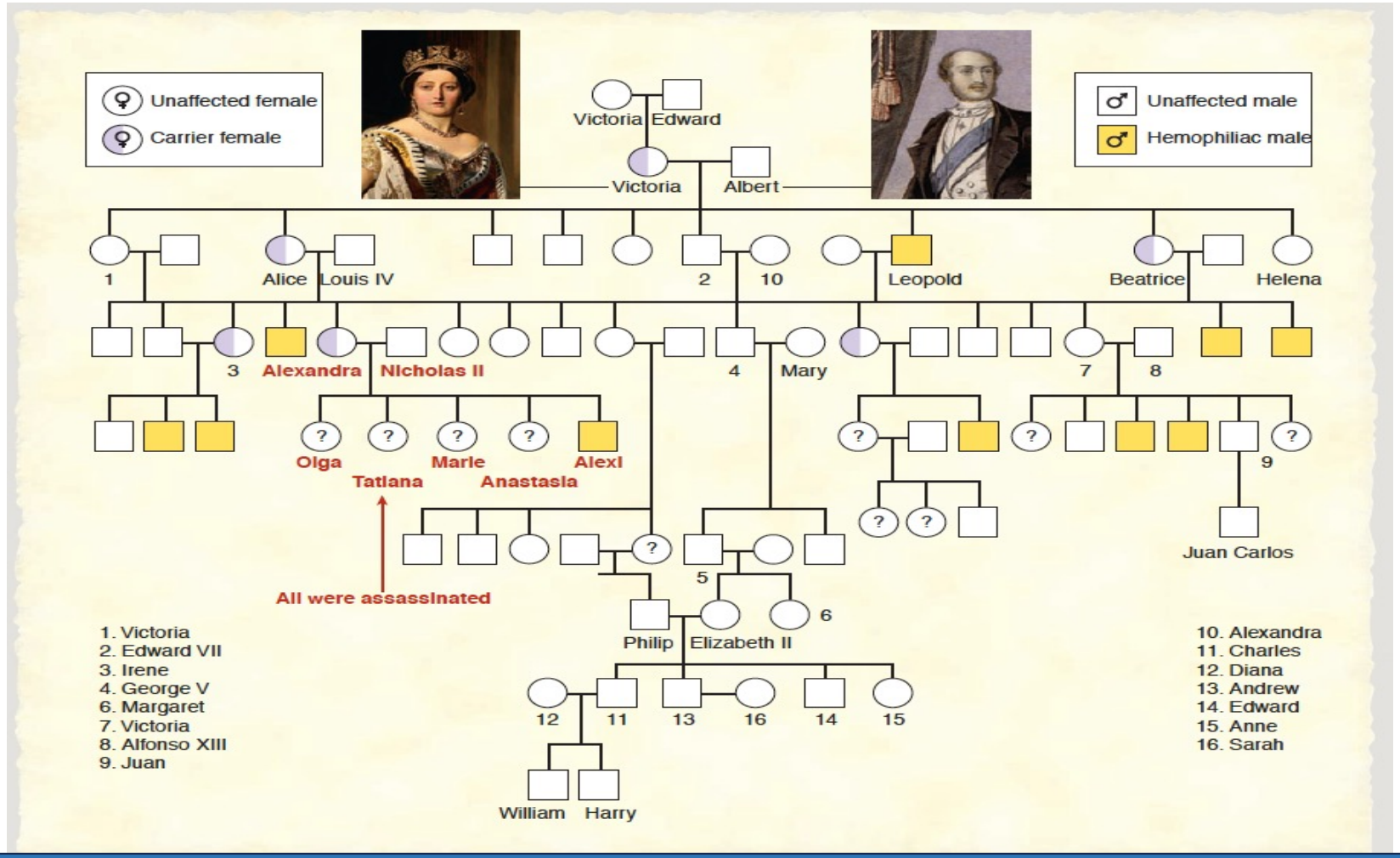
X-linked Recessive Disorder: Hemophilia

- Absence of one or more of the proteins required for blood clotting.
- When a person with hemophilia is injured, bleeding is prolonged because a firm clot is slow to form.
- Small cuts in the skin are usually not a problem, but bleeding in the muscles or joints can be painful and can lead to serious damage

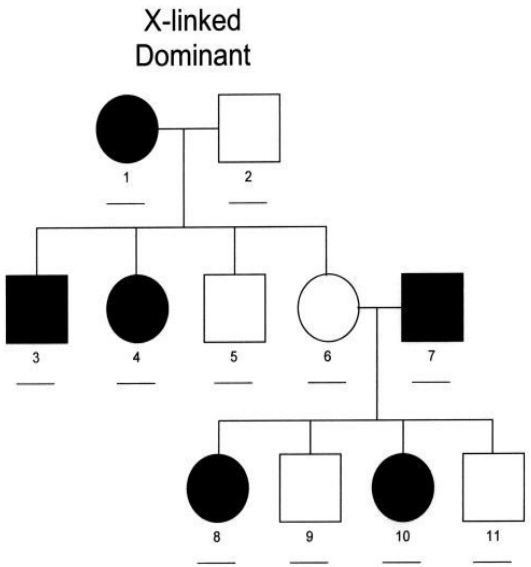
Hemophilia and Royal Family of Europe

- Queen Victoria of England is known to have passed the allele to several of her descendants.
- Intermarriage with royal family members of other nations, such as Spain and Russia, further spread this X-linked trait.

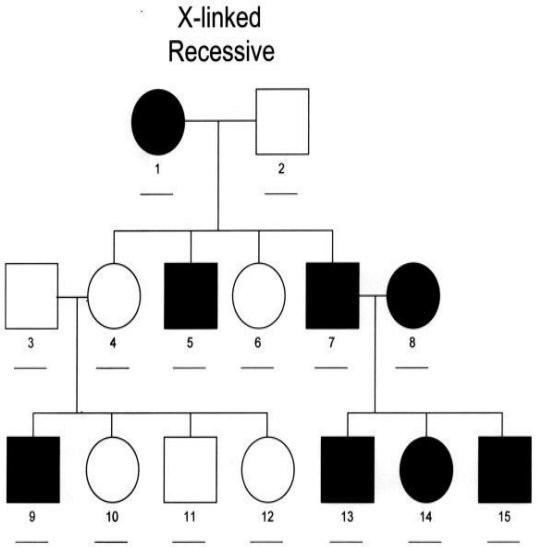
Example: Royal Families of Europe And Hemophilia



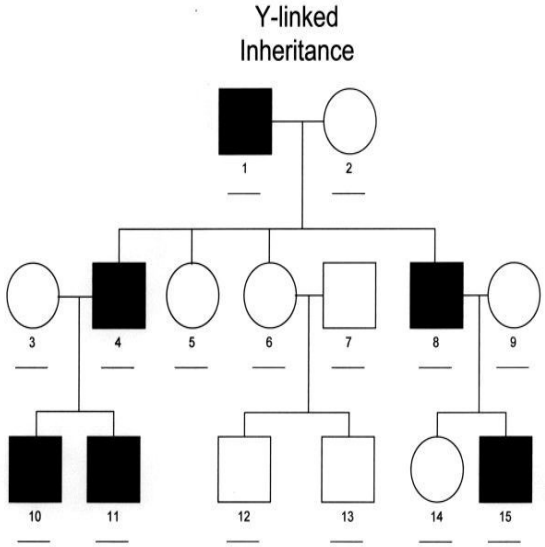
PEDIGREE ANALYSIS OF SEX LINKED DISORDERS



X-linked dominant



X-linked recessive



Y-linked

The genetic basis of the mutation, and how it resulted in a nonfunctional blood-clotting factor, is now understood..

Today, people with hemophilia are treated as needed with intravenous injections of the protein that is missing

PROBLEMS OF GENETICS

In mice, black coat color (*B*) is dominant over brown (*b*), and a solid pattern (*S*) is dominant over white spotted (*s*). Color and spotting are controlled by genes that assort independently. A homozygous black, spotted mouse is crossed with a homozygous brown, solid mouse. All the F1 mice are black and solid. A testcross is then carried out by mating the F1 mice with brown, spotted mice.

a. Give the genotypes of the parents and the F1 mice.

b. Give the genotypes and phenotypes, along with their expected ratios, of the progeny expected from the testcross.

Ans: a. Parents – BBss, bbSS; F1 – BbSs

b. Genotype – Bbss, BbSs, bbss, bbSs; Ratio – 1:1:1:1

Phenotype – Black Spotted, Black Solid, Brown Spotted, Brown Solid

PROBLEMS OF GENETICS

Haemophilia (reduced blood clotting) is an X-linked recessive disease in humans. A woman with haemophilia mates with a man who exhibits normal blood clotting. What is the probability that their child will have haemophilia?

Ans: ½. All the male progenies will be affected.

Why should we know about genetic material?

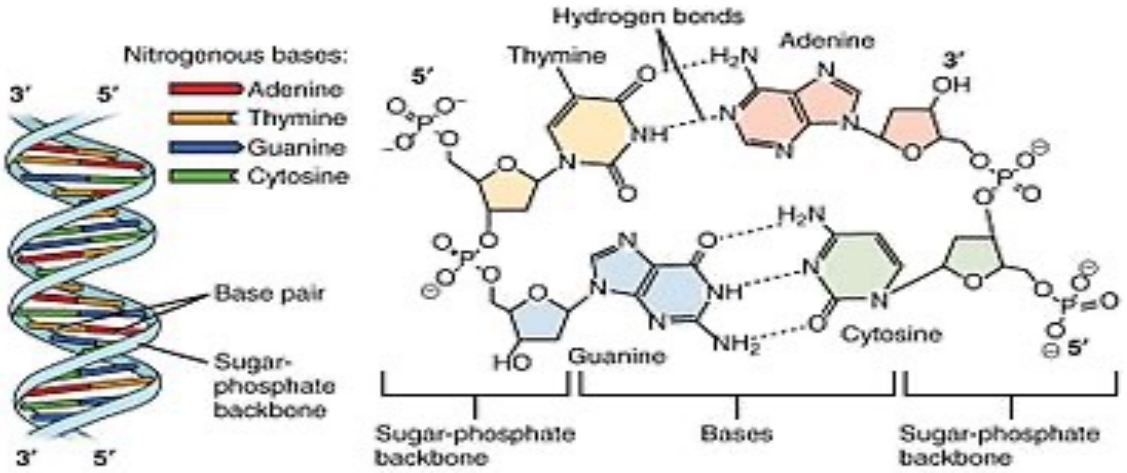
1. The Blueprint of life,
2. Pass genetic information from one generation to the next.
3. Diagnosing genetic disorders, predicting susceptibility to diseases, and developing personalised medicine.

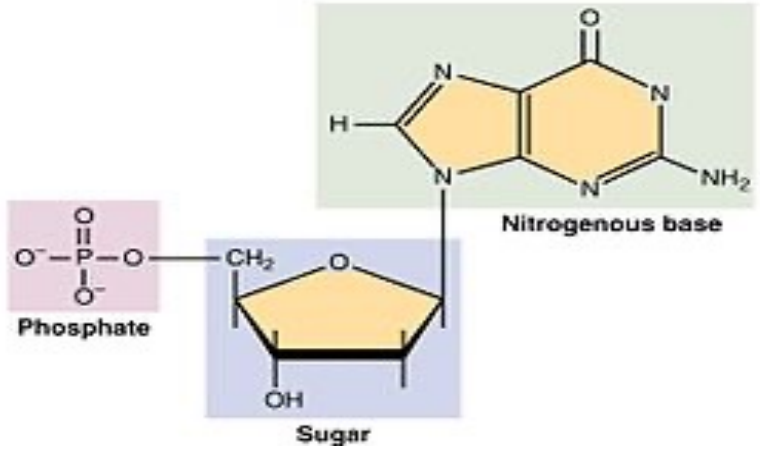
- But which of them is the genetic material and how scientists concluded?

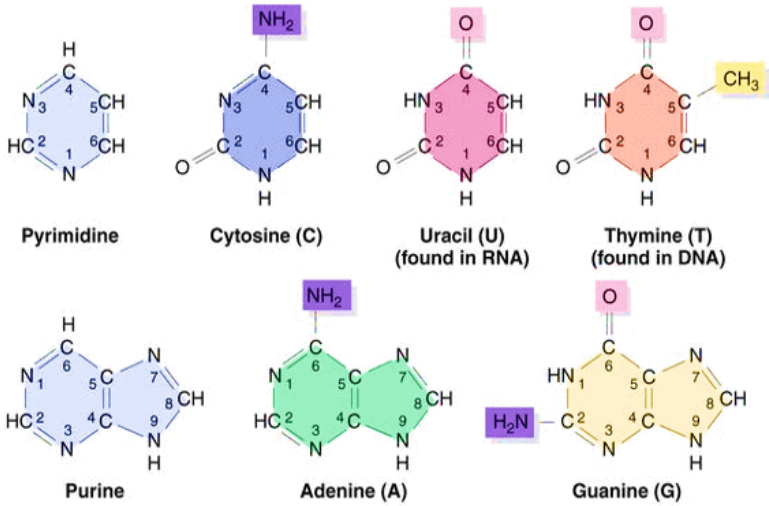
https://as1.ftcdn.net/v2/jpg/05/41/59/98/1000_F_541599815_0DeKJUZLUCdvIBtpAQ955DnbBtoOcbs5.jpg

https://www.ck12.org/flx/show/image/201301131358096717284223_df0d2514c98b5080c8eedc3e48ee5a55-201301131358098216540895.jpg

COMPOSITION OF DNA







Notice the directionality of both strands!

https://www.genome.gov/genetics-glossary/Deoxyribonucleic-Acid

ELUCIDATING THE DNA STRUCTURE

What was already known: DNA is a polymer consisting of A, C, G and T (referred to as nucleotide bases)
(This was based on Fedrick Miescher Albrecht Kossel's research)

CHARGAFF'S OBSERVATIONS:

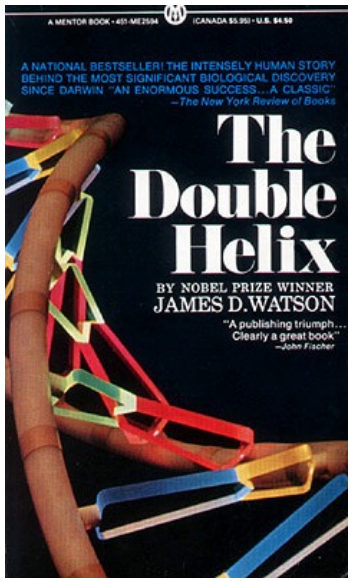
Observation 1: Chargaff noted that the nucleotide composition of DNA varies among species

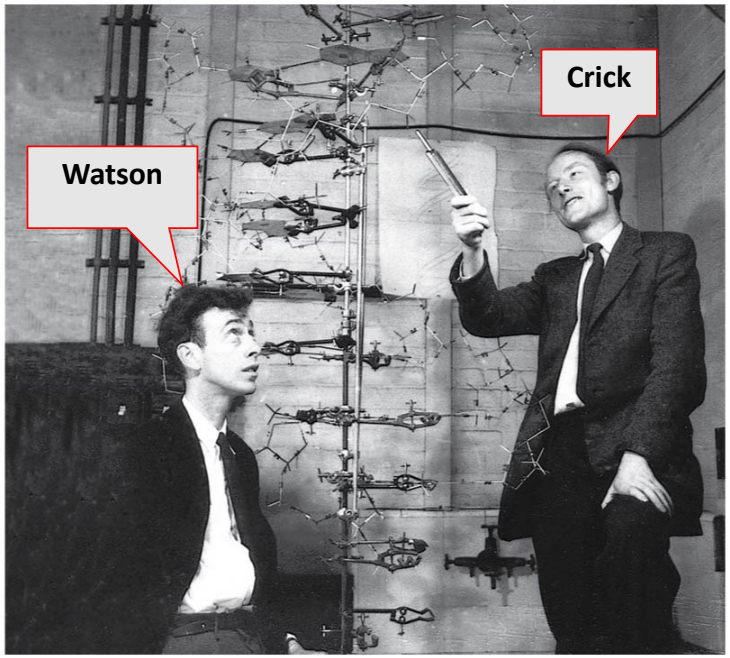
What does it actually imply?

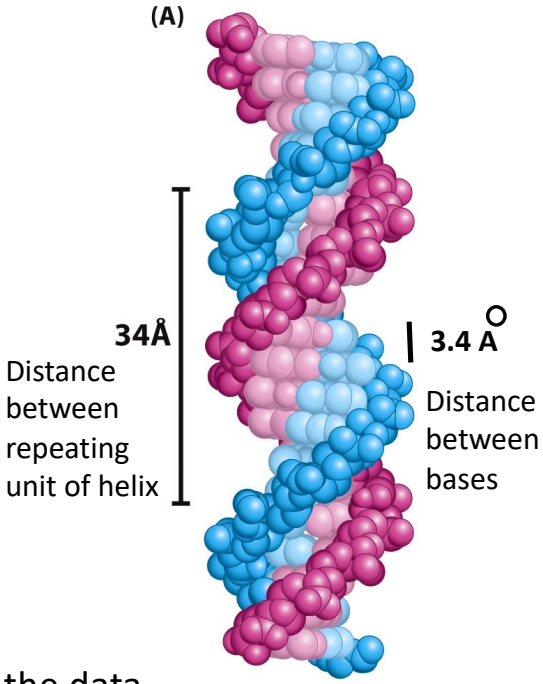
Observation 2: No. of A ≃ No. of T; No. of G ≃ No. of C

DISCOVERY OF STRUCTURE OF THE DNA

Watson-Crick Model of Double-Helical DNA



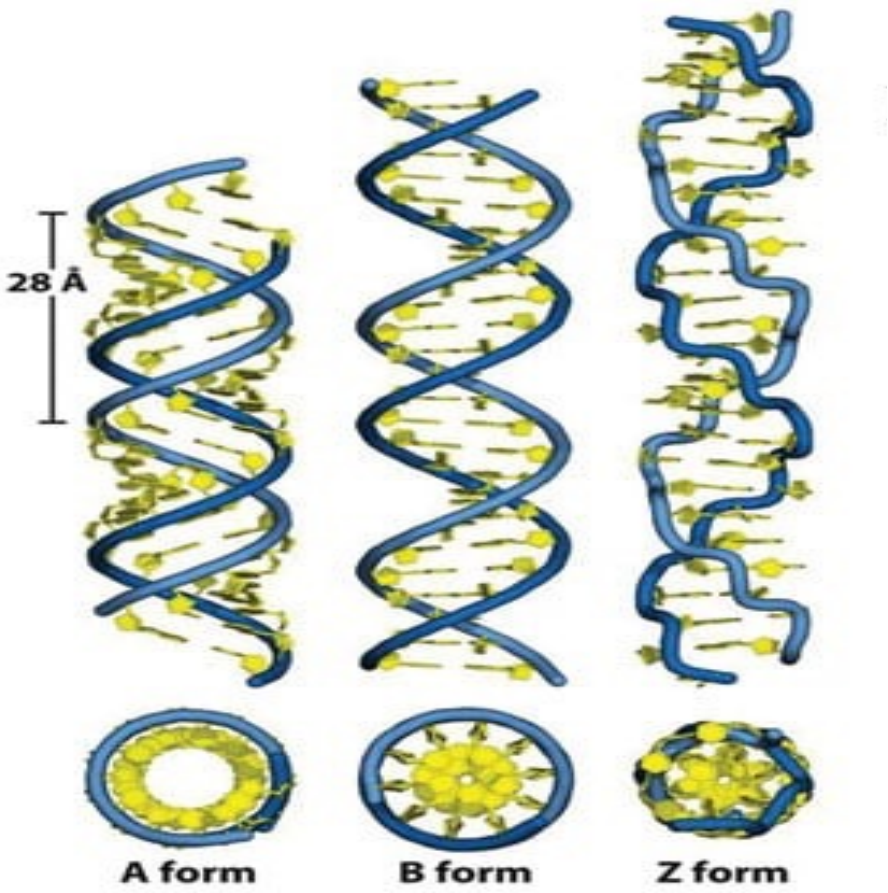




Watson and Crick played with chemical models to come up with a structure that matched the data

BUT DOUBLE HELIX IS NOT THE ONLY STRUCTURE OF DNA…

https://www.nature.com/scitable/topicpage/discovery-of-dna-structure-and-function-watson-397/



https://microbenotes.com/different-forms-of-dna-b-form-a-form-z-form/

STRUCTURE AND COMPOSITION OF DNA

1. If we find the composition of 'C' in DNA to be 20%, what do you think is the composition of base 'A'?

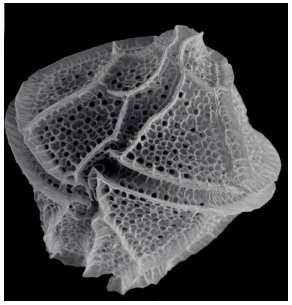
Ans. 30%

1. If the sequence of DNA in the parent stand is 'AGTCC', what do you think is the sequence in the daughter strand strand?

Ans. TCAGG

Does genome size correlate with “complexity”?

Human
3 billion
bp (base
pairs)



An alga
~98 billion bp

Onion
~16
billion bp

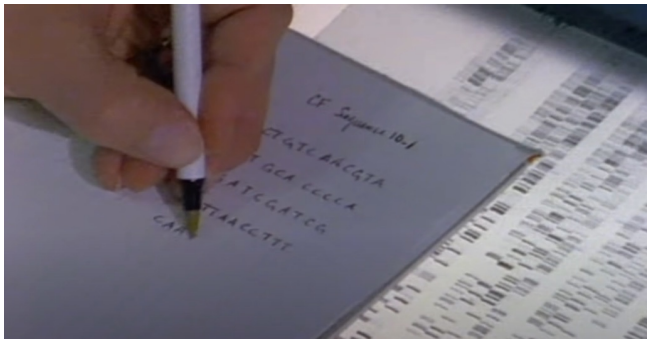
Marbled
lungfish
~130
billion bp

The length of total DNA in our body??

https://humgenomics.biomedcentral.com/articles/10.1186/s40246-022-00396-x

HUMAN GENOME PROJECT

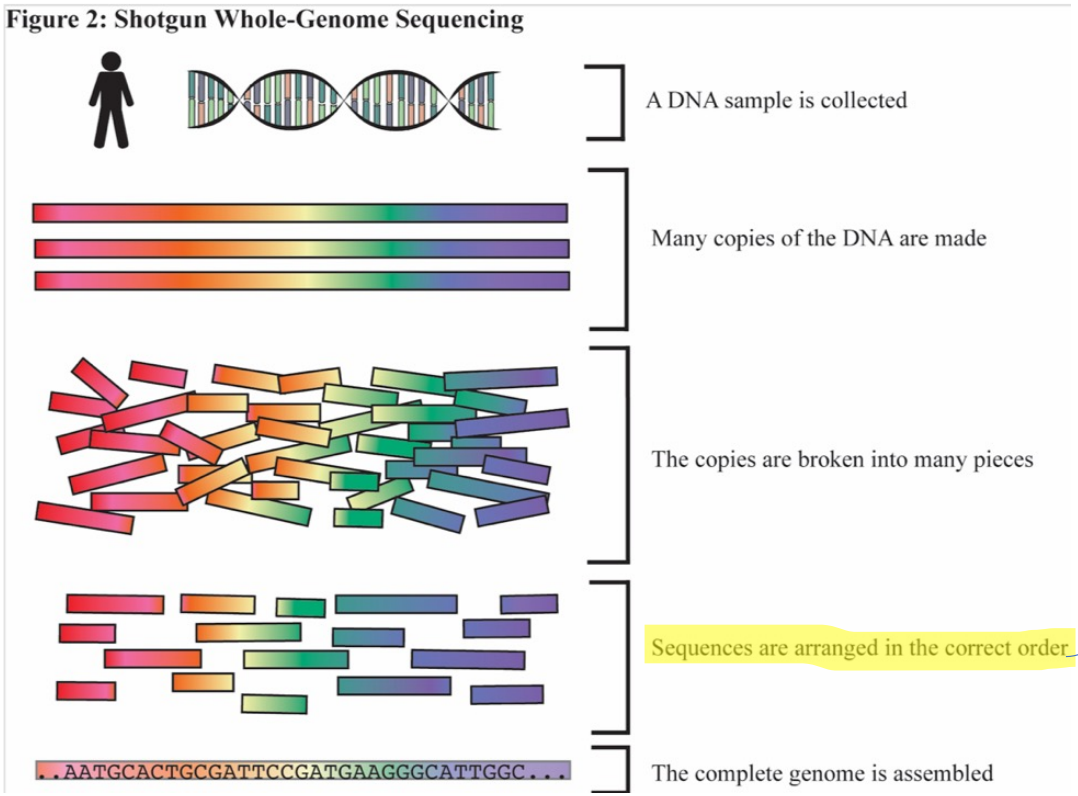
Size of human genome: 3.2 billion base pairs

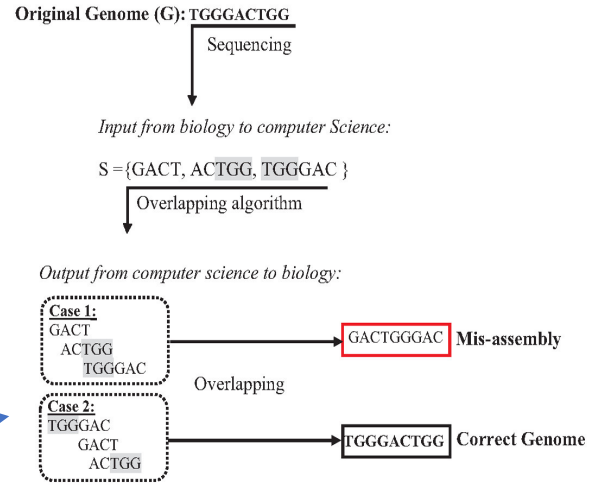


Estimated time for sequencing human genome **BY HAND**: at least 100 years

Computational technologies entered HGP by late 1990s, and the project was finished by 2003

HUMAN GENOME PROJECT – Sequencing the 3 billion bp human genome





YouTube video on HGP: https://youtu.be/qOW5e4BgEa4?si=xsNUC8N-alGADMtl

Application of genome sequencing

- Single base changes between reference and patient genomes

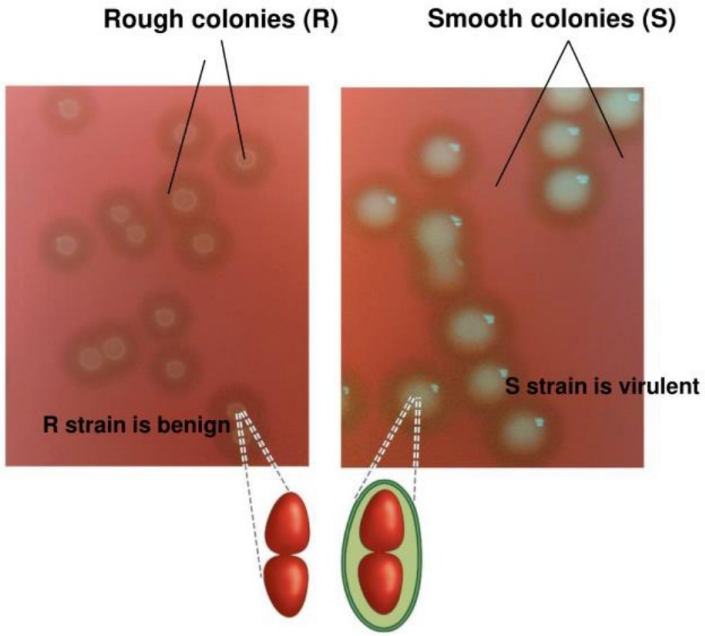
Disease Susceptibility, Diagnosis, Personalized Medicine

BB 101
Molecular Basis of Inheritance & DNA Tools

Tutorial 4

01.02.2024

Experimental proofs-Frederick Griffith



R- non-virulent strain
S- Virulent strain

S strain ⟶ Inject into mice ⟶ Mice die

R strain ⟶ Inject into mice ⟶ Mice live

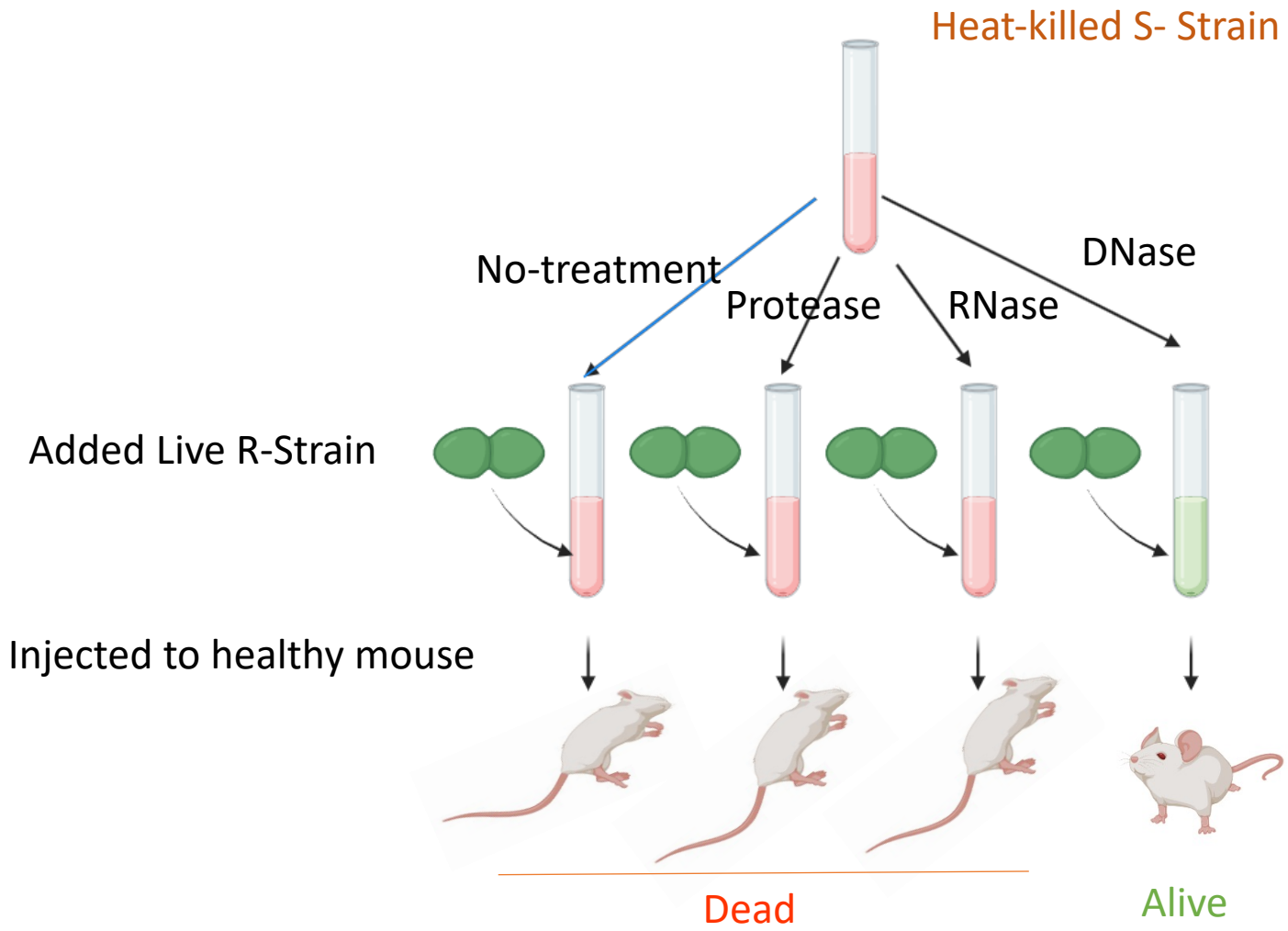
S strain (heat-killed) ⟶ Inject into mice ⟶ Mice live

S strain (heat-killed) + R strain (live) ⟶ Inject into mice ⟶ Mice die

Conclusion-Some 'heritable substance ', transferred from the heat-killed S strain and enabled the R strain to synthesise a smooth polysaccharide coat and become virulent.

How to confirm the nature of the heritable substance out of known biomolecules, protein, RNA and DNA?

Experimental proofs-Frederick Griffith (2)

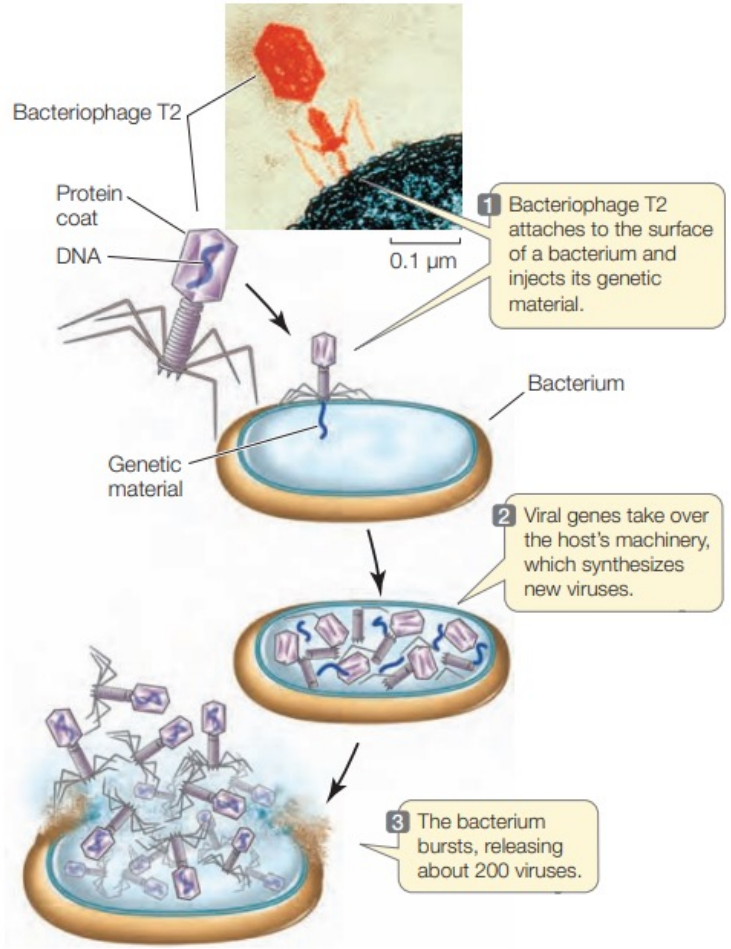


If Mouse Dies:
Transformation occurred

If Mouse Lives:
Transformation Disrupted

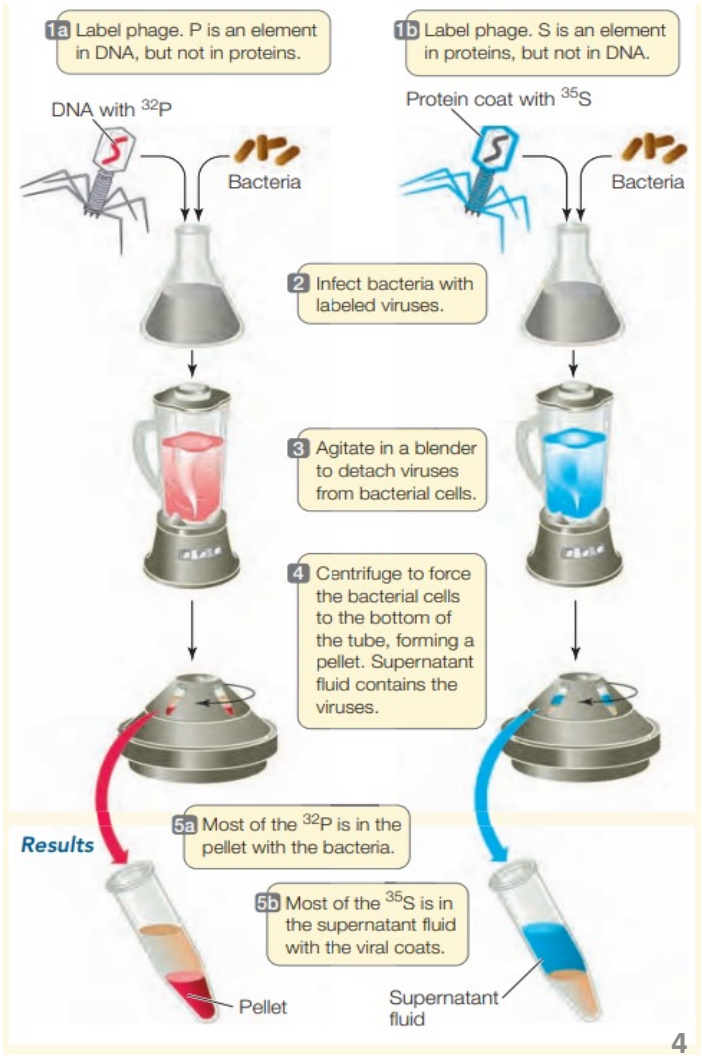
Conclusion: DNA is the transforming principle

Final proof- Hershey and Chase experiment



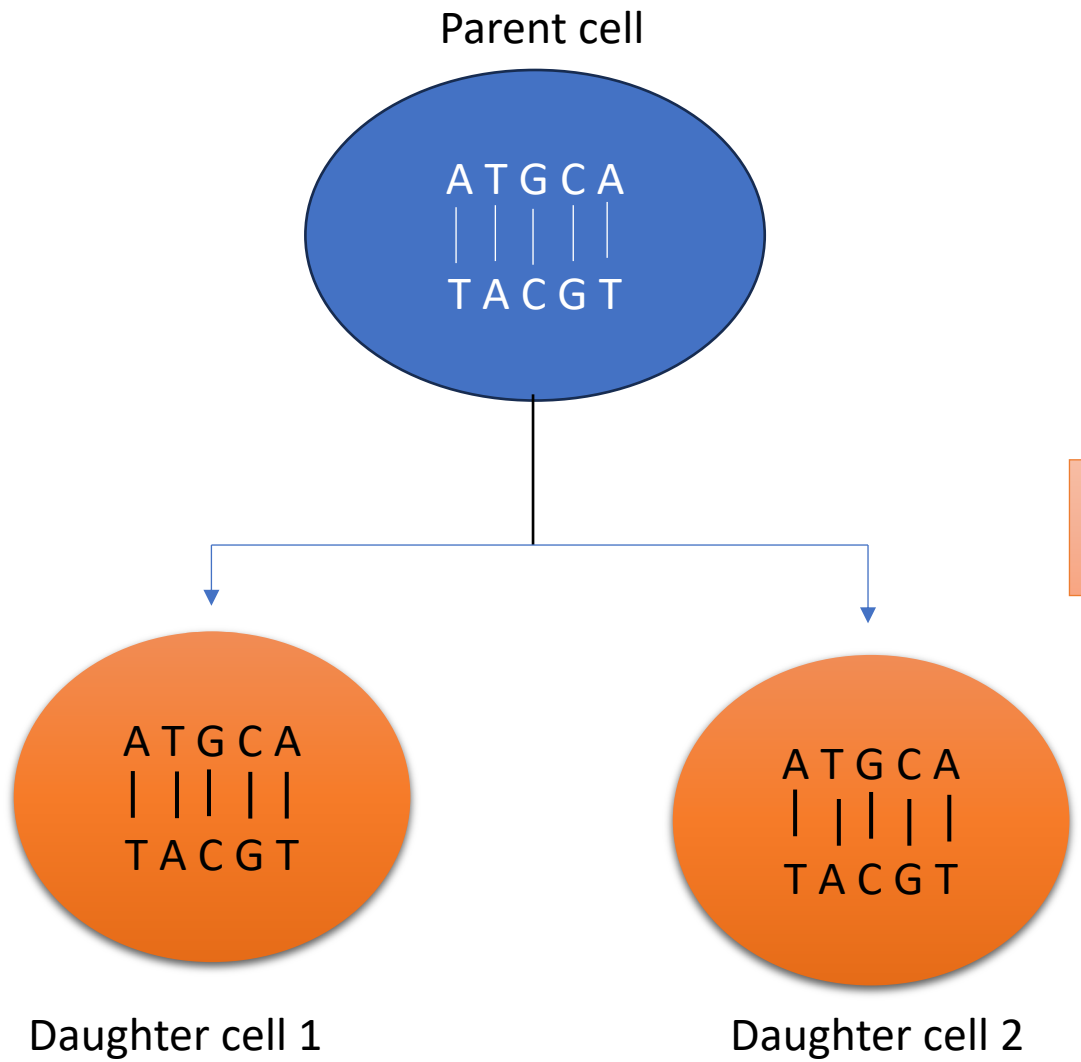
Bacteriophage T2 Reproduction Cycle

HYPOTHESIS: Either component of a bacteriophage—DNA or protein—might be the hereditary material that enters a bacterial cell to direct the assembly of new viruses.



CONCLUSION: DNA, not protein, enters bacterial cells and directs the assembly of new viruses.

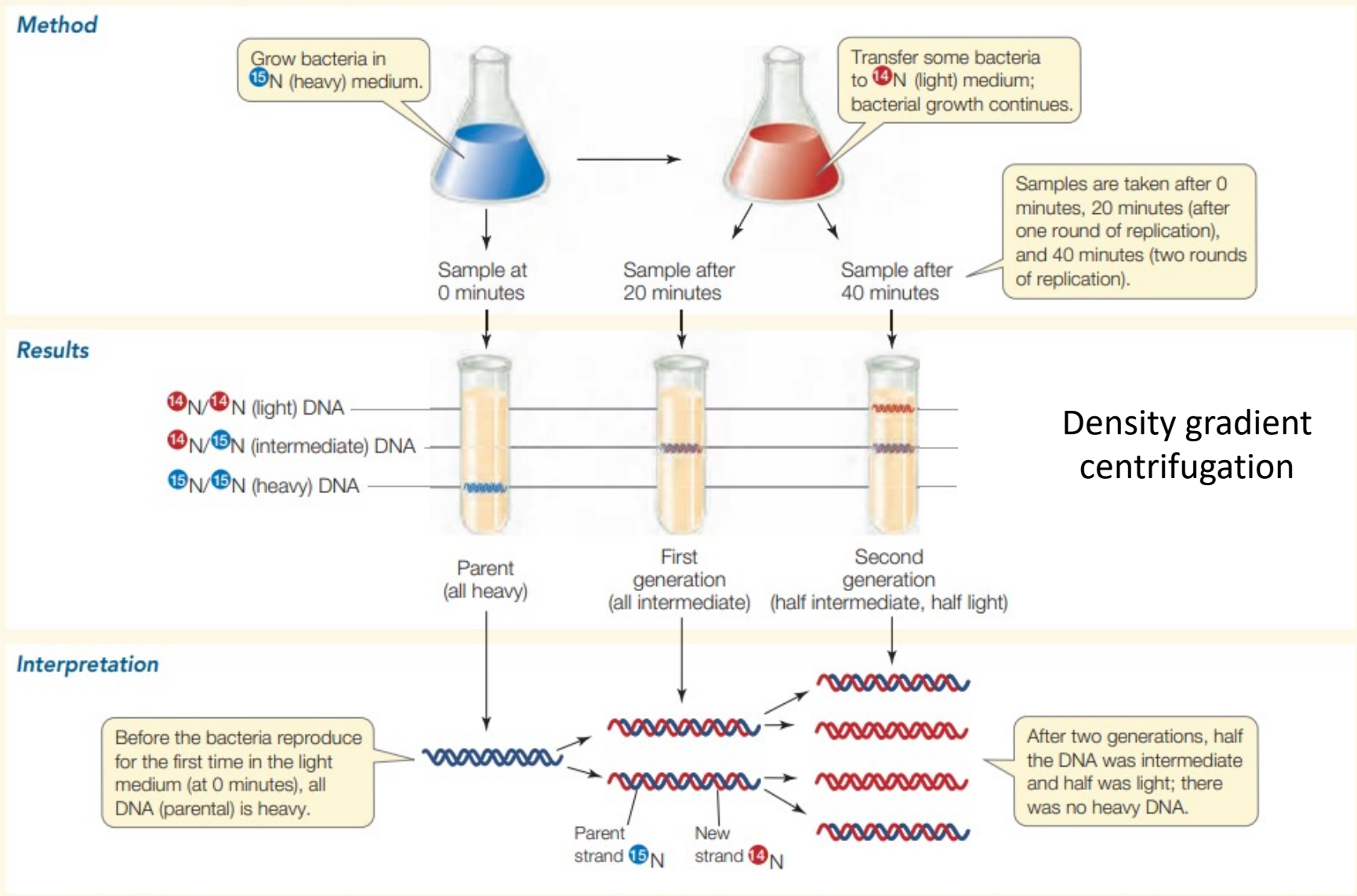
Transfer of genetic material form parent to daughter cell



The two new daughter cells have same genetic information!

Then how do you think DNA replication happens?

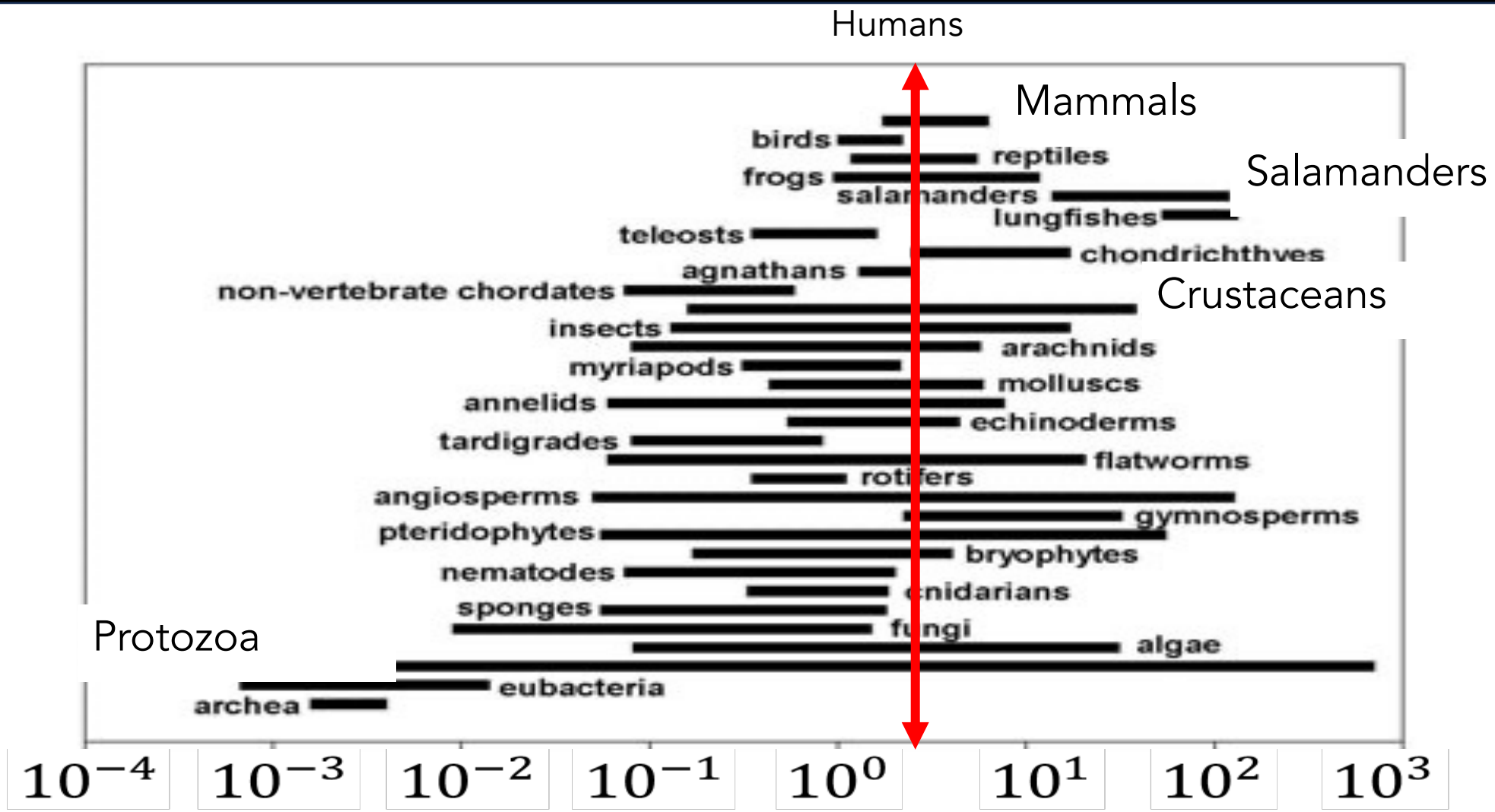
Meselson and Stahl experiment



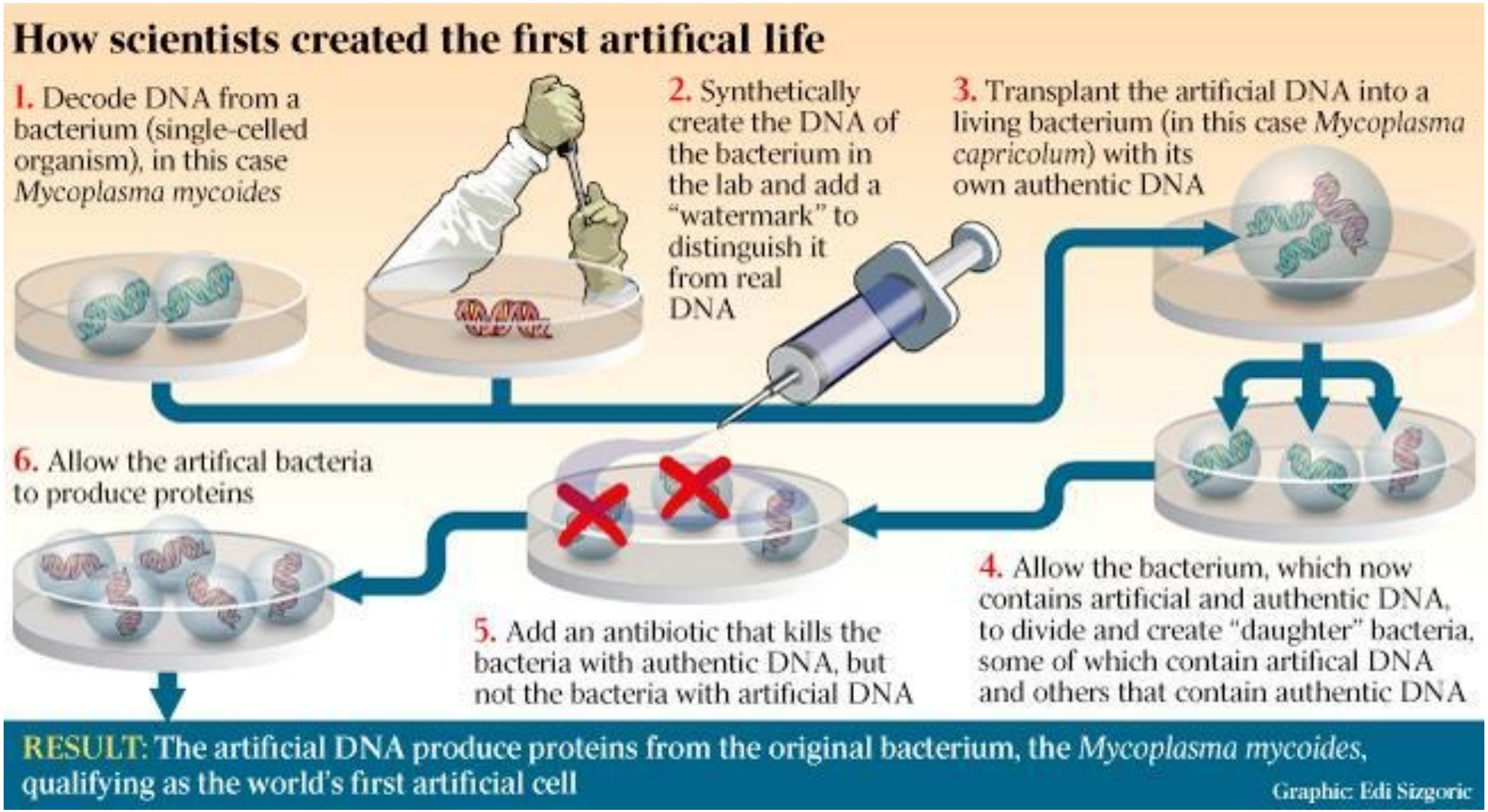
Density gradient centrifugation

CONCLUSION: This pattern could only have been observed if each DNA molecule contains a template strand from the parental DNA; thus DNA replication is semiconservative.

Do humans have the largest genome?



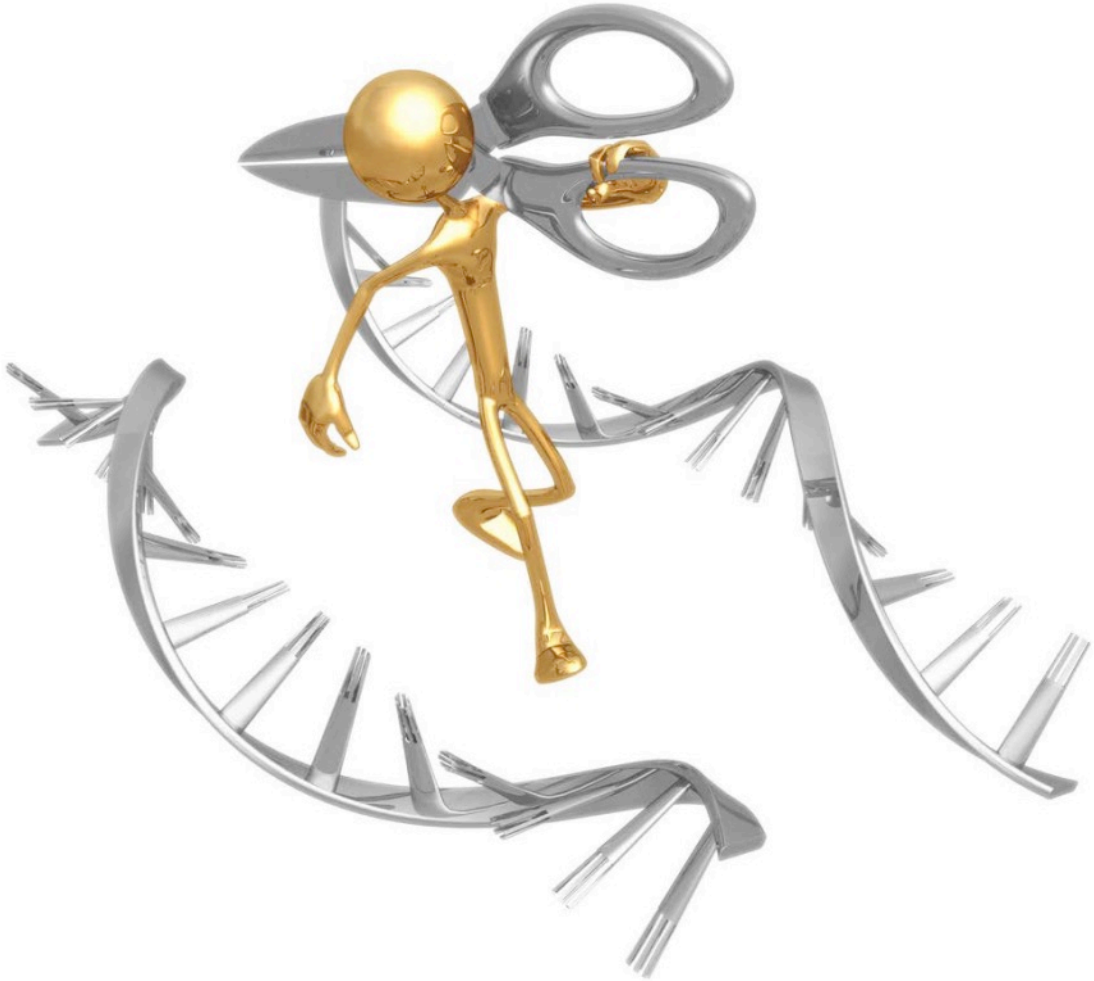
Can we make an organism with a synthetic instruction manual (genome)?



The synthetic genome in each cell contained only 473 key genes thought to be essential for life (half the size of the original genome, approx. 531 kbp, which is smaller than any other autonomously replicating organism found in nature.

Science (2016) 351:1414

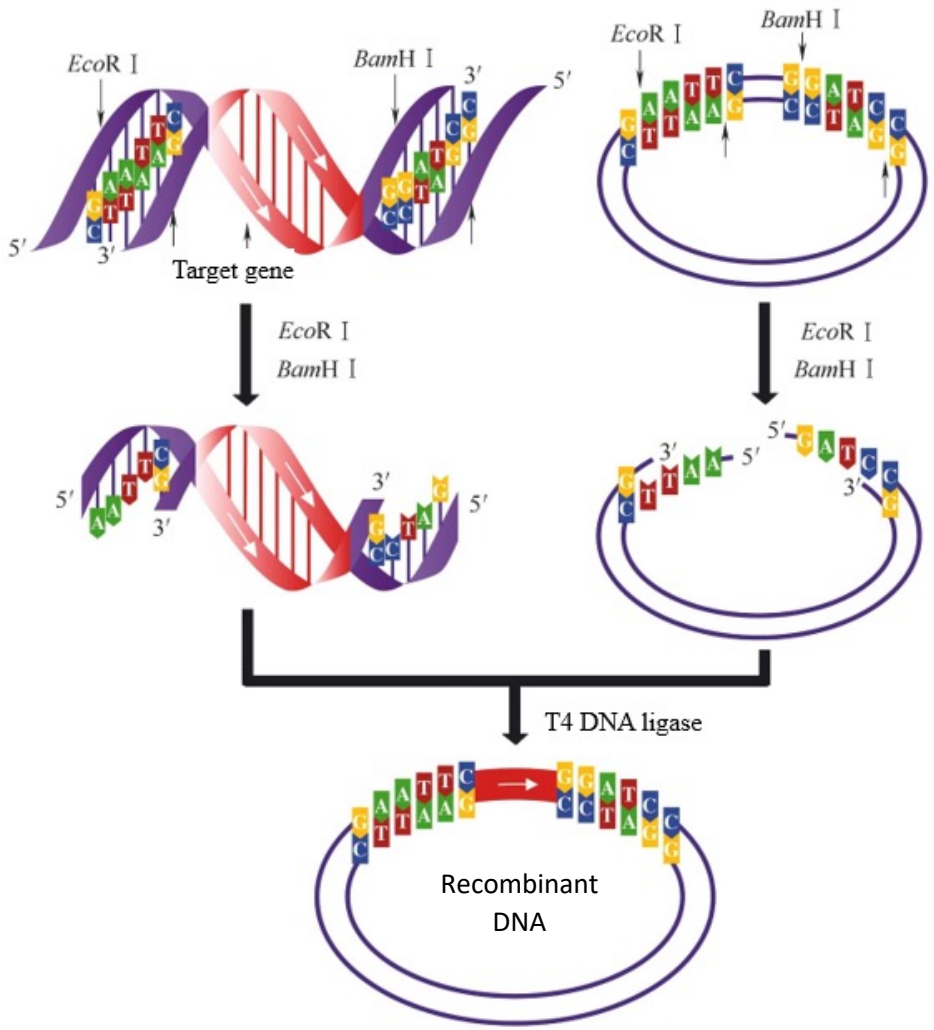
How do People manipulate DNA in Lab?



DNA Tools

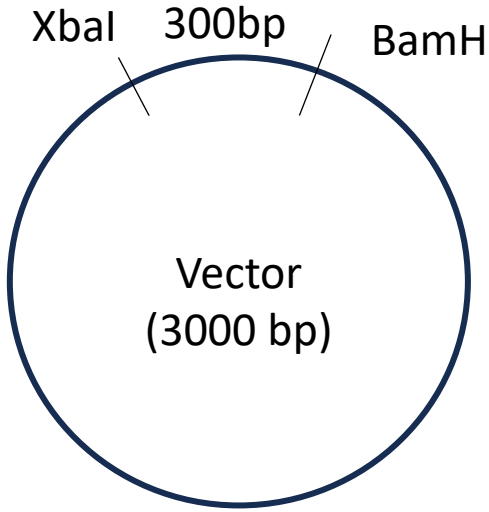
Overview of Genetic Engineering

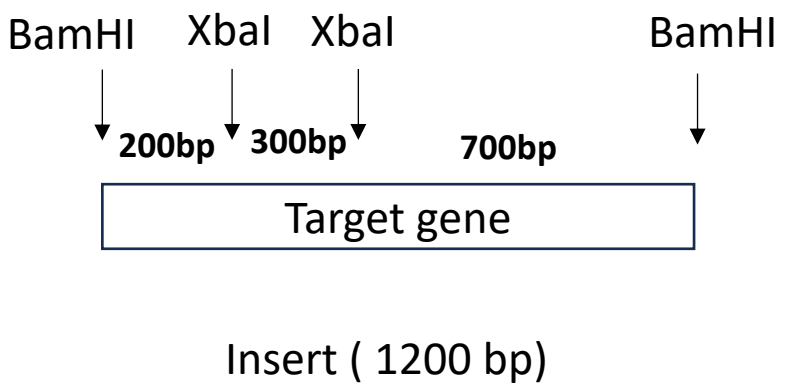
- Both the target gene and the vector are digested with same set of restriction enzyme to produce compatible ends.
- These cut ends are then joined by DNA ligases to form the recombinant DNA molecule.



Problem

The maps of a 1200 base pairs (bp) long target gene and a 3000 bp vector is shown below. The gene is cloned at the BamHI site of the vector using only this restriction enzyme producing a recombinant DNA. The lengths of the DNA in between the restriction sites are indicated in base pairs (bp). What will be the sizes of the fragments produced following complete digestion with XbaI if the insert is cloned in **(i)** correct orientation (right to left) and **(ii)** wrong orientation (left to right)?

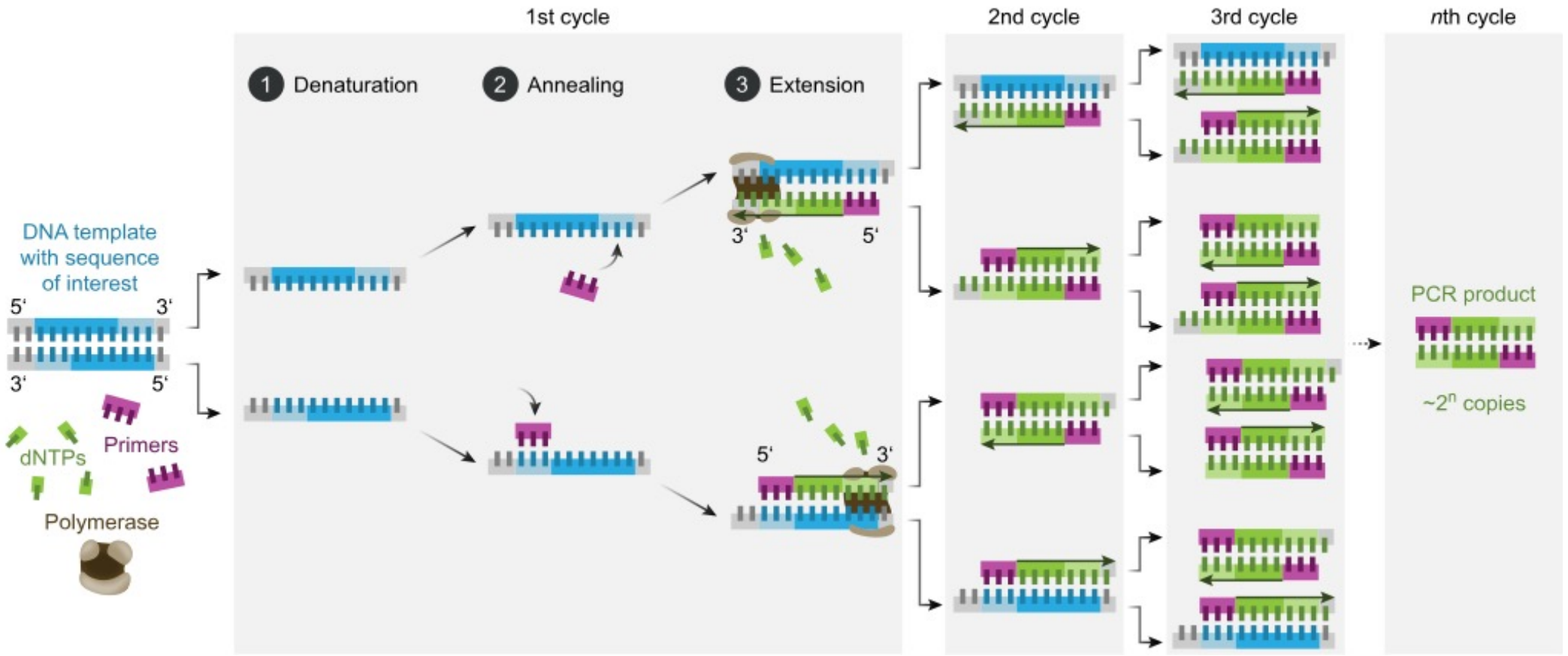




Insert (1200 bp)

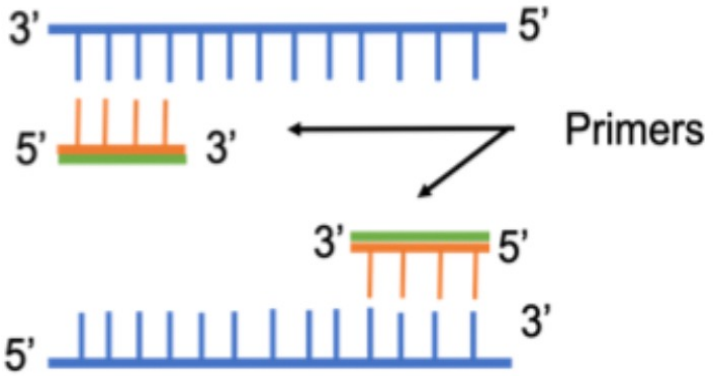
Ans. i) 500 bp, 300bp & 3400 bp
ii) 1000 bp, 300 bp & 2900 bp.

PCR (Polymerase Chain Reaction)



Primers

- Short strand of nucleotides (about 18-28 nucleotides in length) that serves as a starting point for DNA synthesis
- 50-60% GC composition
- Have a balanced distribution of G/C and A/T domains
- No long strings of a single base (<4)
- Tm= (A+T) X 2 + (G+C) X 4
- Primers should not be self complimentary



Q. For the primer 5' GATCCGATTGGACACTGTACTA 3' calculate the Tm.

Ans: 64 °C

Primer designing

Design primers for the following sequence. Location of 2 primers is indicated by >>'s. (Remember, that when both strands of DNA are shown the top strand runs 5'-3')

CTGTCCACACAATCTGCCCTTTCGAAACCATGGGATCCCAACGAAAAGAATTCCCACATGGTCCTT -upper strand
GACAGGTGTGTTAGACGGGAAAGCTTTGGTACCCTAGGGTTGCTTTTCTTAAGGGTGTACCAGGAA –lower strand
>>>>>>>>>>>>>>>>>>

CTTGAATTCGTAACAGCTGCTGGGATTACACATGGCATGGATGAACTATACAAATAA

GAACTTAAGCATTGTCGACG**ACCCTAATGTGTACCGTAC**CTACTTGATATGTTTATT
<<<<<<<<<<<<<<<<<<

The forward primer (>>>>>) will be complementary to the lower strand and must run 5'-3'
5'-CTGTCCACACAATCTGCC -3'

For the reverse primer, you will need to write the sequence of the other DNA strand. The reverse primer (<<<<<) which will be complementary to the upper strand and must run 3'-5'. However, we always write DNA sequences in the 5'-3' direction so the reverse primer would be written: 5'-CATGCCATGTGTAATCCCAG-3'

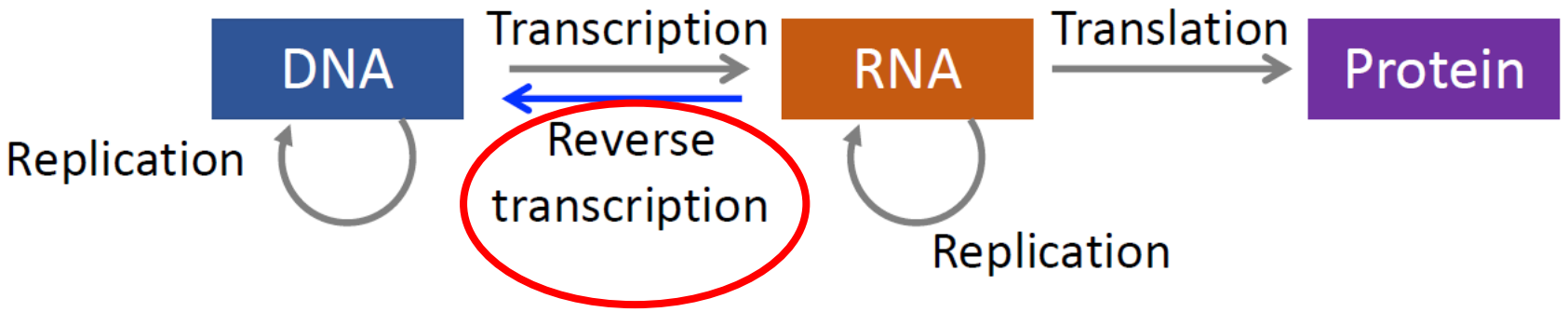
Primer 3 : https://bioinfo.ut.ee/primer3-0.4.0/

Primer- BLAST : https://www.ncbi.nlm.nih.gov/tools/primer-blast/

Central Dogma

A new disease causing organism is spreading quickly in your city. To determine whether a person is infected or not, his or her nasal swabs are being tested through a technique that involves a process called "**Reverse Transcription**". Given this information, can you comment about the type of genetic material that the organism have?

Recall...



Genetic Code

A popular brand yogurt has been shown to provide several health benefits including alleviation of negative emotions like depression. After a lot of research it was found that a bacteria used in the yogurt secretes a small protein molecule (20 amino acids) which have anti-depressant qualities. What would be the size of the gene encoding this protein?

Recall…

- Each codon consists of 3 nucleotide bases coding for an amino acid.
- A stop codon in a gene signals for end of the synthesis of that protein.

- So, the size of the gene would be (20*3)+3 = 63 base pairs.

Genetic Code

Now, you want to find out which part of the bacterial genome is responsible for secretion of this protein. What are the basic criteria that you would include in your search string?

Things to remember…

- START Codon: AUG (ATG)
- STOP Codon: UAA (TAA) or, UAG (TAG) or, UGA (TGA).

So, We need to look for presence of “ATG” and any one of “TAA”, “TAG” or “TGA”; and these two separated by 57 other nucleotides (19 codons, none of them being a STOP codon) in the sequence of the bacterial genome.

Genetic Code

Further research showed that, another gene with the following sequence is also important in promoting anti-depressant behaviour.
5’-ATGGACAGCCCAGCCGACTACTAA-3’
3’-TACCTGTCGGGTCGGCTGATGATT-5’

- What would be the mRNA sequence encoded by this gene?

Answer..
“T” would replaced by “U” in the coding sequence of the gene for mRNA.

So, it would be: 5’-AUGGACAGCCCAGCCGACUACUAA-3’

Genetic Code

Now as you have the mRNA sequence (5’-AUGGACAGCCCAGCCGACUACUAA-3’), find out the amino acid sequence of the protein that the gene encodes by referring to the given Genetic code table:

Answer…
Met-Asp-Ser-Pro-Ala-Asp-Tyr.

No need to mug the table.

UUU, UUC: Phe UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr UAA, UAG: Stop	UGU, UGC: Cys UGA: Stop UGG: Trp
CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg
AUU, AUC, AUA: Ile AUG: Met	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn AAA, AAG: Lys	AGU, AGC: Ser AGA, AGG: Arg
GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly

BB 101
Gene regulation and Cell Communication
Tutorial 5
08.02.2024

Complementary DNA (cDNA) Synthesis

1. mRNA & Reverse transcriptase added

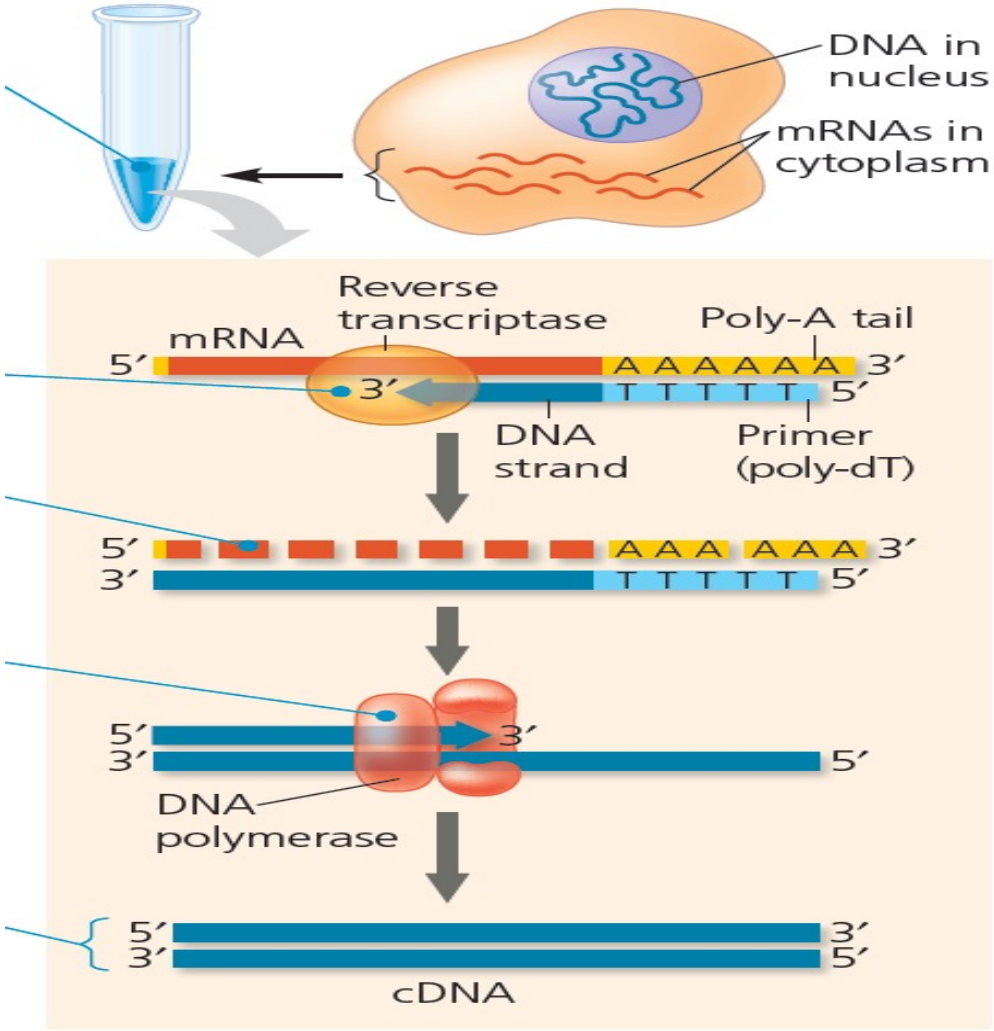
3' end of mRNA has a stretch of adenine - poly-A tail, which allows use of a short complementary strand of poly-dT primer for synthesis of DNA strand

2. RT makes first DNA strand (mRNA template; poly-dT DNA primer)

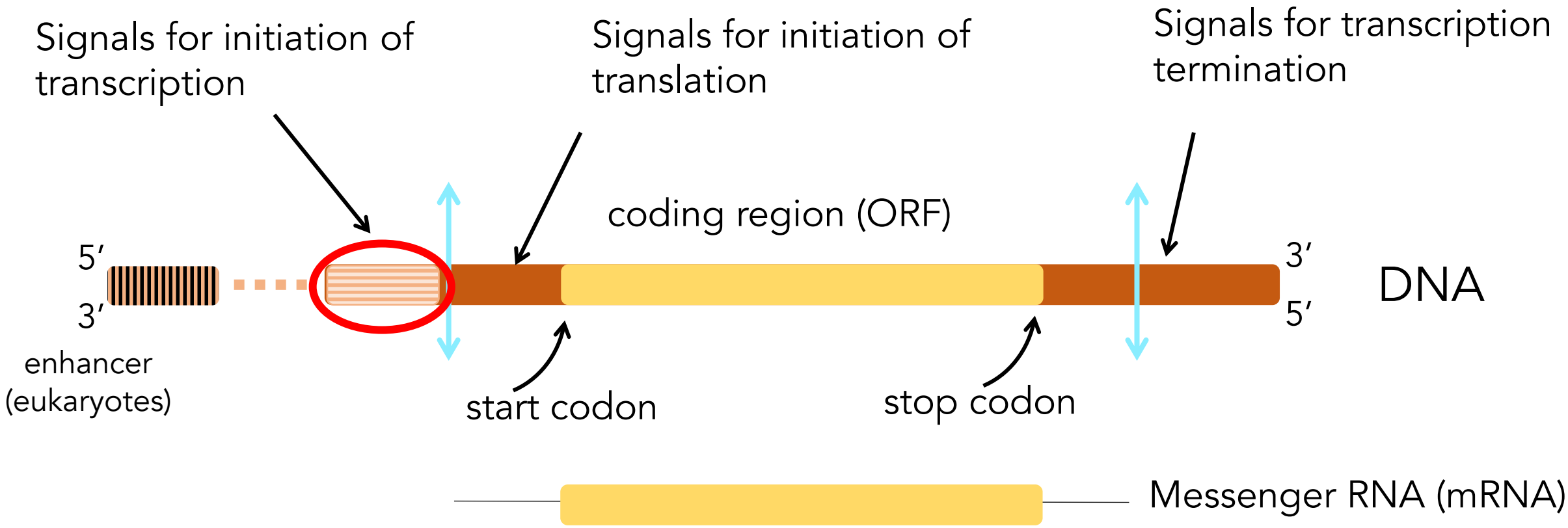
3. mRNA degraded by enzyme

4. DNA polymerase synthesizes 2nd DNA strand

5. cDNA is synthesized which carries complete coding sequence of gene but no introns

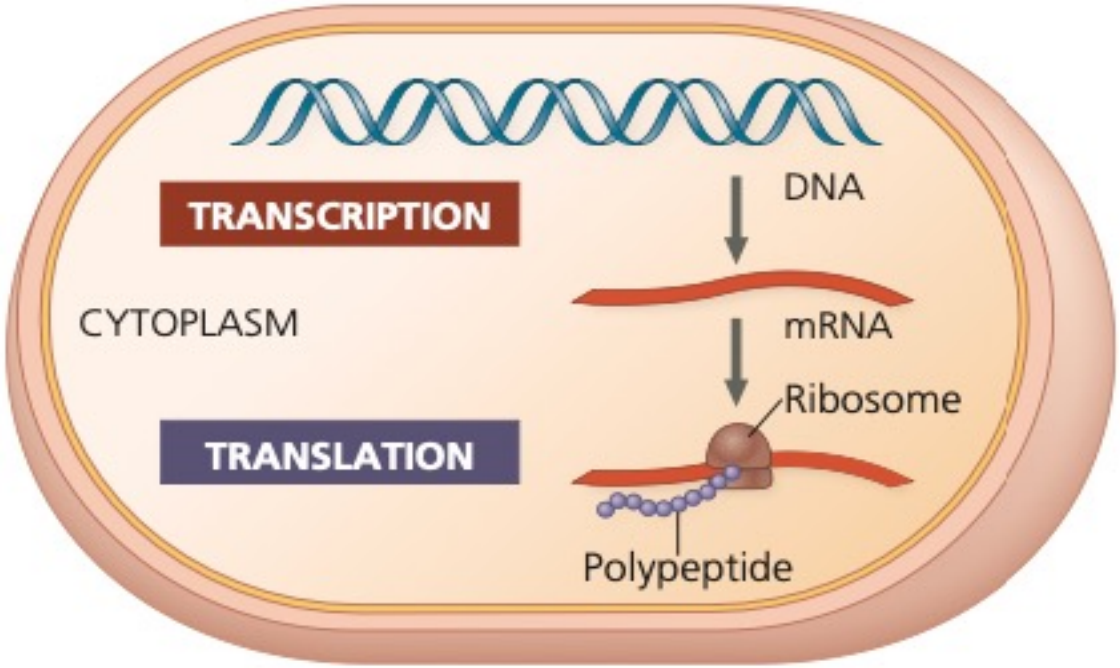


Gene: stretch of DNA that encodes a protein



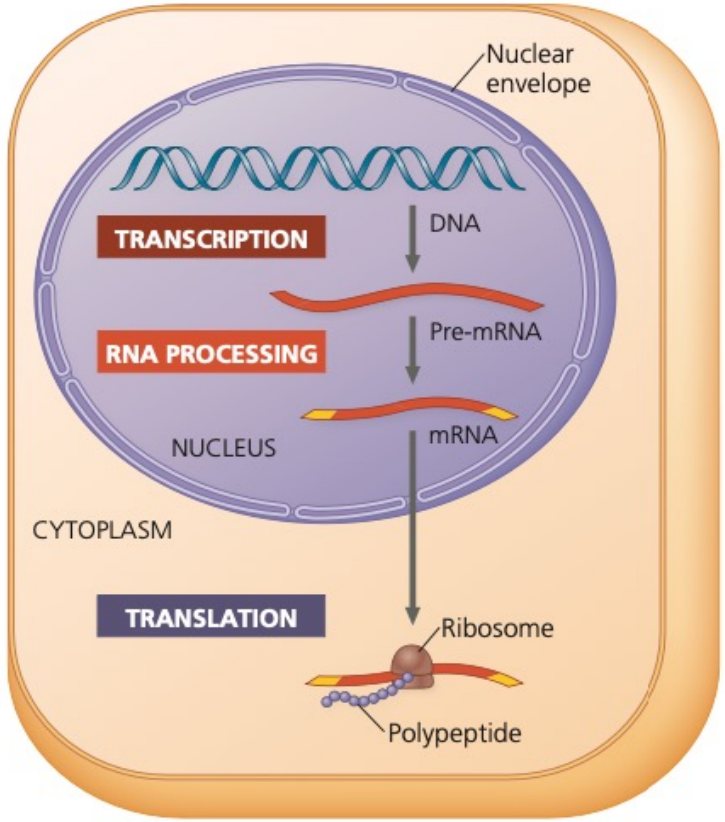
A gene includes the entire sequence represented in mRNA

Comparison of Transcription & Translation in Prokaryotes & Eukaryotes



Bacteria do not have nuclei, their DNA is not separated by nuclear membranes from ribosomes and the other protein-synthesizing equipment.

The lack of compartmentalization allows translation of an mRNA to begin while its transcription is still in progress

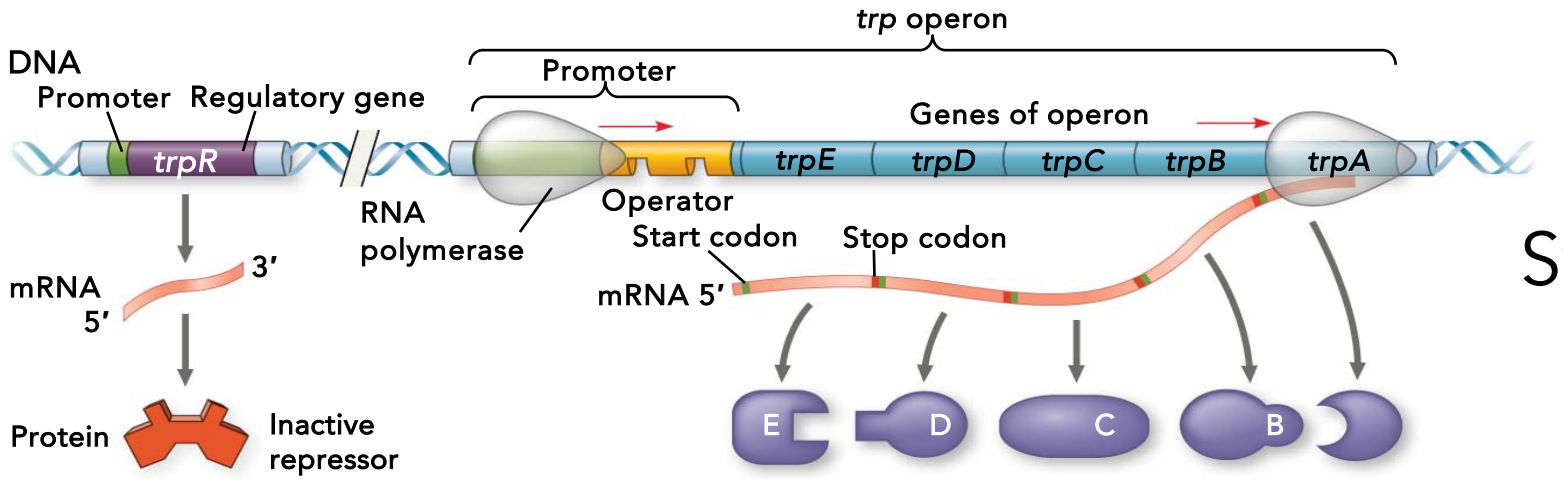


In a eukaryotic cell, by contrast, the nuclear envelope separates transcription from translation in space and time

Gene Regulation

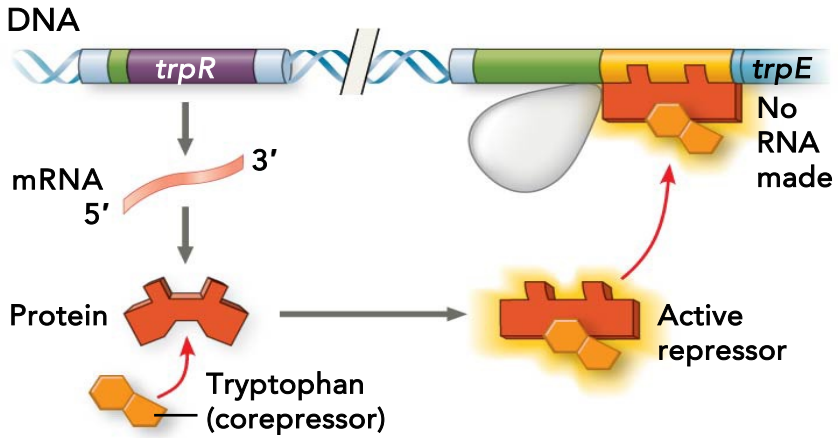
A hallmark of prokaryotic and eukaryotic cells alike—from a bacterium to the cells of a fish - is their intricate and precise regulation of gene expression.

An Overview of trp operon in E. coli: regulated synthesis of repressible enzymes



(a) Tryptophan absent, repressor inactive, operon on

Switch is ON



(b) Tryptophan present, repressor active, operon off

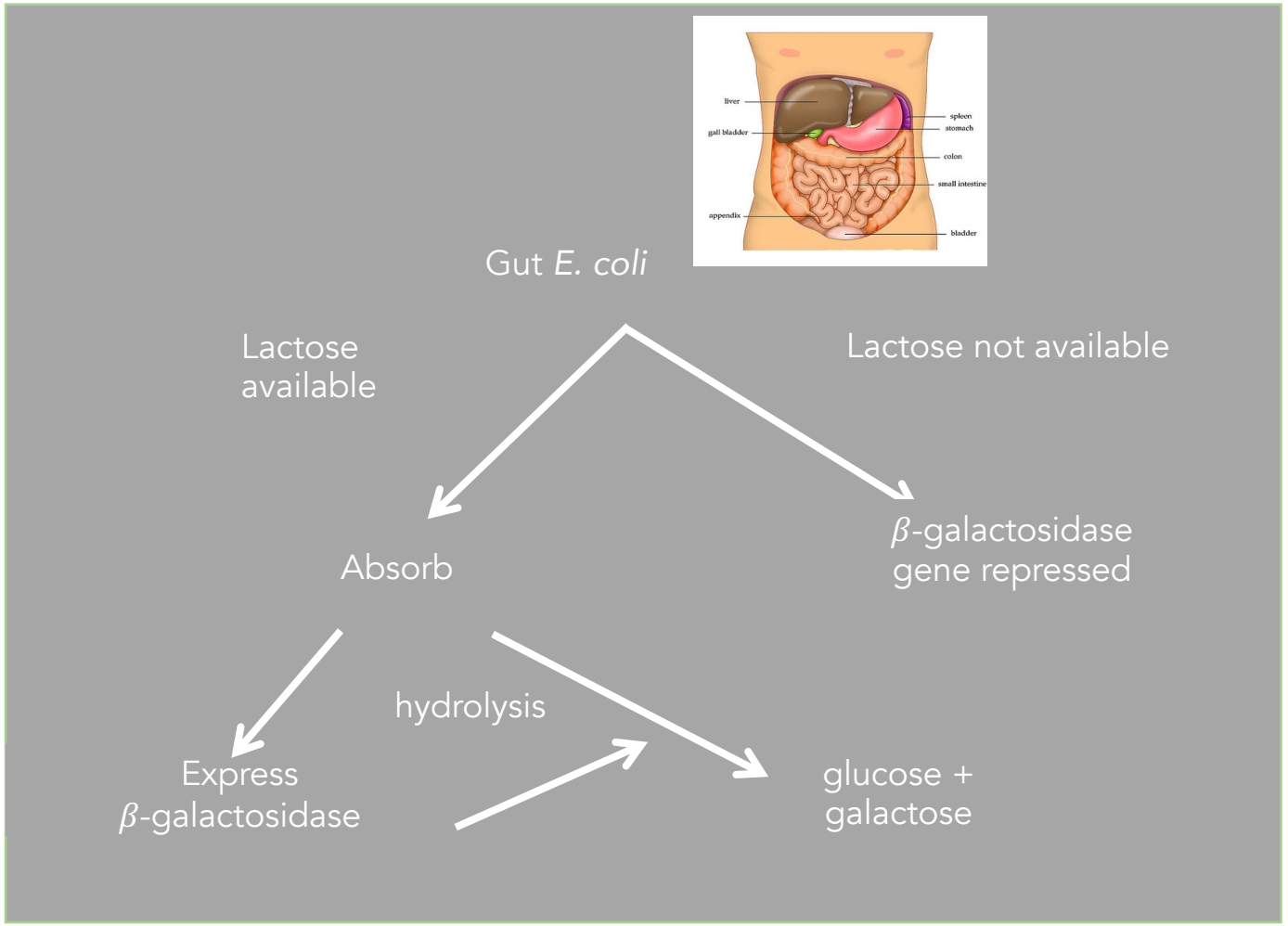
Switch is OFF

Inducible Operons

An inducible operon is usually off but can be stimulated (induced) when a specific small molecule interacts with a regulatory protein. Example of an inducible operon is the lac operon (lac for lactose).

The lac Operon

- *E. coli* inhabits human gut
- Disaccharide lactose is available from milk

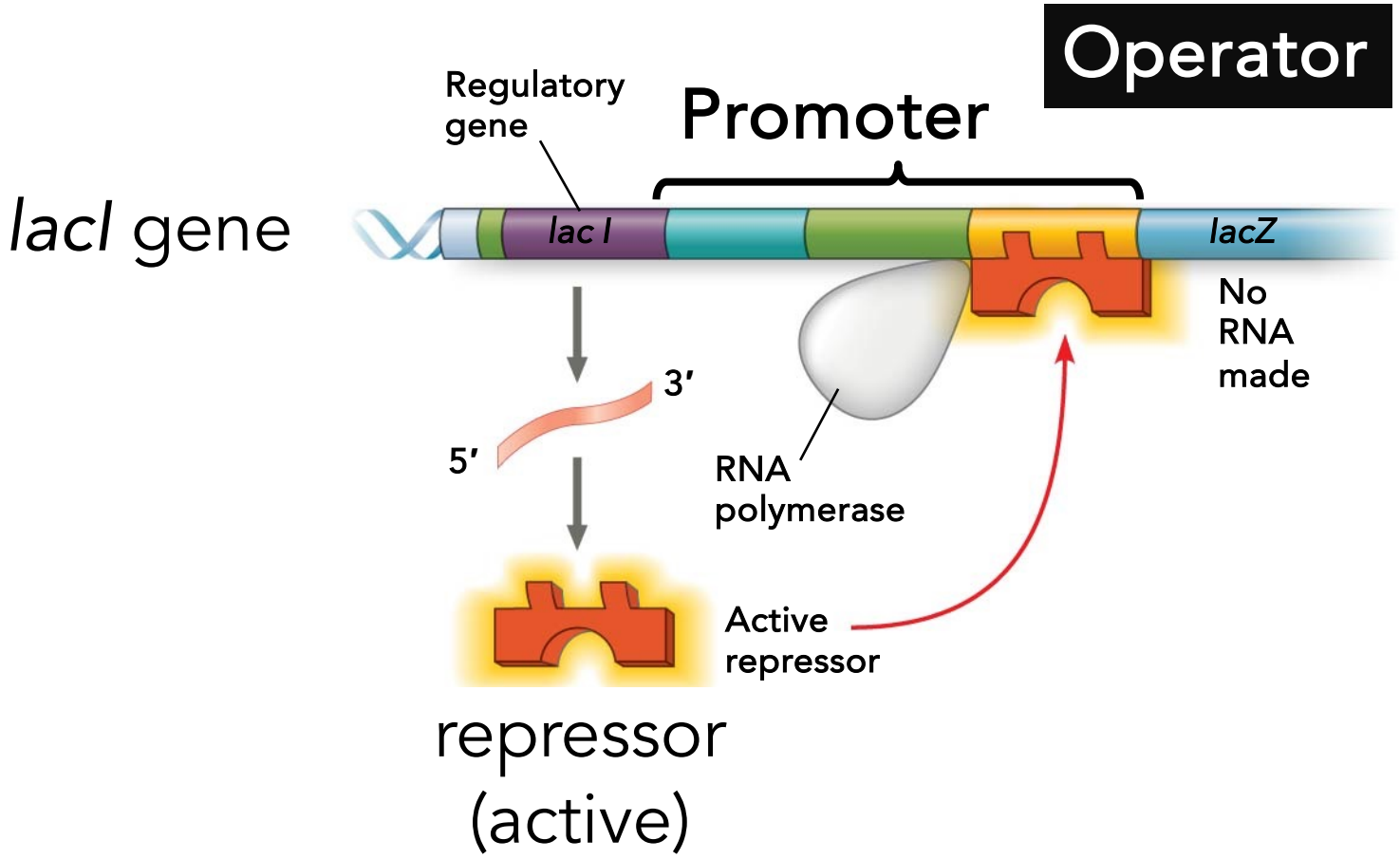


Induction of the lac operon

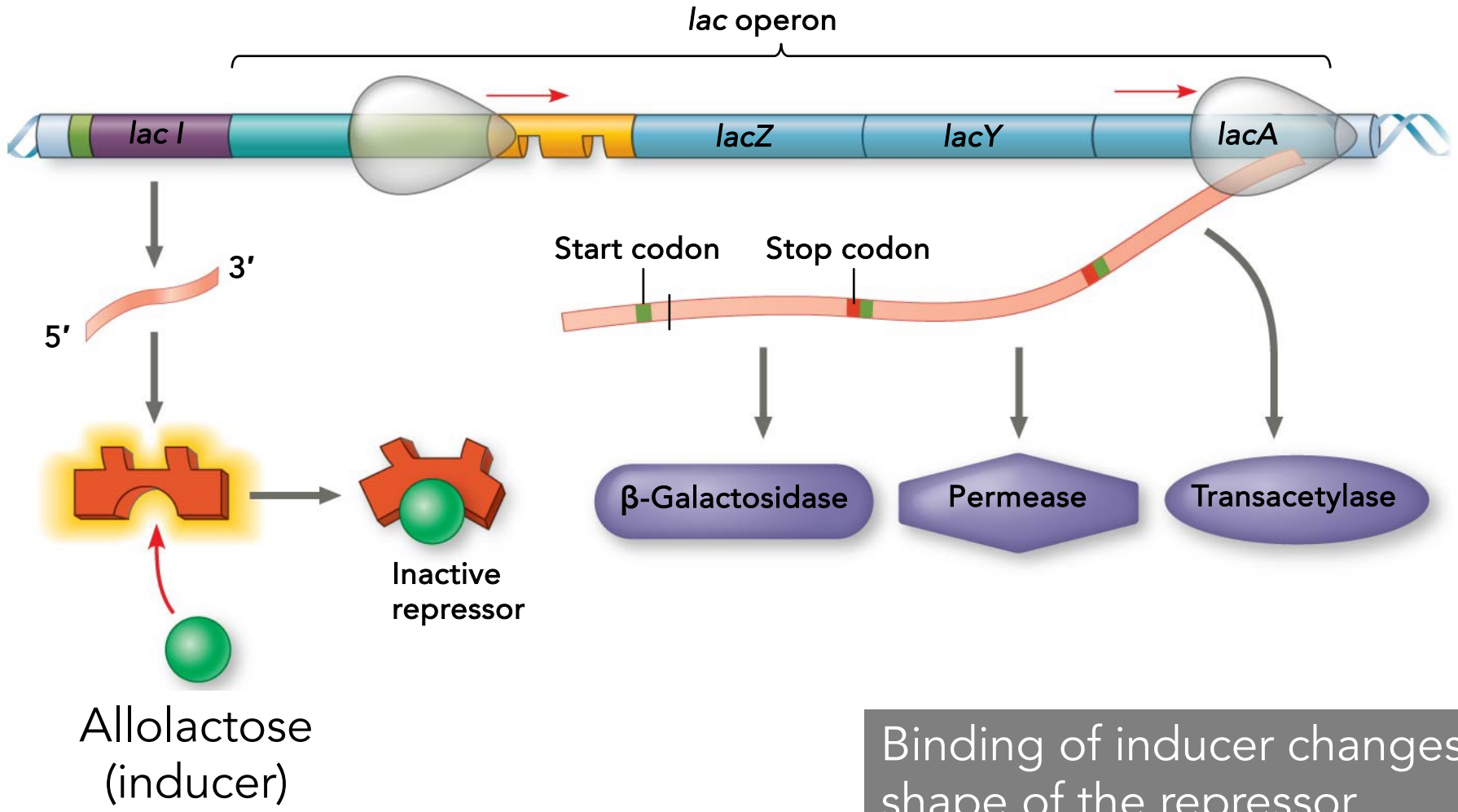
Lactose absent	Only a few molecules of β-galactosidase
Lactose present	1000-fold increase in the number of β-galactosidase Time taken: about 15 minutes

Is the *lac* operon similar to the *trp* operon?

Induction of the lac operon



Induction of the lac operon



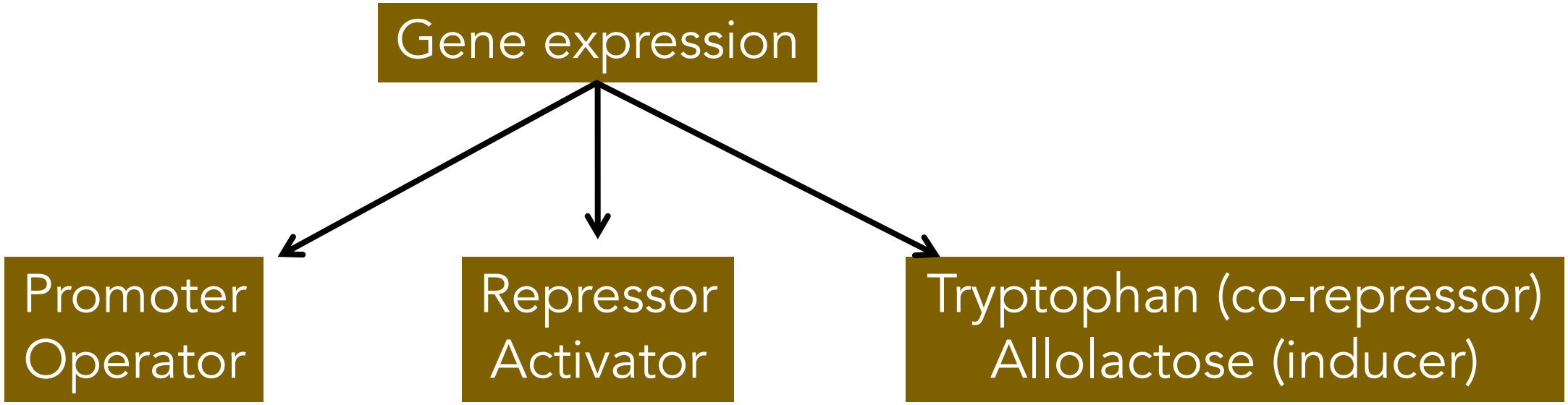
Binding of inducer changes the shape of the repressor

Summary: trp and lac operons – two designs

***trp* operon**	***lac* operon**
Repressible operon	Inducible operon
"usually" on	"usually" off
Repressor inactive by itself	Repressor active by itself
Tryptophan: co-repressor	Lactose: inducer
Typical: biosynthetic pathway enzymes	Typical: degradation pathway enzymes
Regulation: negative	Regulation: negative

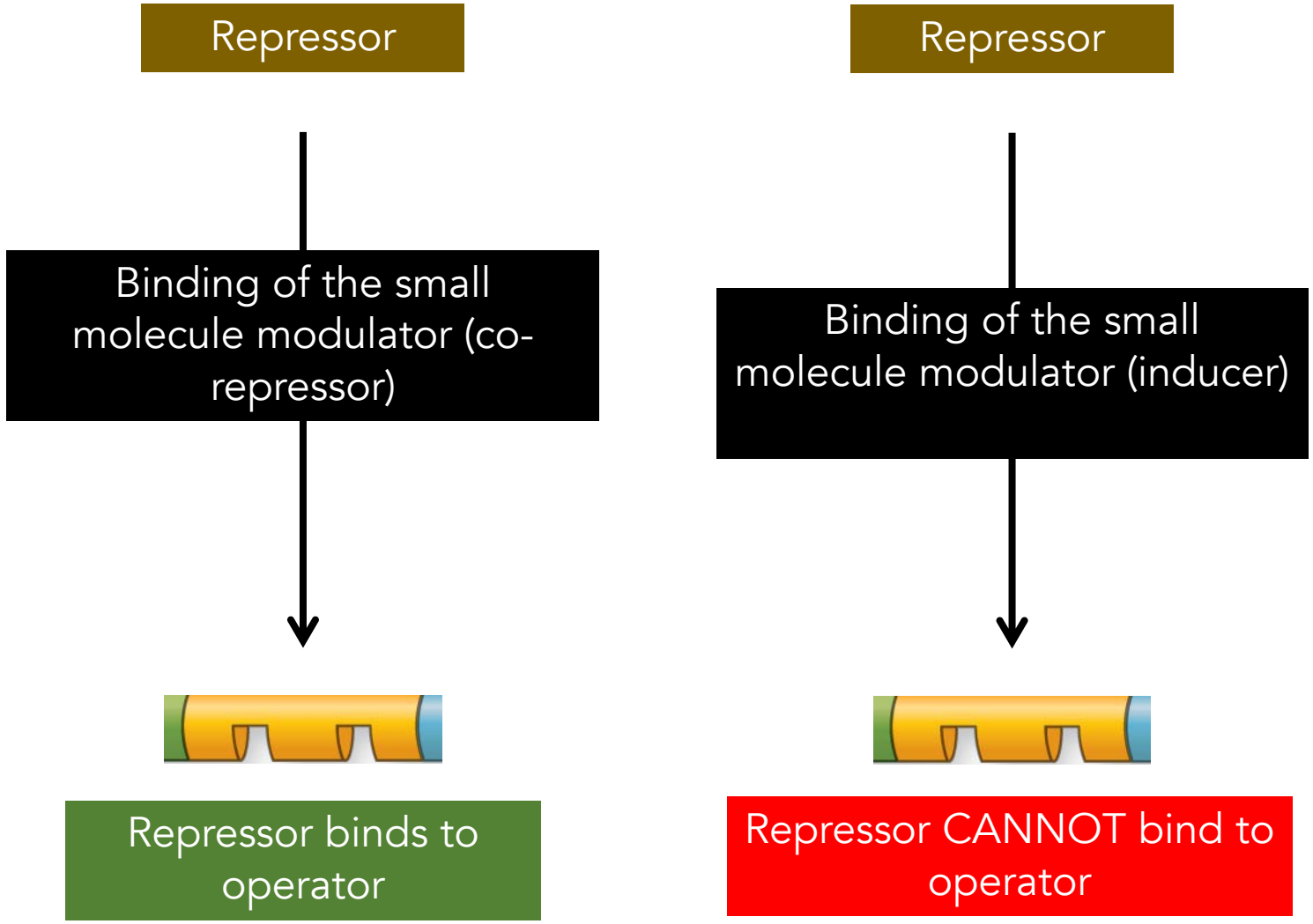
Negative regulation: binding of repressor shuts down gene expression

Summary: trp and lac operons



Summary: trp and lac operons

These are examples of genetic switches!

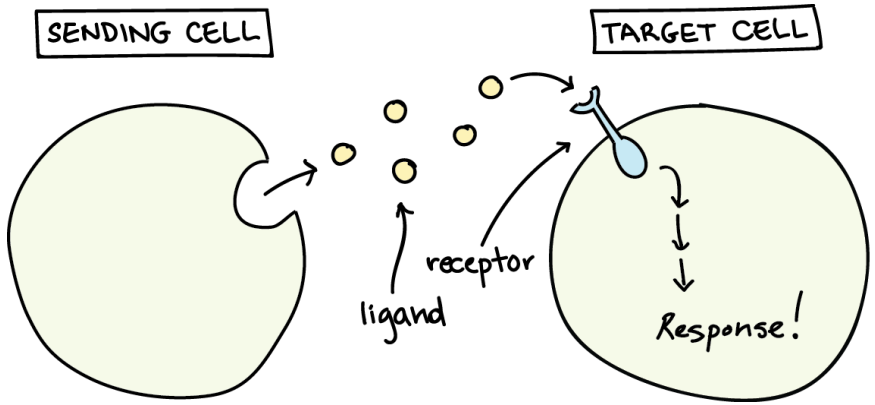


Cell Communication

- Cell communication is the ability of the cells to communicate with adjacent cells within an organism (cell signaling)
- All cells receive and respond to signals from their surroundings.
- Signaling by extracellular signal molecules usually involves:
  - Synthesis and release of the signal molecule by signaling cell
  - Transport of the signal molecule to the target cell
  - Binding of the signal by specific receptor leading to activation
  - Initiation of signal transduction pathways

Signal molecule

Receptor

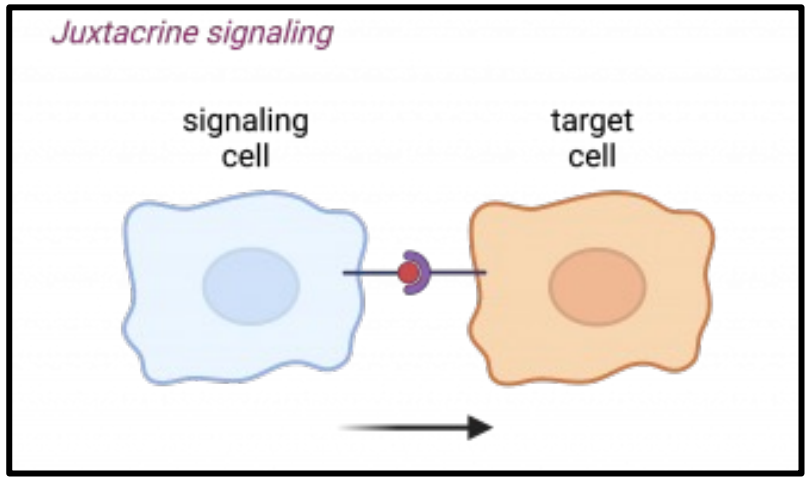


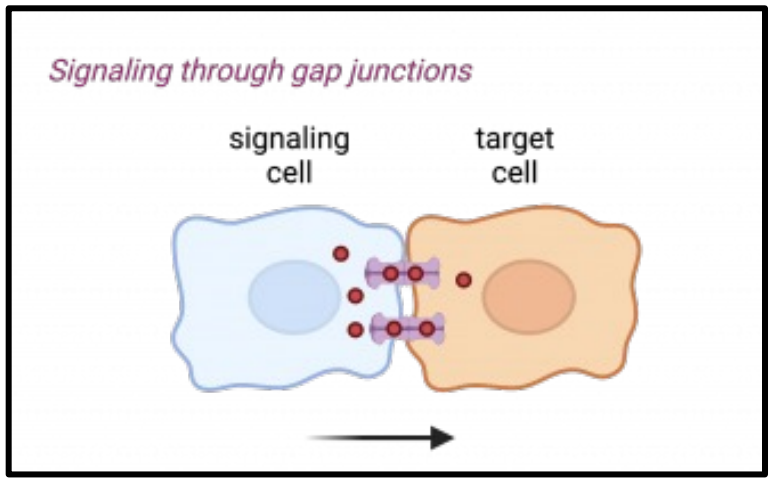
Types of signaling

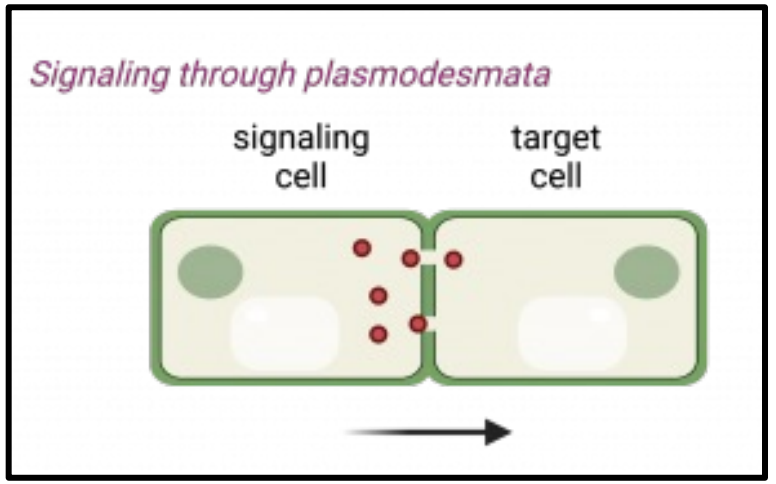
- Direct signaling- E.g.→ Gap junction
- Autocrine signaling- E.g.→ Leptin
- Paracrine signaling- E.g.→ Estrogen
- Endocrine signaling- E.g.→ Insulin

Direct Signaling: between the cells that are in direct contact with each other

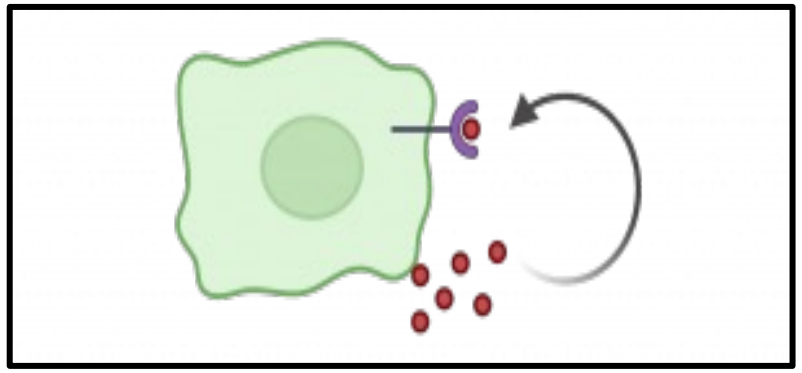
Example: cell-cell communication (juxtacrine signaling), cell-junction communication (gap junctions)







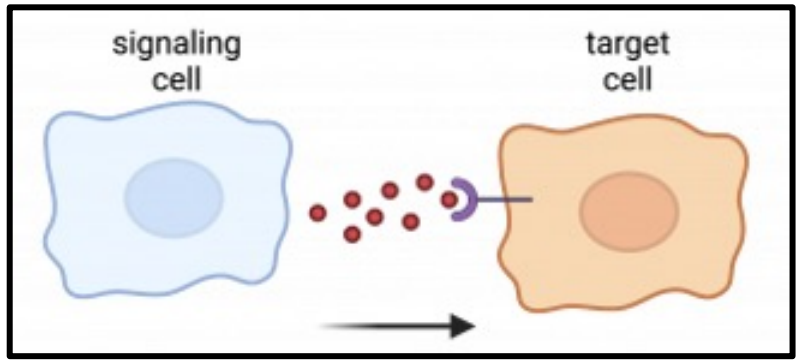
Types of signaling



A cell targets itself

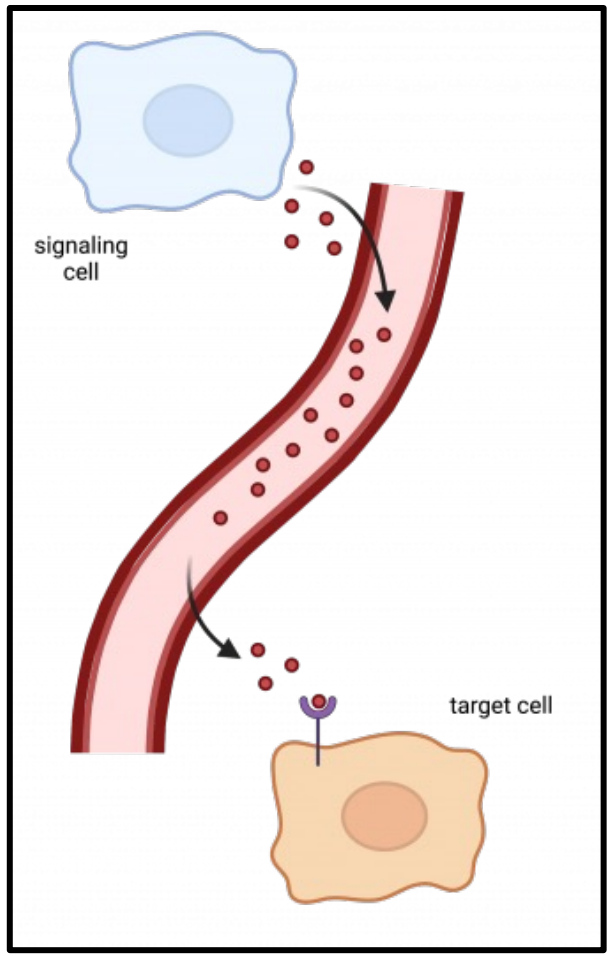
Autocrine

Endocrine



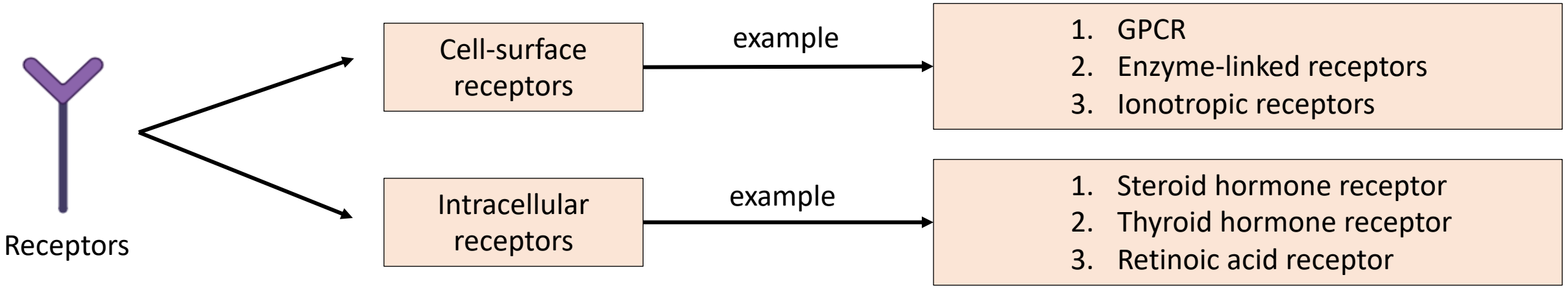
A cell targets a nearby cell

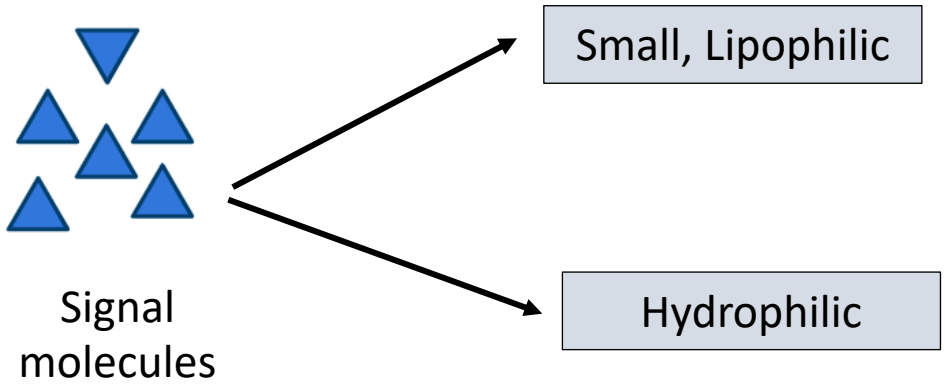
Paracrine



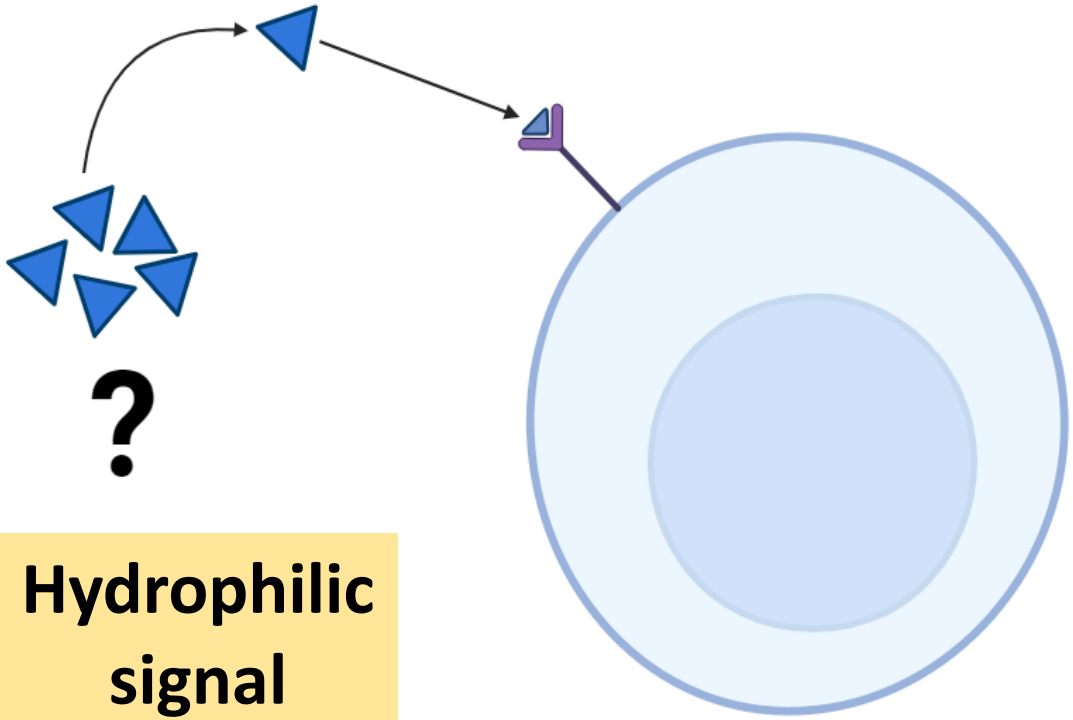
A cell targets a distant cell through bloodstream

Receptors & Signal molecules

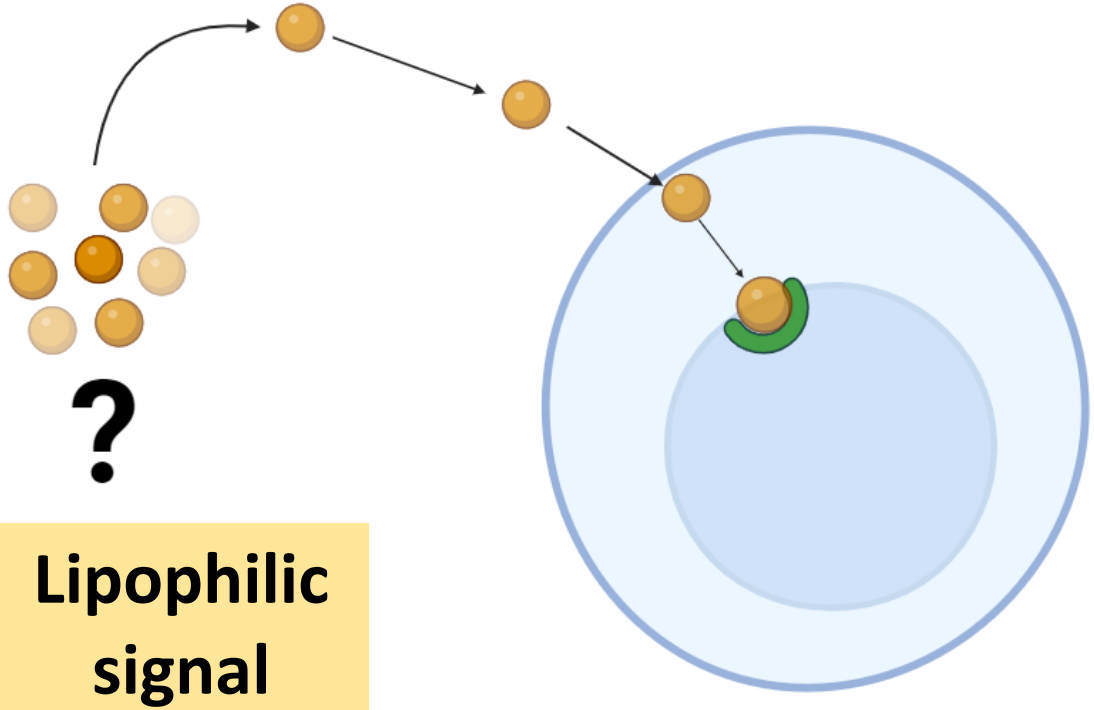




Signal molecule: which path to follow??



Hydrophilic signal

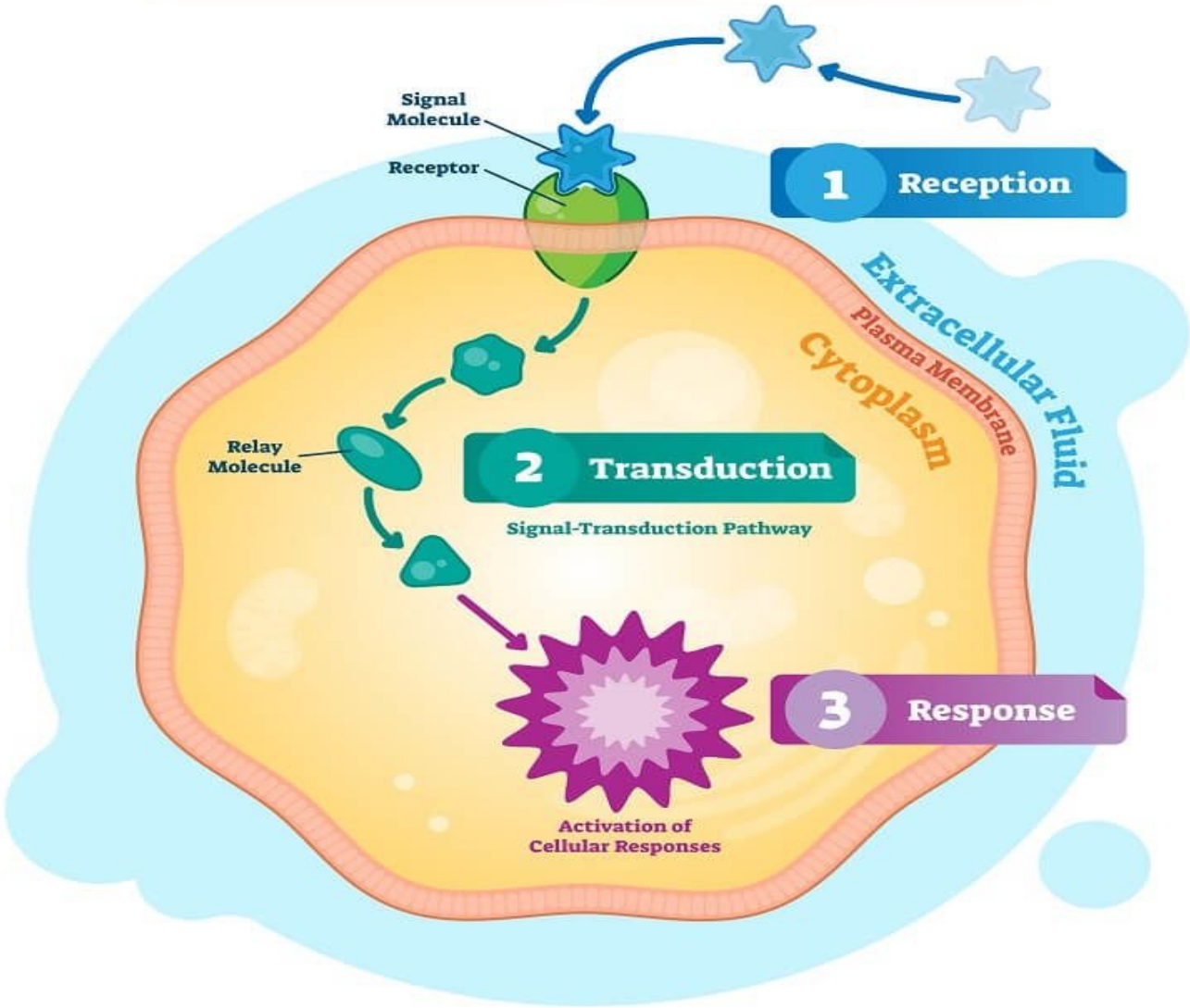


Lipophilic signal

Signal Transduction

- **Signal transduction**: the transmission of molecular signals from a cell's exterior to its interior.

- Steps involved:
  1. **Reception:**
     - Ligand binding; cell contact
  2. **Signal Transduction:**
     - Transfer of signal to the cell interior
     - Modulate the activity of Protein Kinases and phosphatases
  3. **Response:**
     - Phosphorylate on the state of the target
     - Modulation of effector activity



https://biologydictionary.net/cell-signaling/

Quorum (Ko-rum)

The minimum number of members of a society/group that must be present in a meeting to make the proceedings of that meeting valid.

Bacteria are capable of quorum sensing! Regulate gene expression depending upon cell-population density

How do the bacteria “know” the population density of their surroundings?

Luminescence and bioluminescence

Quorum-sensing is most extensively studied in the bacteria *Vibrio fischeri*

Luminescence: emission of light by a substance that is not heated

Lux: unit of luminescence

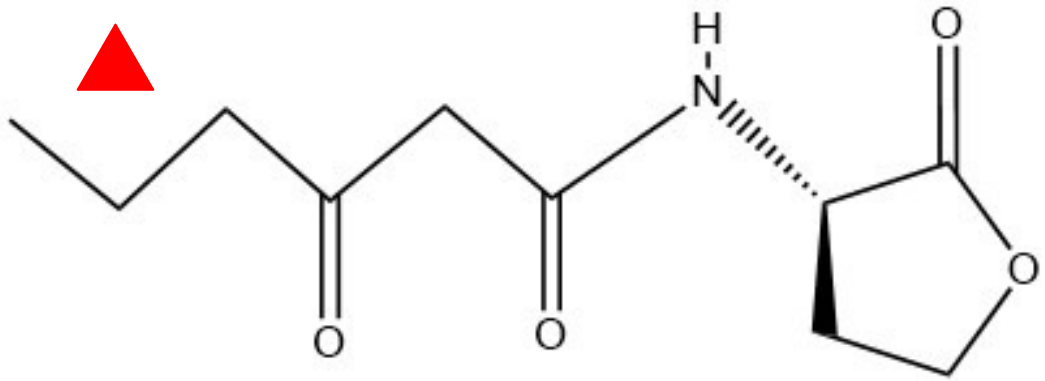
Genes involved in bioluminescence are named as lux genes in *V. fischeri*

Gene names: italics + all letters in lower case
Encoded proteins: normal font + first letter in upper case

Quorum sensing in Vibrio fischeri

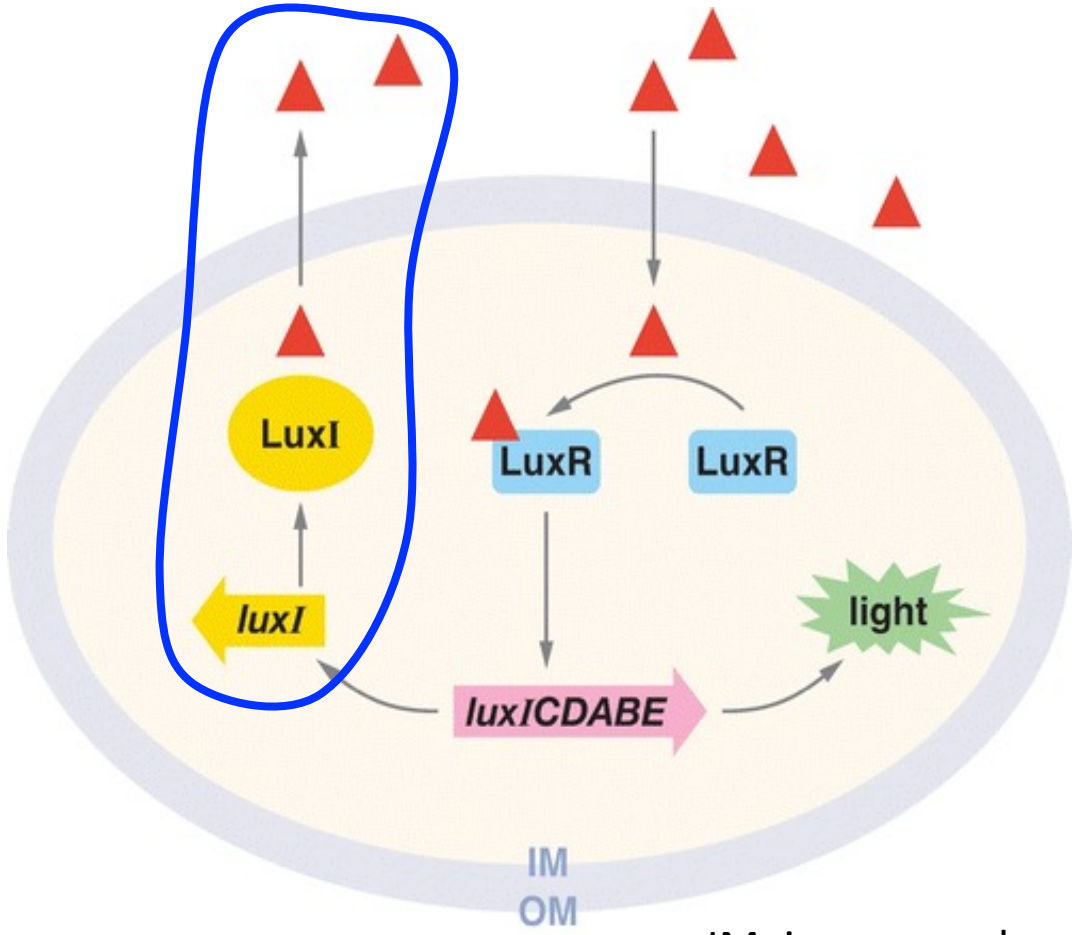
luxI: basal level of expression

LuxI: is an enzyme responsible for the synthesis of “auto-inducer”



3-Oxo hexanoyl homoserine lactone

Auto-inducer (AI) diffuses out of the cell



Waters CM, Bassler BL. 2005.
Annu. Rev. Cell Dev. Biol. 21:319–46

IM: inner membrane
OM: outer membrane

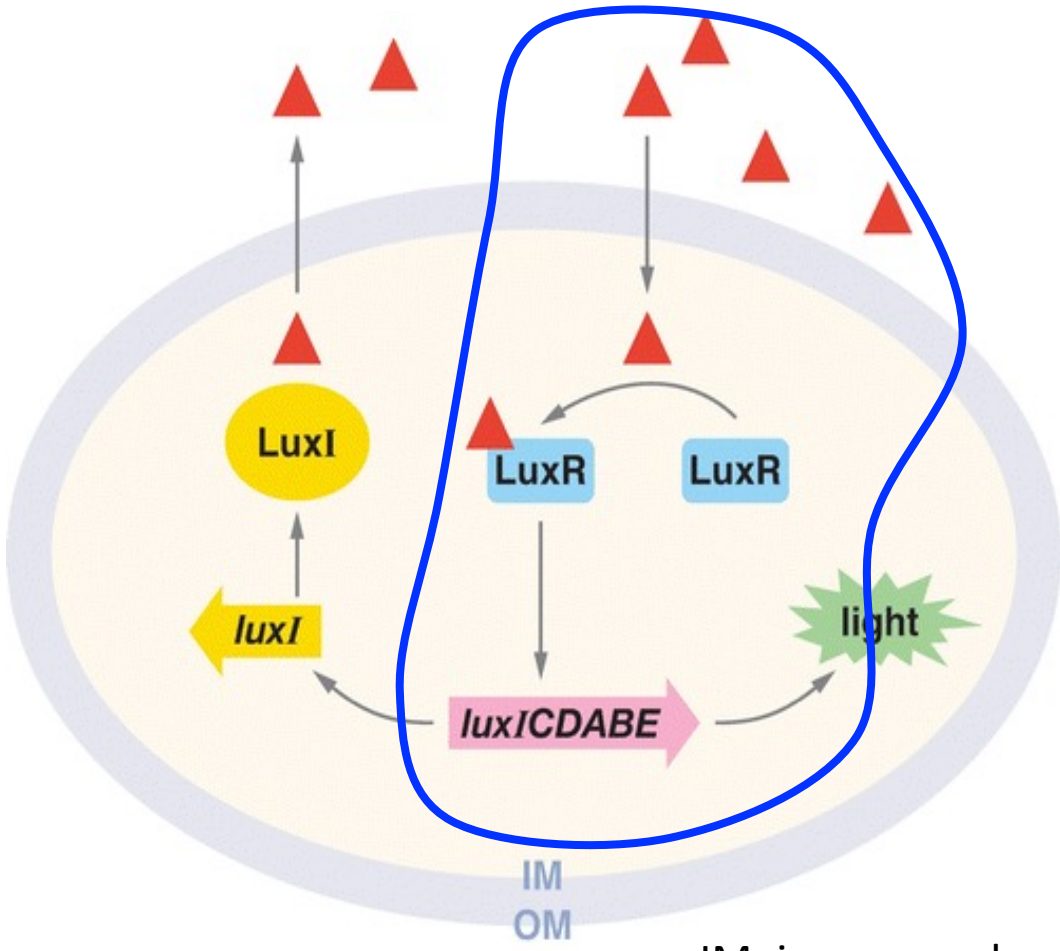
22

Quorum sensing in *Vibrio fischeri*

If quorum is met i.e., the number of bacteria reaches a certain critical level, then $[AI]_{extracellular}$ reaches a critical level

AI diffuses back into the cell and binds to LuxR, its cytosolic receptor

The LuxR-AI complex activates the transcription of the *lux* operon (*luxI* and *luxC* + *luxD* + *luxA* + *luxB* + *luxE*) resulting in **LIGHT!**



Waters CM, Bassler BL. 2005.
Annu. Rev. Cell Dev. Biol. 21:319–46

IM: inner membrane
OM: outer membrane

luxA, *luxB*: α, β subunits of luciferase
luxC, *luxD*, *luxE*: synthesis + recycling of luciferase substrate

Luminescence in *Vibrio fisheri*: purpose?

Luminescence is an energy-consuming process

- For the generation of light
- For the biosynthesis of the relevant proteins / associated molecules

Inference:

- Luminescence ought to be beneficial
- Why retain this phenotype if there is no advantage (growth / survival)?

Absence of luminescence in seawater suggests that the luminescent phenotype is produced under some other condition(s)

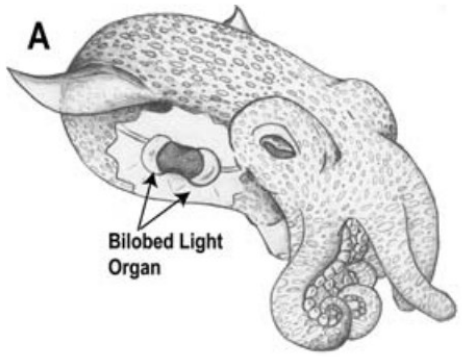
What are these other conditions?

J. Molec. Microbiol. Biotechnol. (1999) 1:5

Squid – bacteria (Vibrio fischeri) symbiosis

- Hawaiian bobtailed squid
- Luminescence in the light organ by symbiont *V. fischeri*
- Matches light intensity of the light organ to that of background light (moonlight / starlight), helps the squid to “cloak” and catch its prey
- Bioluminescence also controls circadian rhythms of the squid

What do the bacteria get out of this symbiosis? Nutrients from the light organ.

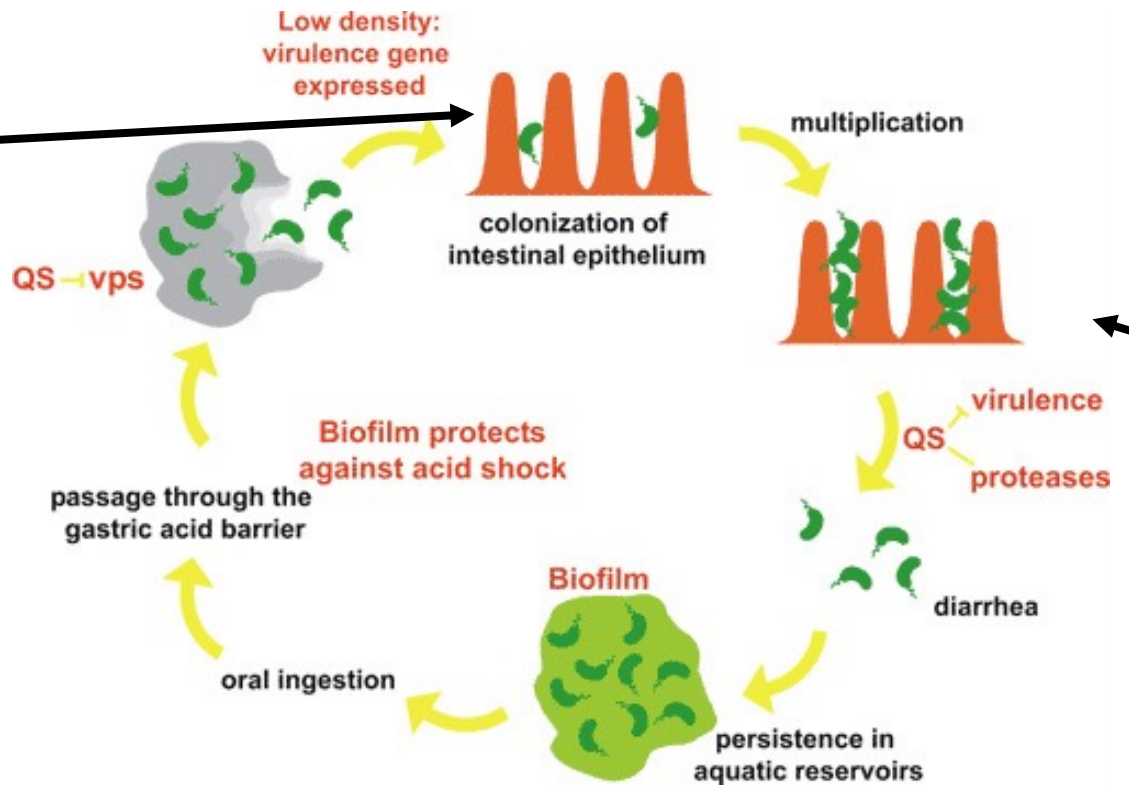


http://nishsymbiosislab.com/wp-content/uploads/2017/07/2-2004-JonesNish.pdf https://multimediaquest.c

Vibrio cholerae: causes diarrhea

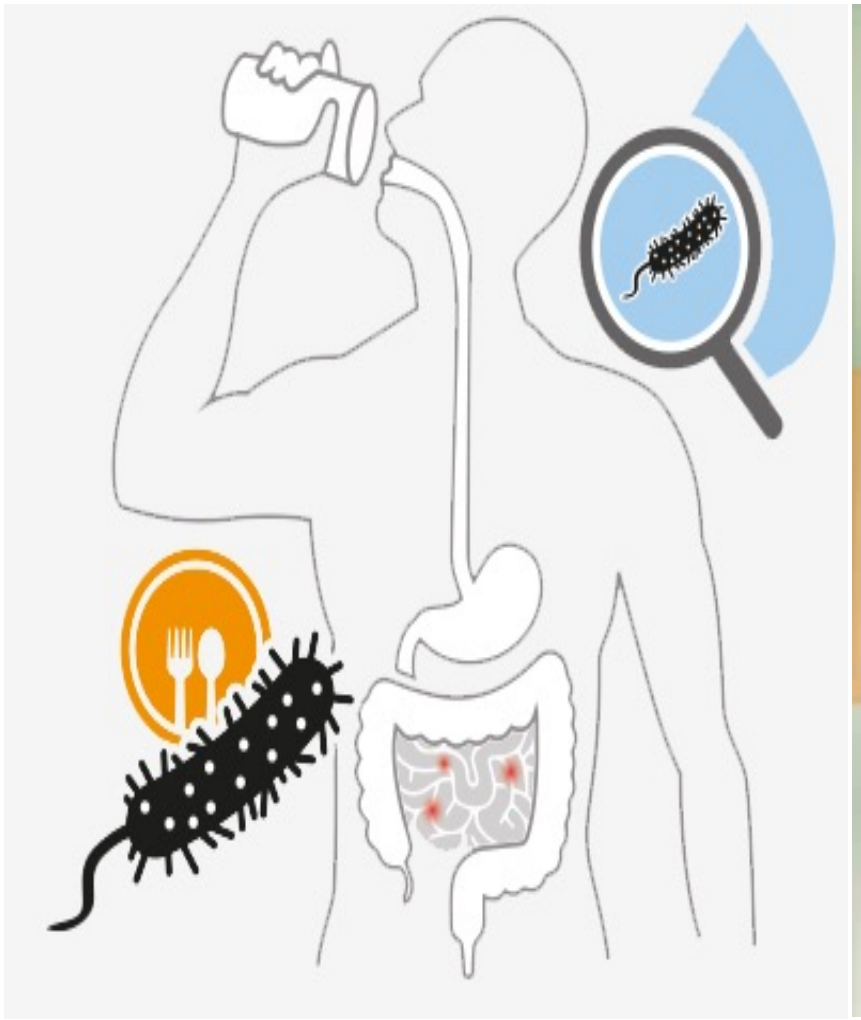
Quorum Sensing (QS) at different parts of the pathogenic cycle

Low density of bacteria:
Virulence genes expressed



High density of bacteria: Protease genes expressed, leading to diarrhea so that the bacteria can escape from the human host

As cells communicate for the "common good", we can study cooperation/cheating/etc.




CHOLERA DISEASE

How does Cholera toxin causes diarrhea??

A-subunit of cholera toxin ribosylates the alpha subunit of the Gs protein

Leads to activation of adenylate cyclase

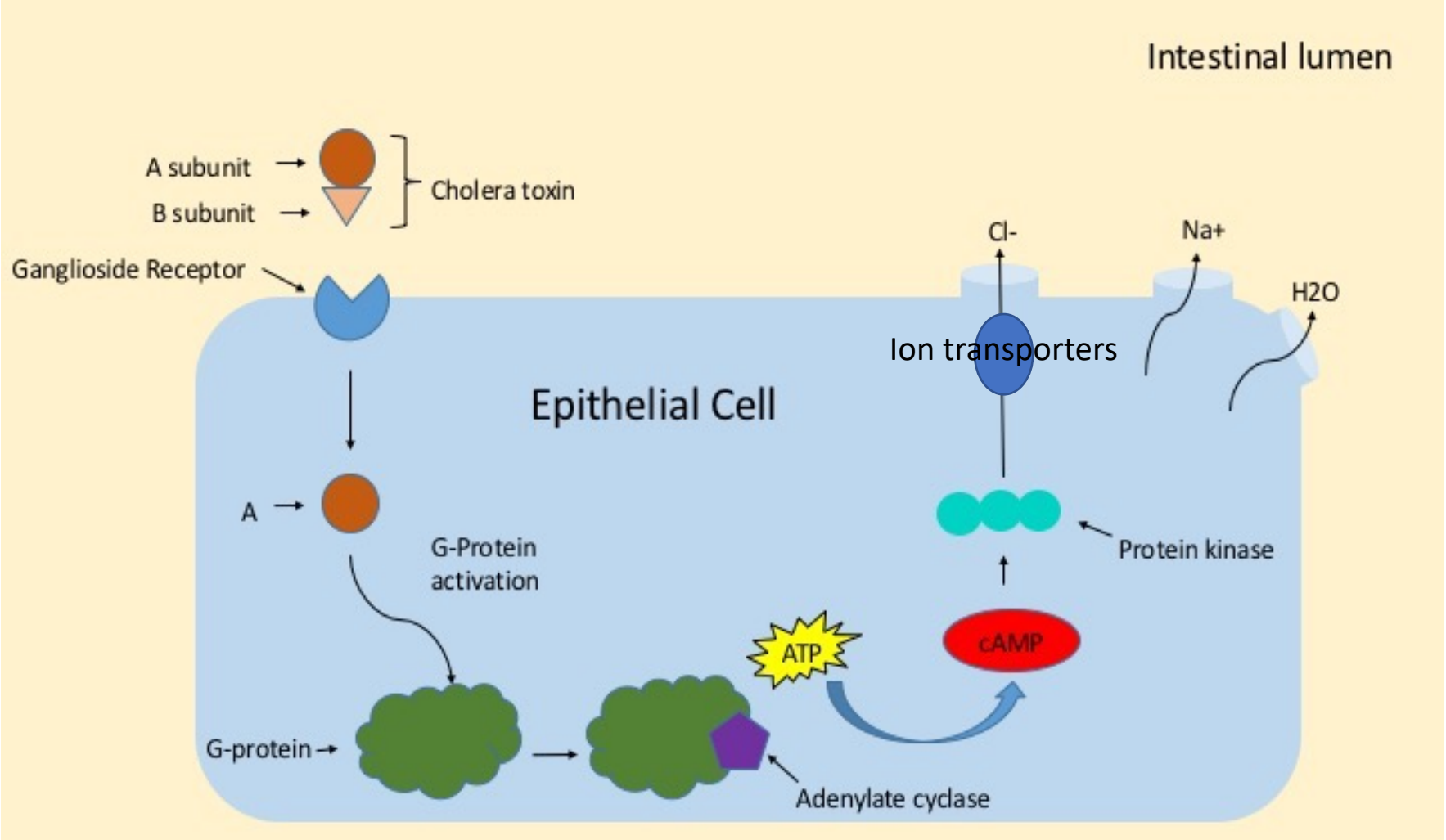
Results in increased levels of cAMP

This leads to the activation of PKA

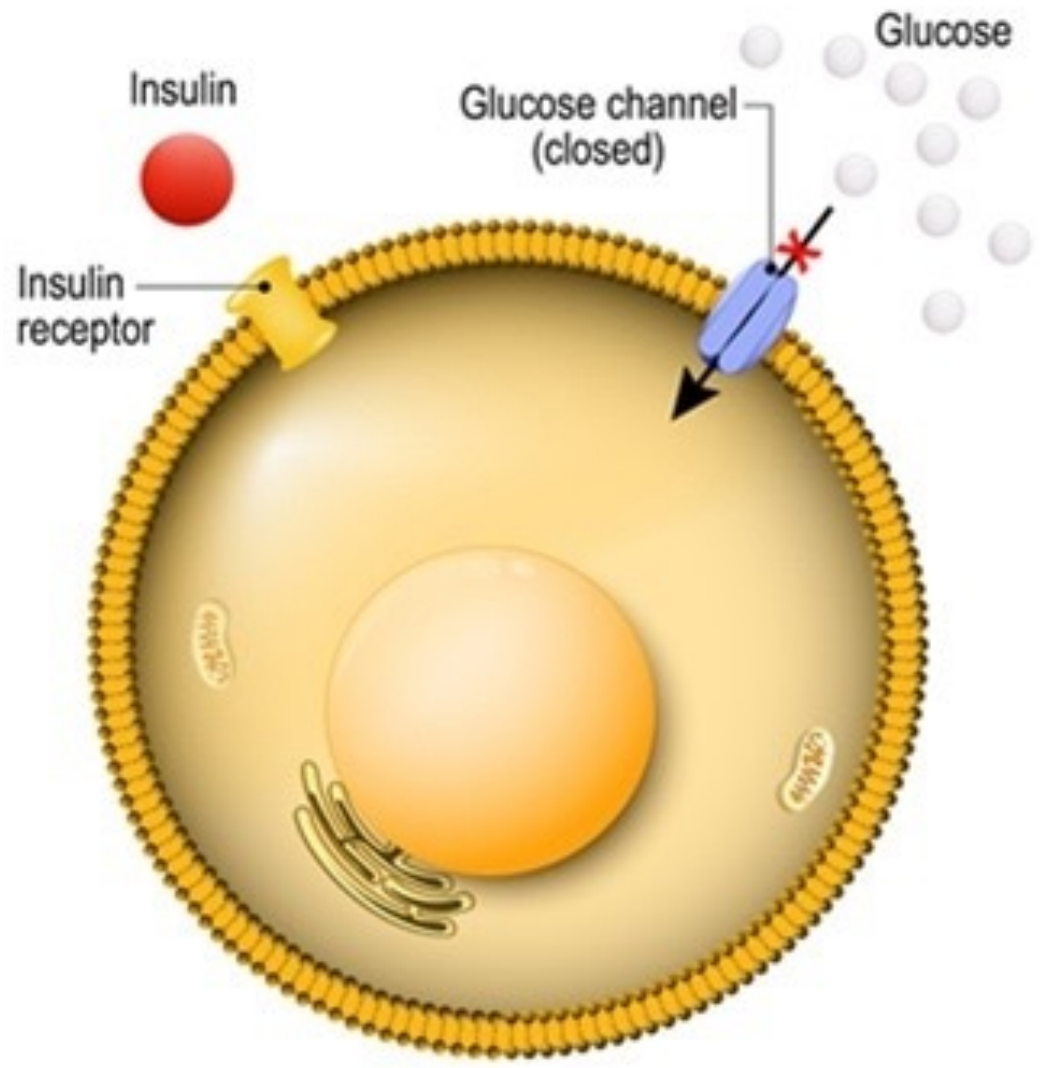
PKA phosphorylates CFTR and Na-H exchanger

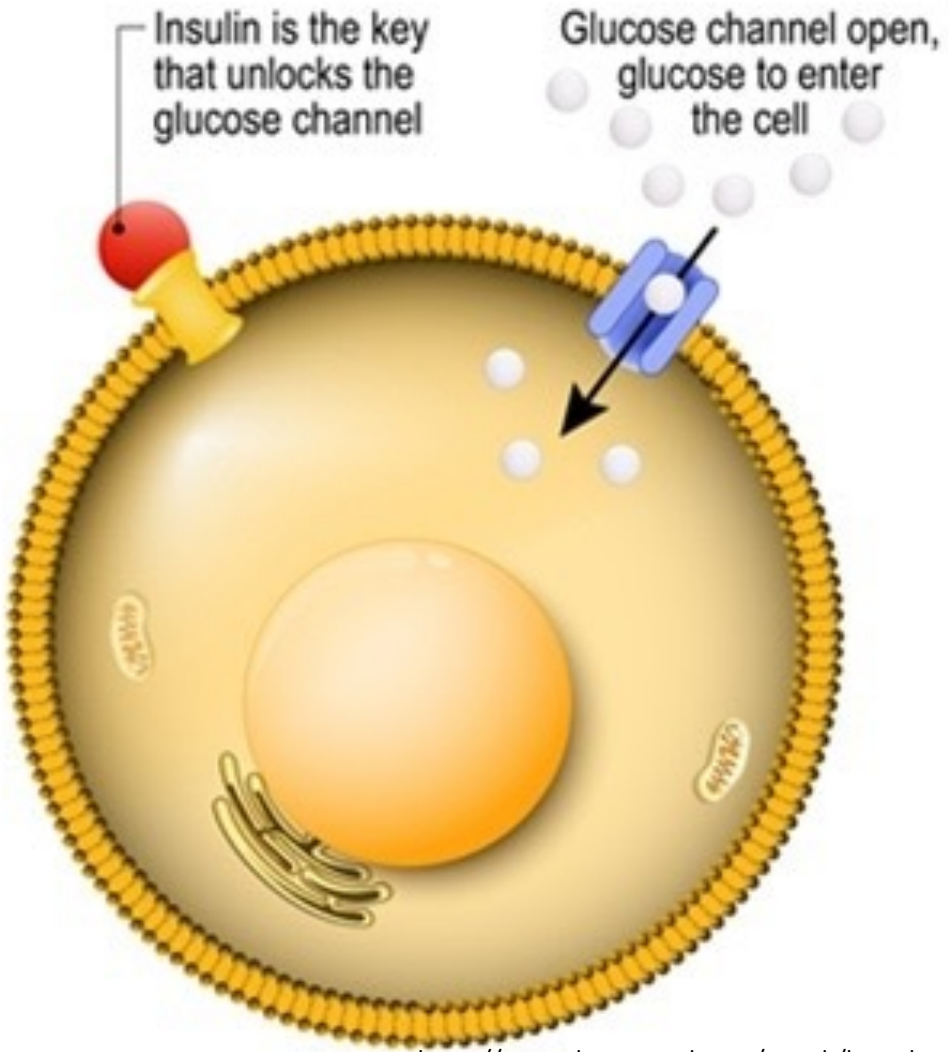
Causes efflux of chloride and Na and H2O

Hence causing severe diarrhea



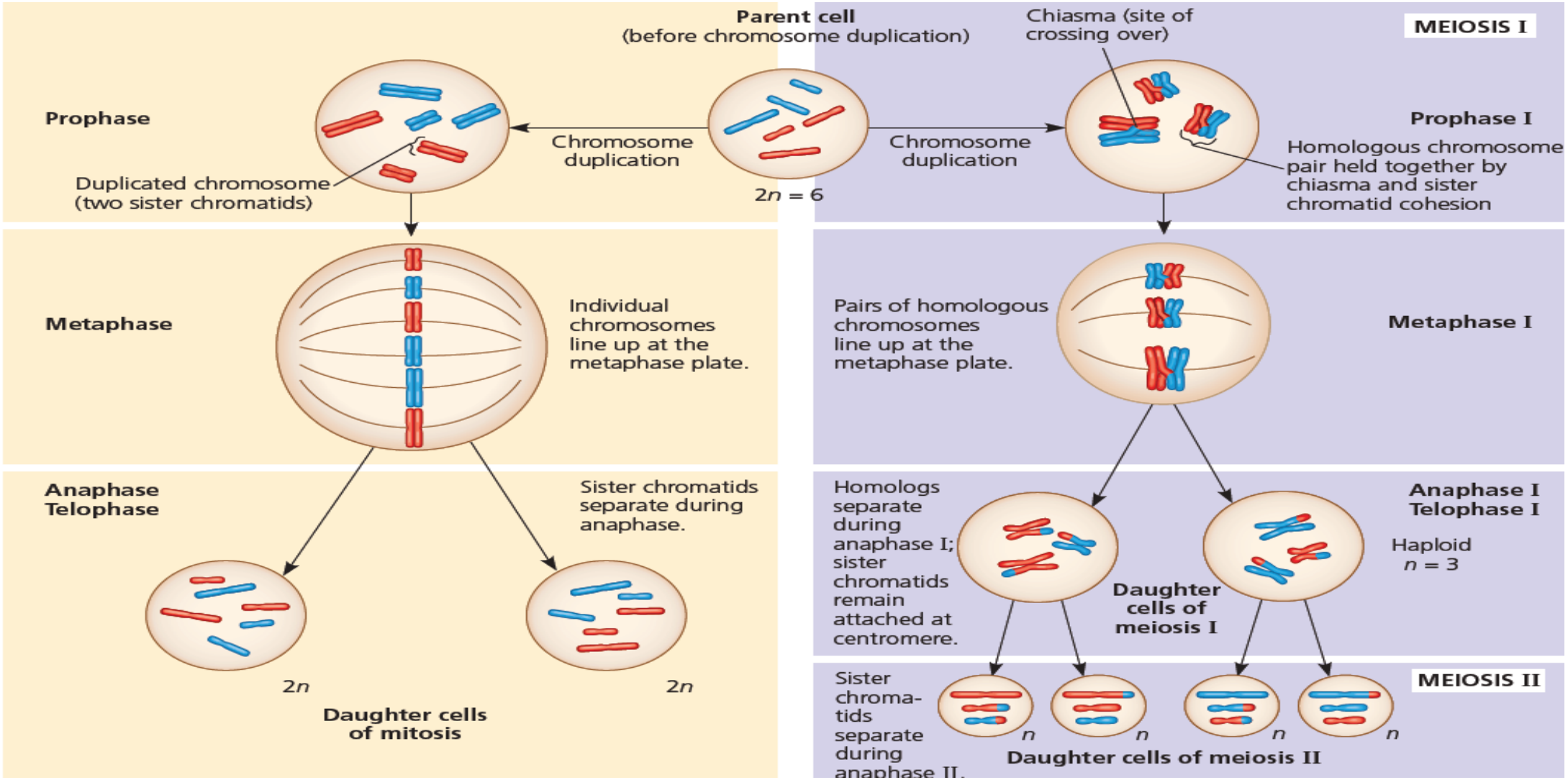
How does Insulin work?





https://www.shutterstock.com/search/how-does-insulin-work

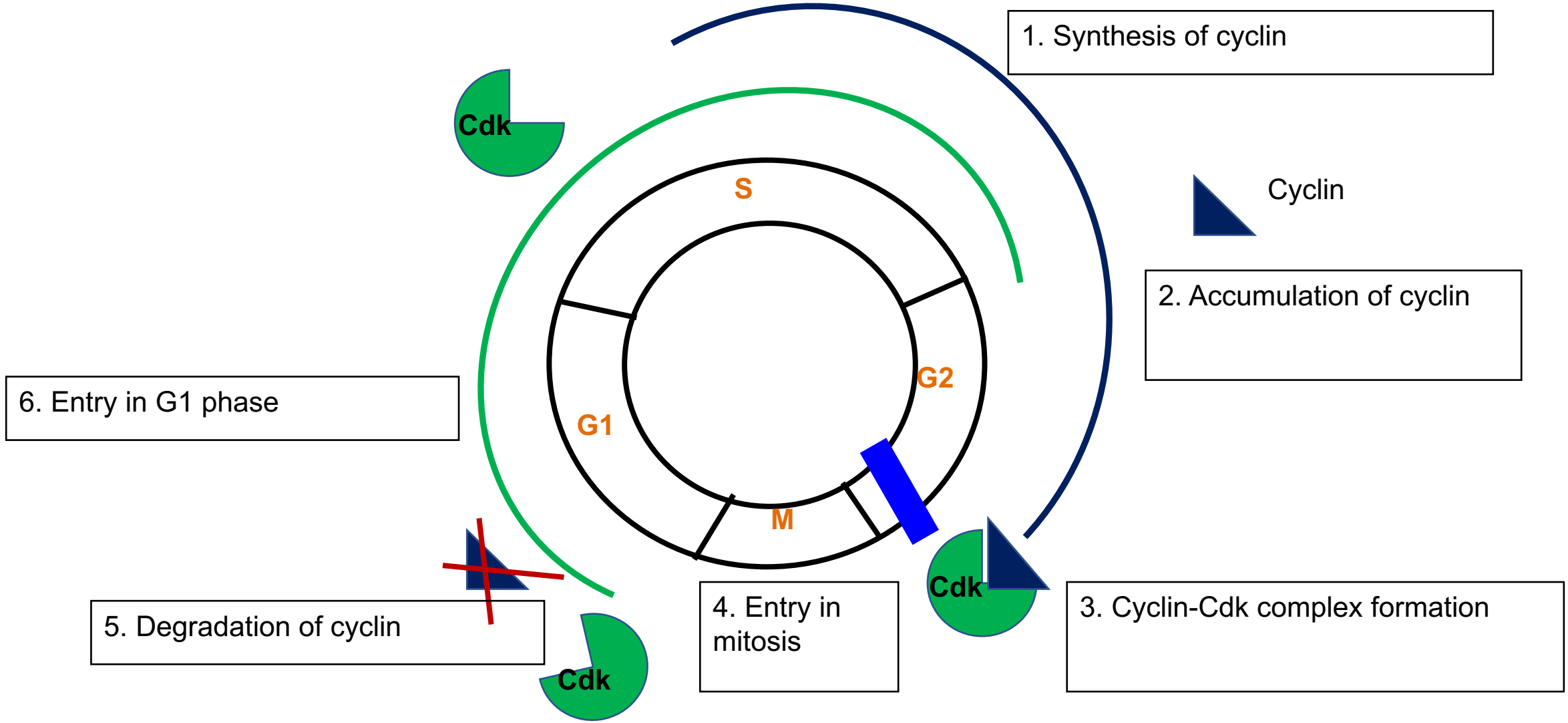
Cell Division: Mitosis vs. Meiosis



A comparison of mitosis and meiosis

Property	**Mitosis** (occurs in both diploid and haploid cells)	**Meiosis** (can only occur in diploid cells)
DNA replication	Occurs during interphase before mitosis begins	Occurs during interphase before meiosis I begins
Number of divisions	One, including prophase, prometaphase, metaphase, anaphase, and telophase	Two, each including prophase, metaphase, anaphase, and telophase
Synapsis of homologous chromosomes	Does not occur	Occurs during prophase I along with crossing over between nonsister chromatids; resulting chiasmata hold pairs together due to sister chromatid cohesion
Number of daughter cells and genetic composition	Two, each genetically identical to the parent cell, with the same number of chromosomes	Four, each haploid (*n*); genetically different from the parent cell and from each other
Role in the animal or plant body	Enables multicellular animal or plant (gametophyte or sporophyte) to arise from a single cell; produces cells for growth, repair, and, in some species, asexual reproduction; produces gametes in the gametophyte plant	Produces gametes (in animals) or spores (in the sporophyte plant); reduces number of chromosome sets by half and introduces genetic variability among the gametes or spores

Regulation of Cell Cycle by Cyclins and Cyclin Dependent Kinases



Cell cycle and its checkpoints

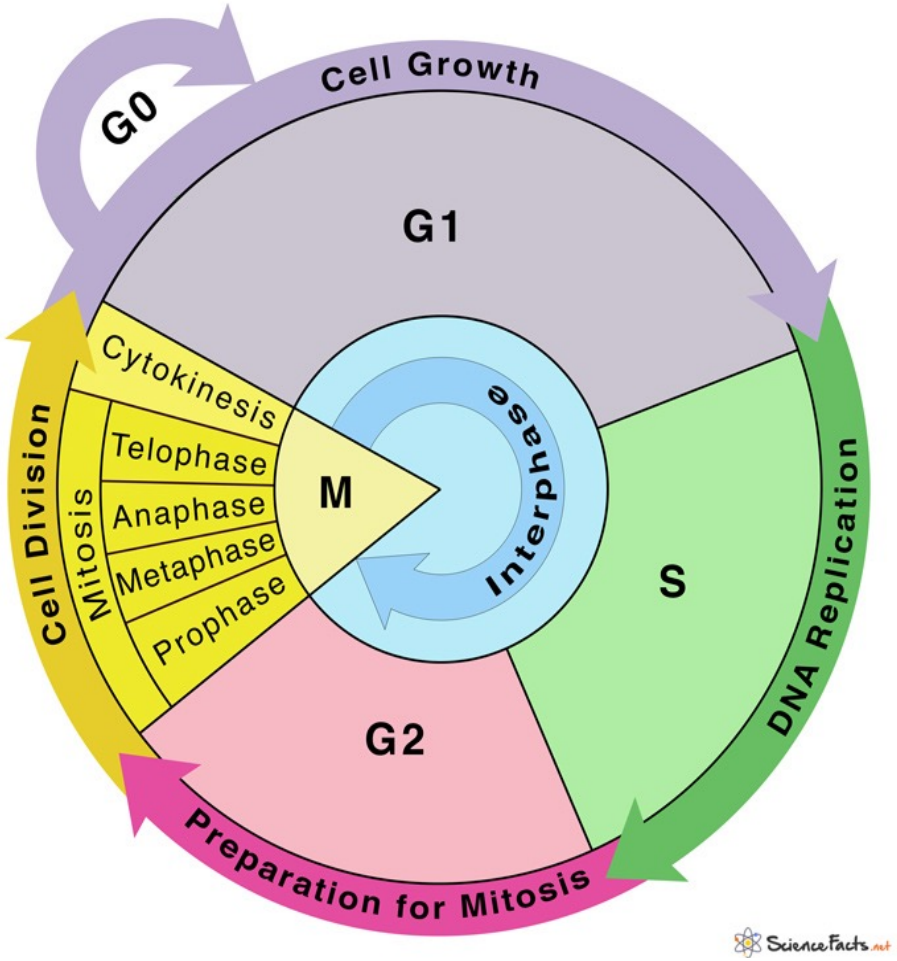


Fig.: Cell cycle

Important checkpoints:

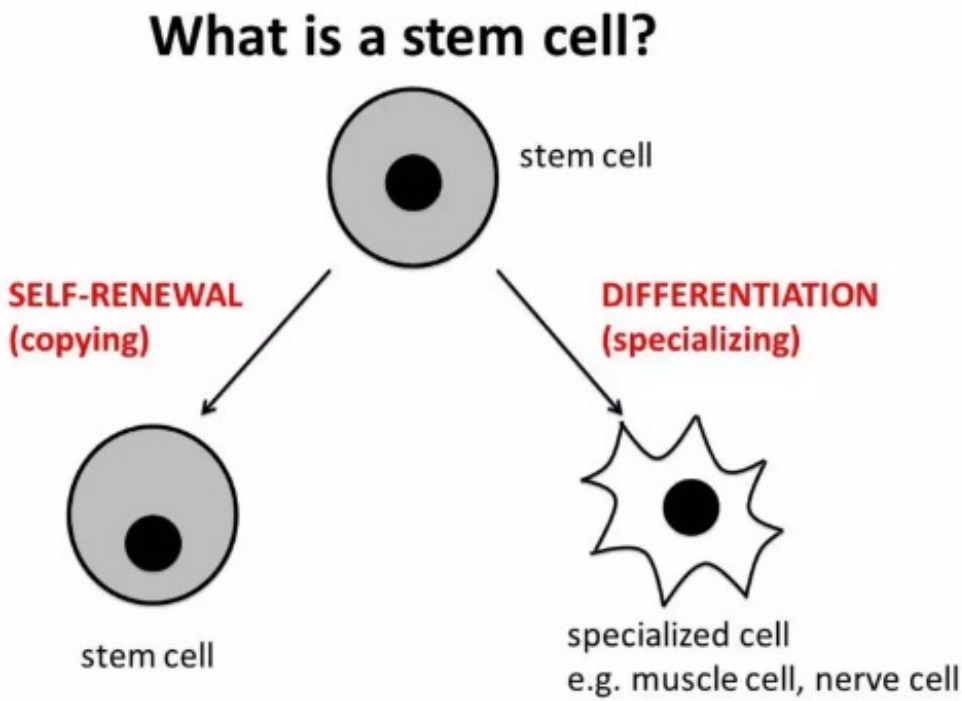
1. G1 Checkpoint- Nutrients, growth factors, DNA damage
2. G2 Checkpoint- Cell size, DNA replication
3. M Checkpoint- Chromosome spindle attachment

Source: https://www.sciencefacts.net/cell-cycle.html

BB 101
Stem Cells, Cancer and Protein
Tutorial 6
15.02.2024

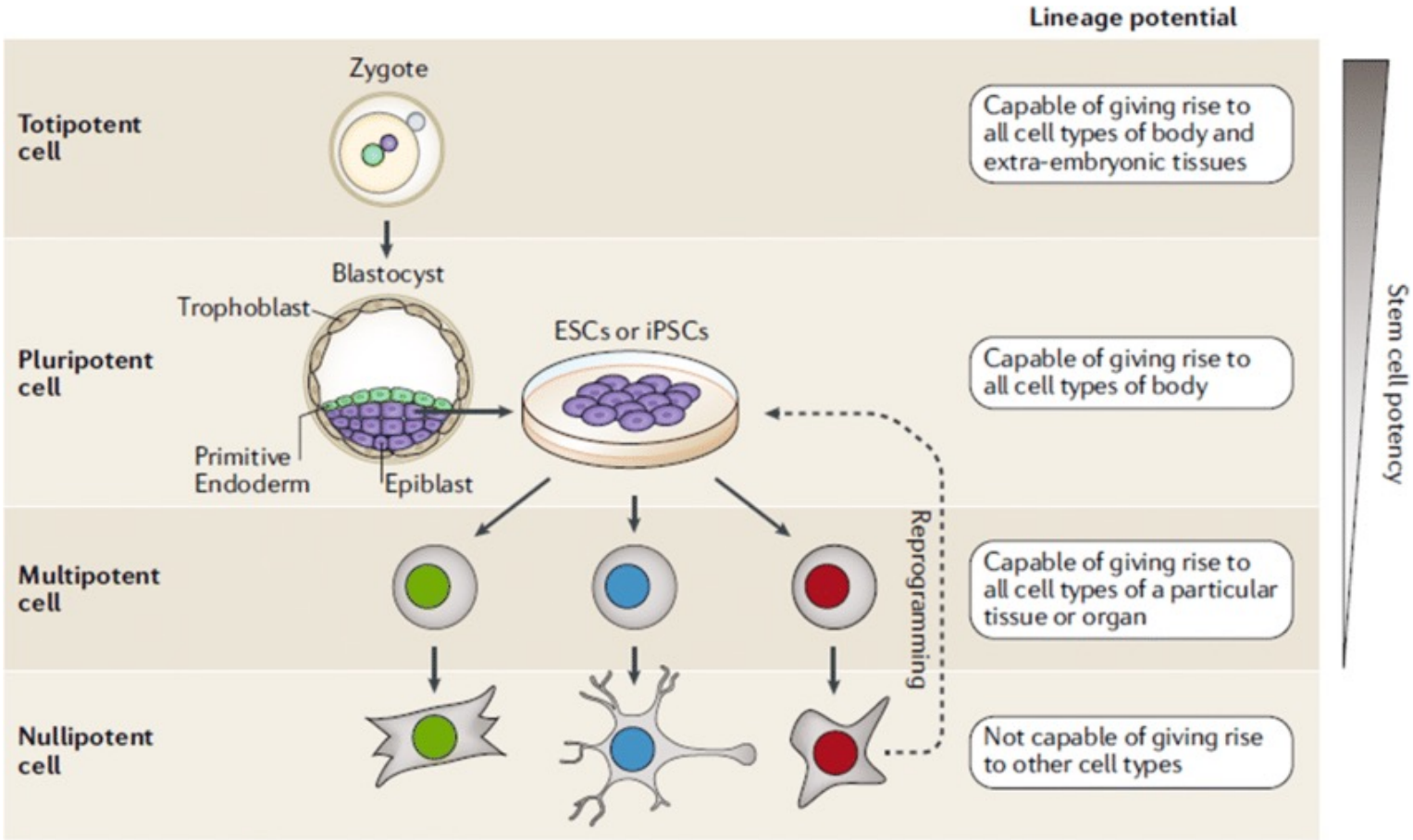
Stem Cell

- Undifferentiated or Unspecialized cells
- Ability to divide and differentiate
- Capable of self-renewal
- Form different types of specialized cells



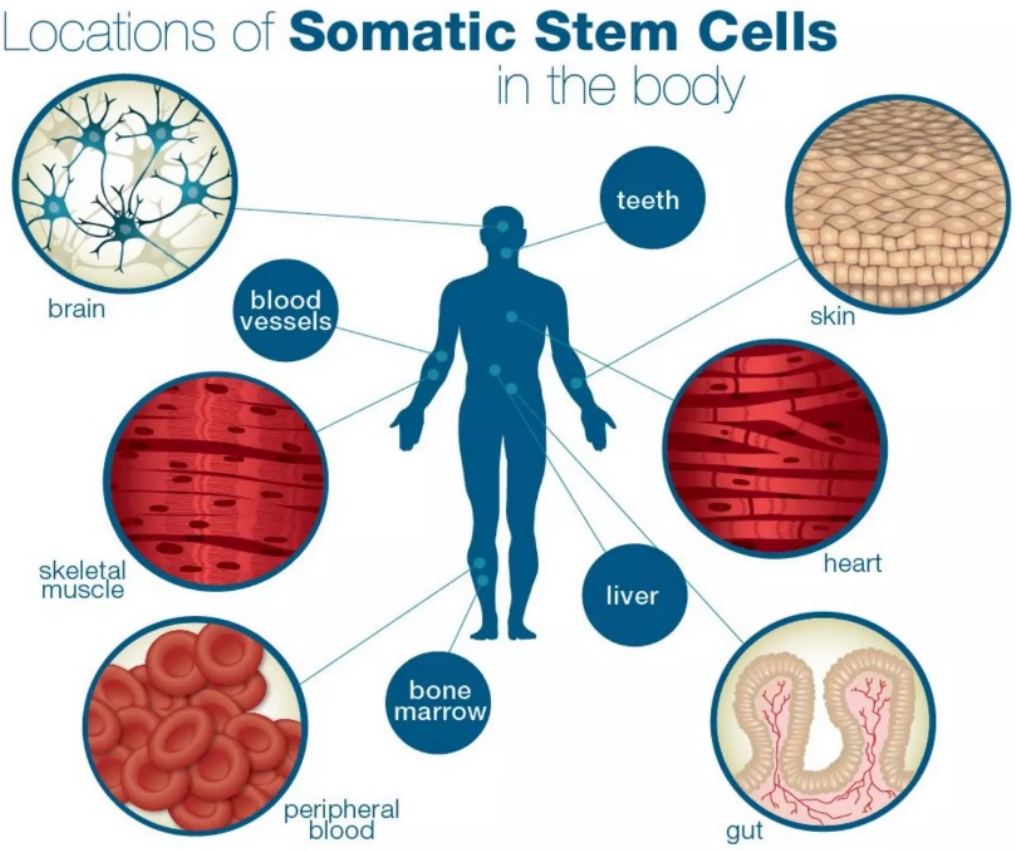
Types of Stem Cells

- Totipotent, pluripotent, and multipotent
- *Examples*- Embryonic SCs, Hematopoietic SCs, Mesenchymal SCs, Neural SCs, Epithelial SCs, Skin SCs



Source: Balistreri et al

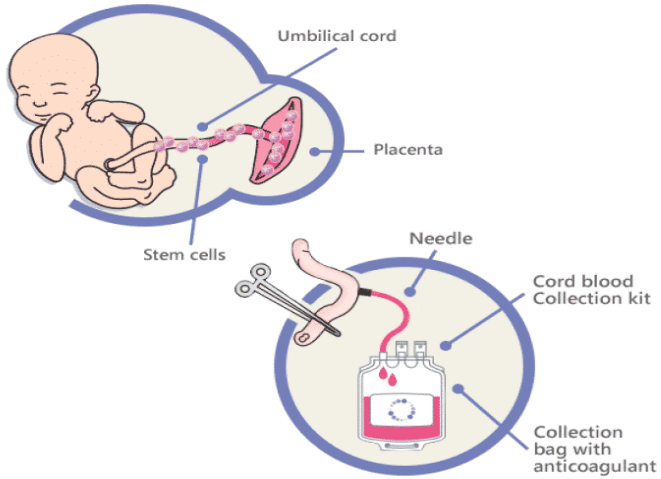
Importance of stem cells



Stem cell therapy, also known as **regenerative medicine**, promotes the repair response of diseased, dysfunctional, or injured tissue.

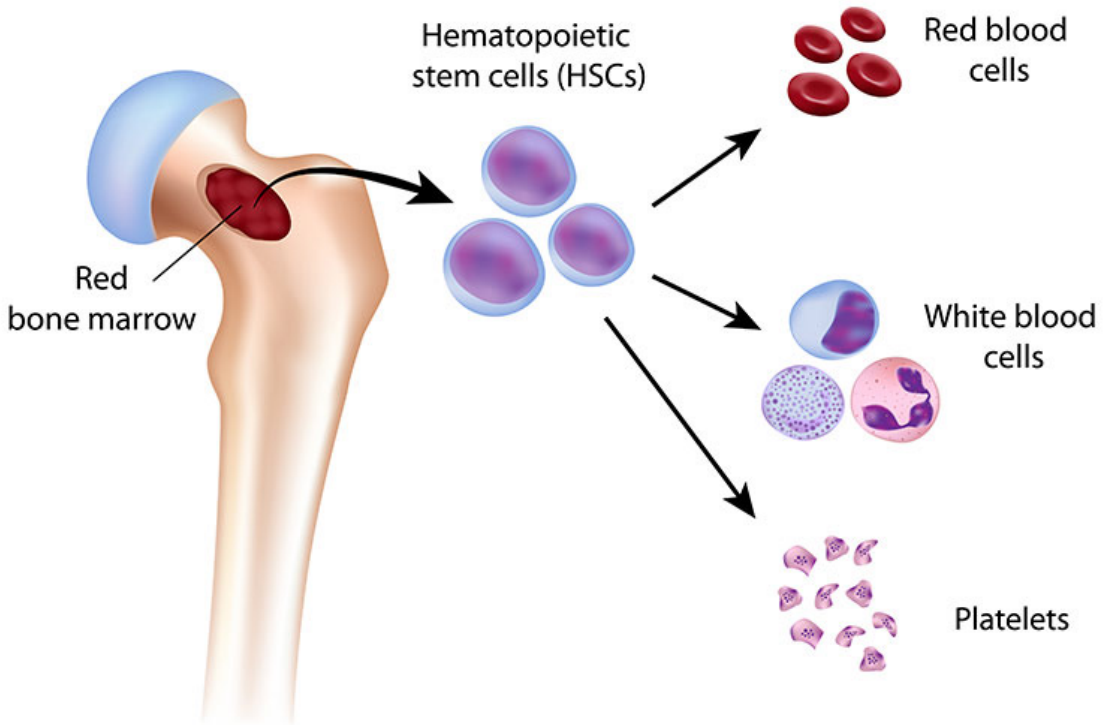
Example: For the treatment of leukemia (blood cancer)

- **Umbilical cord blood**



Stem Cell Therapy

- **Bone marrow transplant:** Doctors collect stem cells from marrow with a hollow needle.
- **Peripheral blood stem cell transplant**: PBSCs are collected from blood drawn with a small needle.



https://www.stemcellcareindia.com

Projects under trials....

1. Injecting modified stem cells directly into the brain after a stroke

2. Using stem cells to replace damaged cells in the inner ear that detect sound, helping to restore hearing

3. Altering the genes of stem cells to make them resistant to diseases, such as AIDS, and then inserting them into people with the disease

4. Cultivating stem cells to repair the fragile bones of people with osteoporosis

But…how do cells divide?

What happens to cell division when there is something wrong with the cell? And…how exactly do the cells know that something is wrong?

Cell cycle and its checkpoints

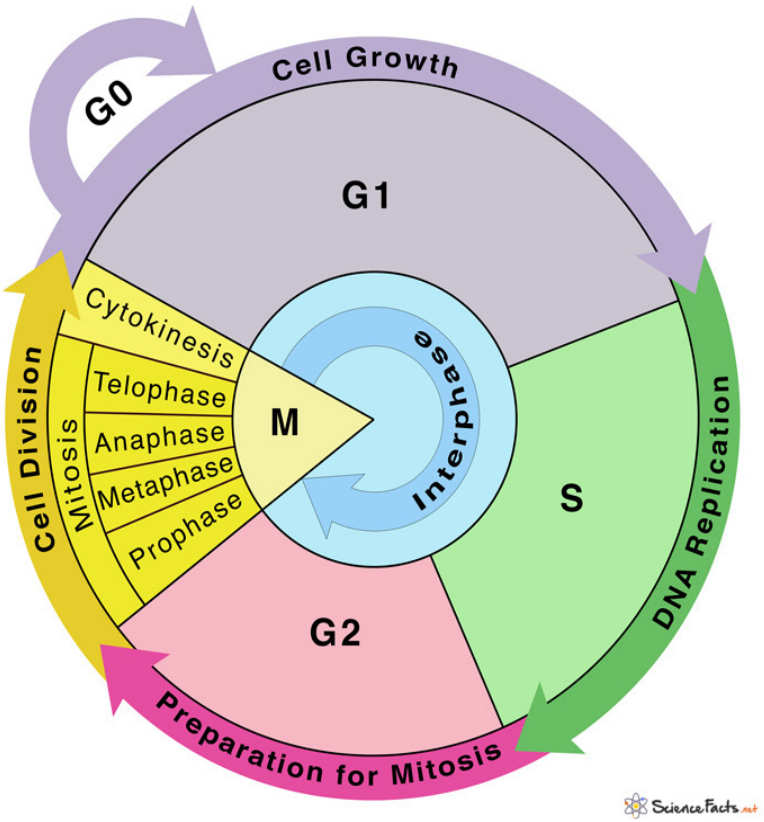


Fig.: Cell cycle

Important checkpoints:

1. G1 Checkpoint- Nutrients, growth factors, DNA damage
2. G2 Checkpoint- Cell size, DNA replication
3. M Checkpoint- Chromosome spindle attachment

Source: https://www.sciencefacts.net/cell-cycle.html

Is it possible for cells to show uncontrolled division?

Cancer

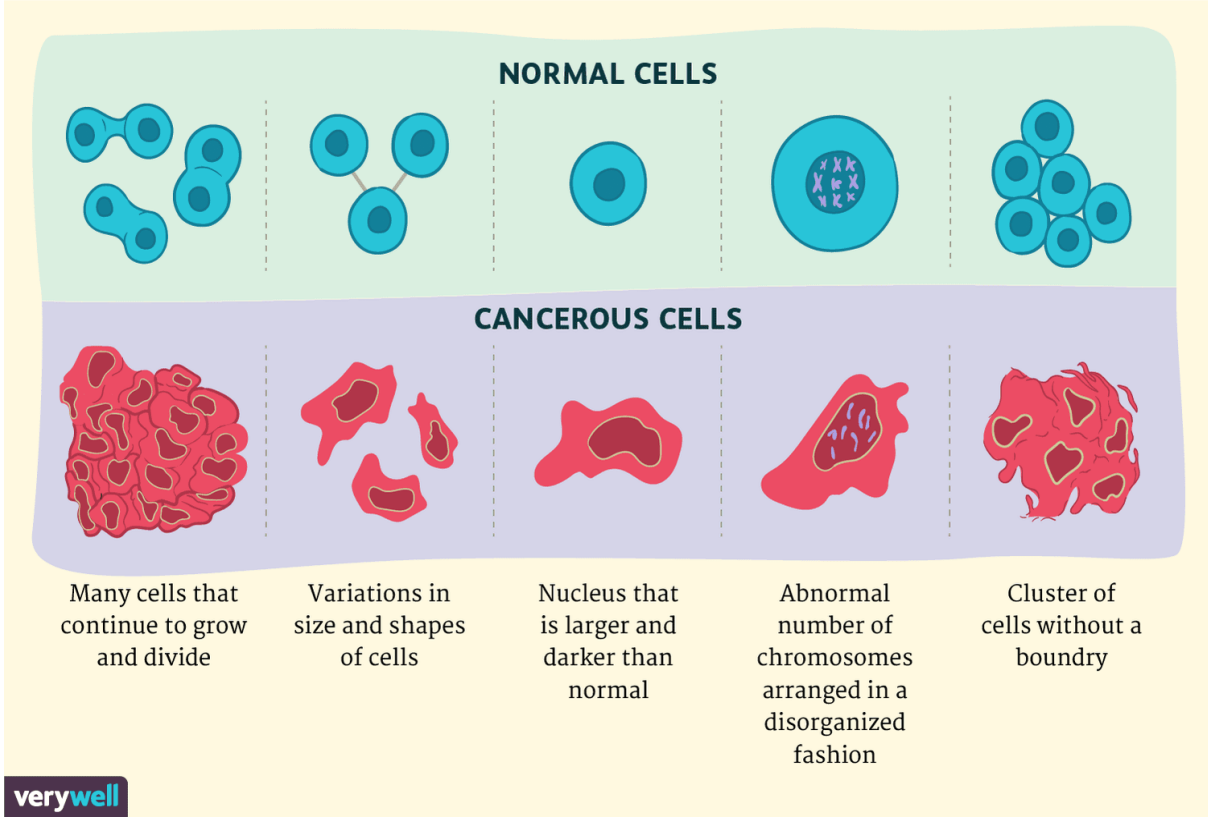


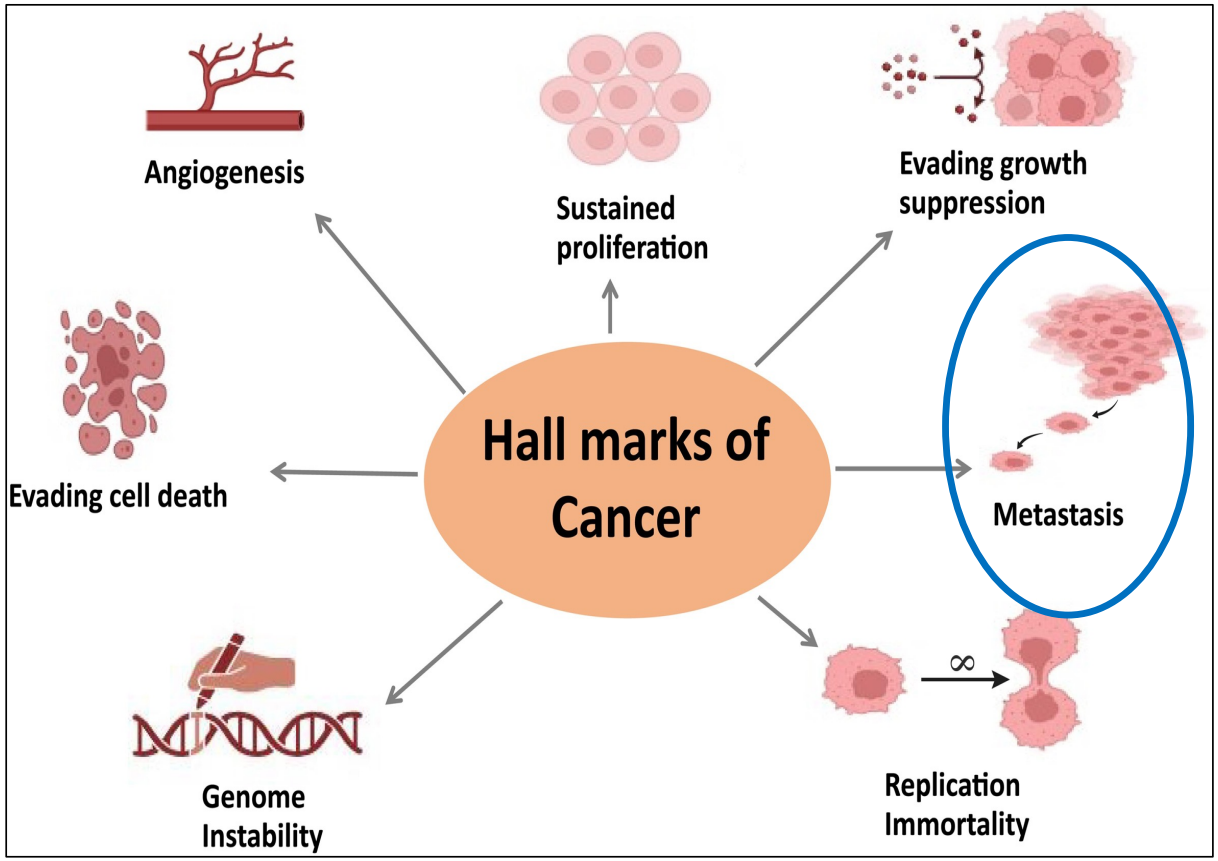
Fig.: Normal v/s Cancer cells

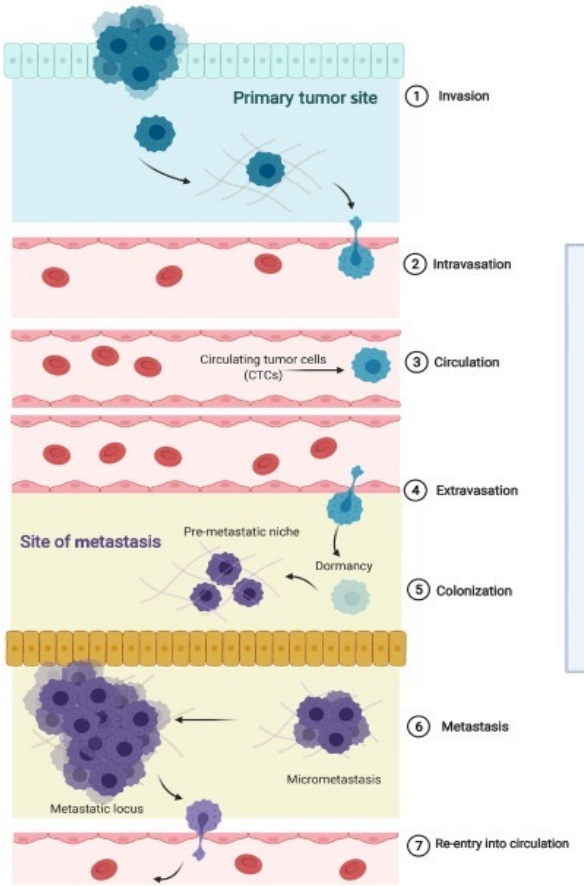
- Uncontrolled proliferation
- Bypass checkpoints
- Types:
  1. Benign
  2. Malign

Cause: Change in genetic material (mutations)

Source: https://www.verywellhealth.com/cancer-cells-vs-normal-cells-2248794

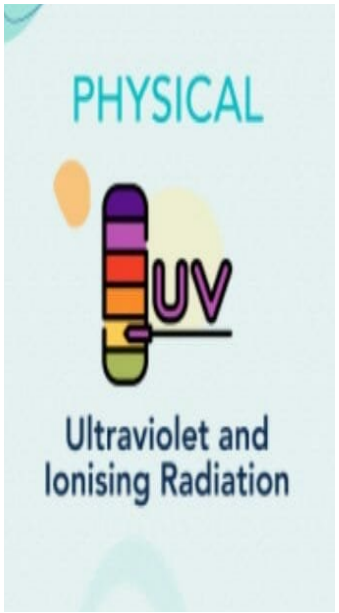
Hallmarks of Cancer

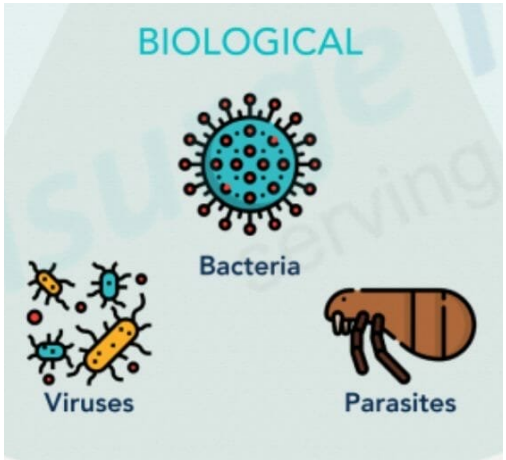




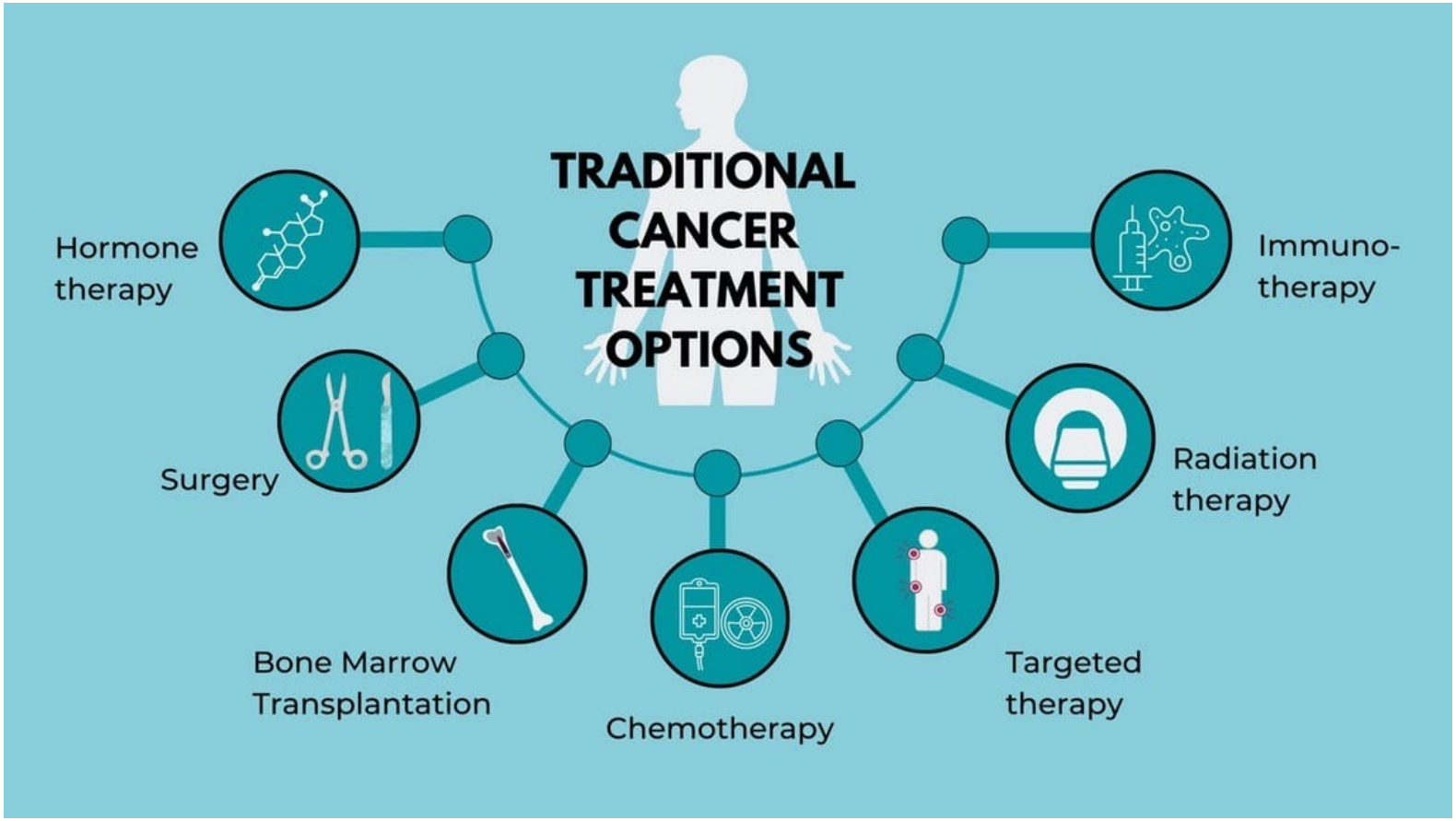
What causes mutations??

Cancer Causes





Cancer Treatment



Source: FLCCC Alliance

How can you help biologists ???

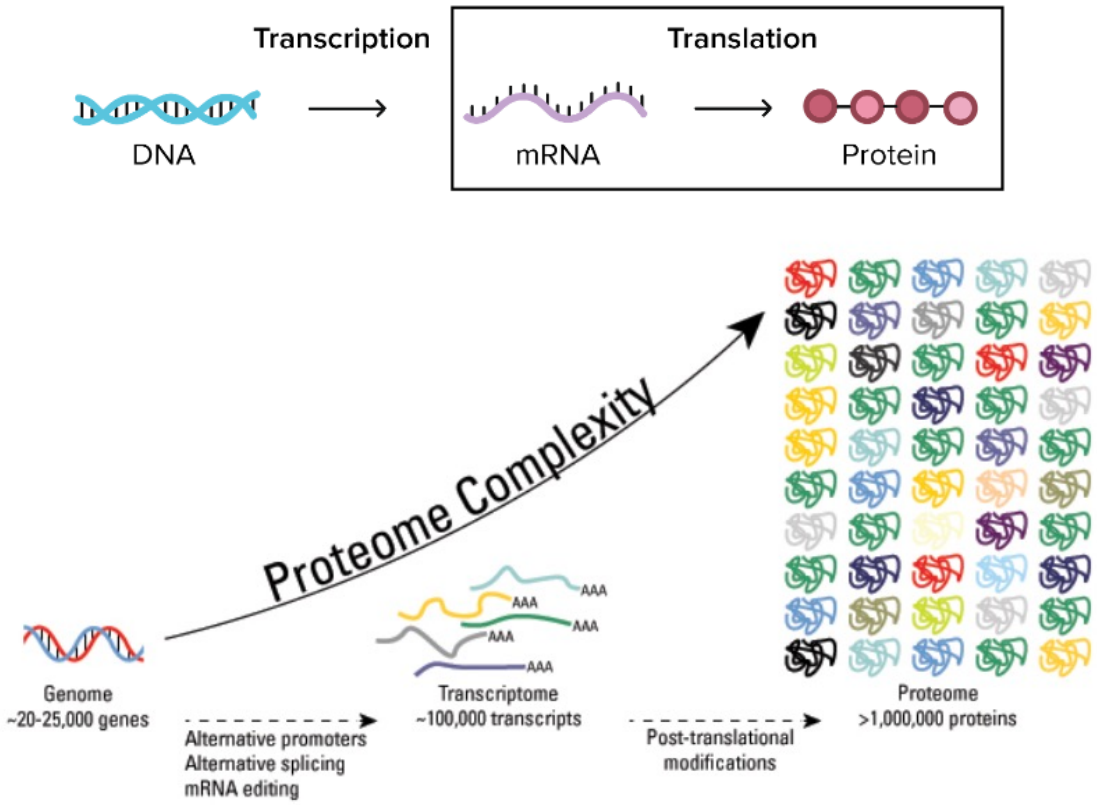
Working with biologists…..

- **Previous problem**: difficult to diagnose cancer at an early stage
- But, now, with the help of powerful techniques such as Mass Spectrometer one has huge proteomics data.
- With the help of computational biology and machine learning programs, biologists are working on targeting specific proteins for treatment.
- *For example*: Detection of **biomarkers**

Biomarker panel	Cancer prediction
OVA1™ (CA 125, prealbumin, apolipoprotein A-1, beta2 microglobulin, transferrin)	Prediction of ovarian cancer risk in women with adnexal mass
DCP and AFP-L3	Risk assessment for development of hepatocellular carcinoma
Risk of Ovarian Malignancy (ROMA)	Prediction of ovarian cancer risk in women with pelvic mass
PCA3 (Prostate Cancer Antigen 3)	Determination of need for biopsy or repeat-biopsy in patients at risk for prostate cancer
Overa (CA 125, apolipoprotein A-1, transferrin, follicle-stimulating hormone, human epididymis protein 4)	Prediction of ovarian cancer risk in women with adnexal mass

https://edrn.nci.nih.gov/about-edrn/fda-approved-tests/

Synthesis of Proteins from Gene

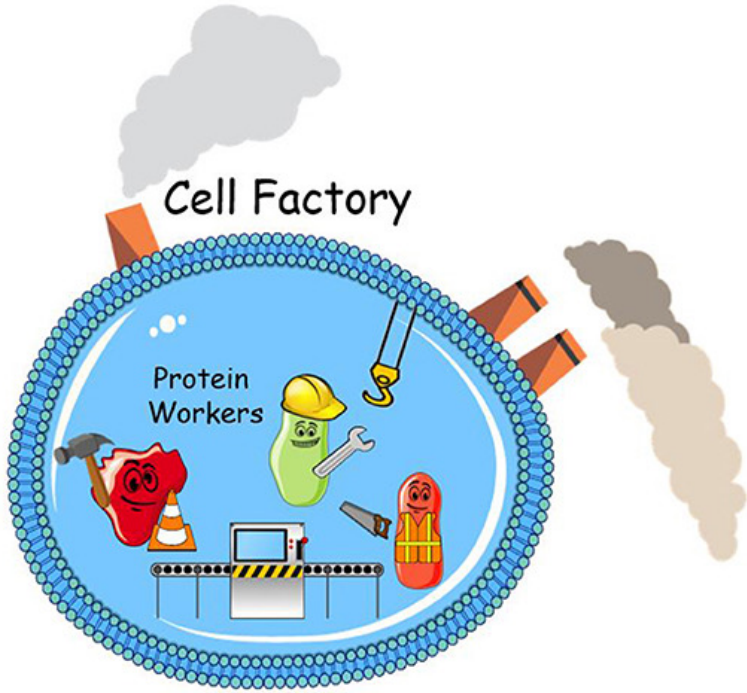


Post-transcriptional modification: The processes of polyadenylation, 5' capping, and splicing.

Post-translational modification: Covalent processing events that change the properties of a protein by proteolytic cleavage and adding a modifying group, such as acetyl, phosphoryl, glycosyl, and methyl, to one or more amino acids

What are Proteins?

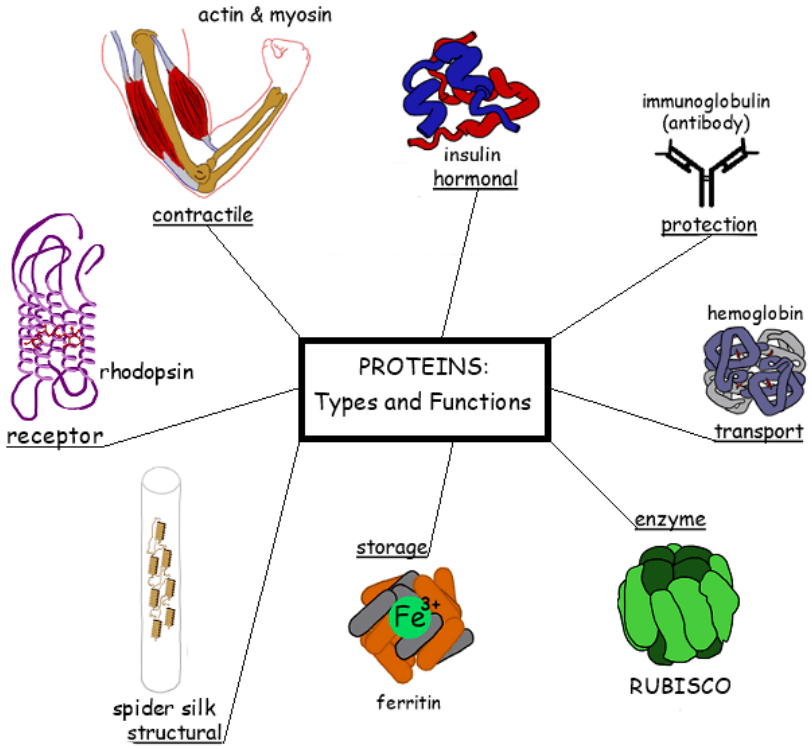
- Large biomolecules
- Found in every cell in the body
- Made up of chains of **amino acids**
- Peptides: fewer than 50 amino acids
  - Dipeptides: 2 amino acids
  - Tripeptides: 3 amino acids
  - Polypeptides: more than ten amino acids
  - Proteins: more than 50 amino acids
- The 20 amino acids commonly found as residues in proteins
- **Proteome-** complete set of proteins expressed by an organism



What are the different roles of Protein?

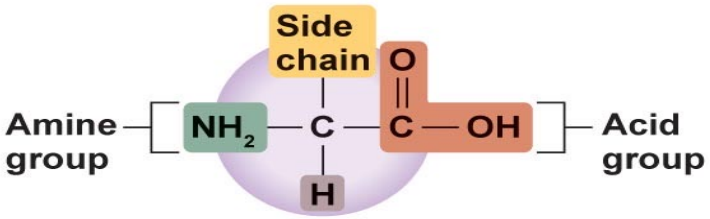
Proteins can be classified into several types based on their functions:

- Enzymes
- Structural Proteins
- Transport Proteins
- Hormones
- Antibodies (Immunoglobulins)
- Motor Proteins
- Storage Proteins
- Receptor Proteins
- Defensive Proteins



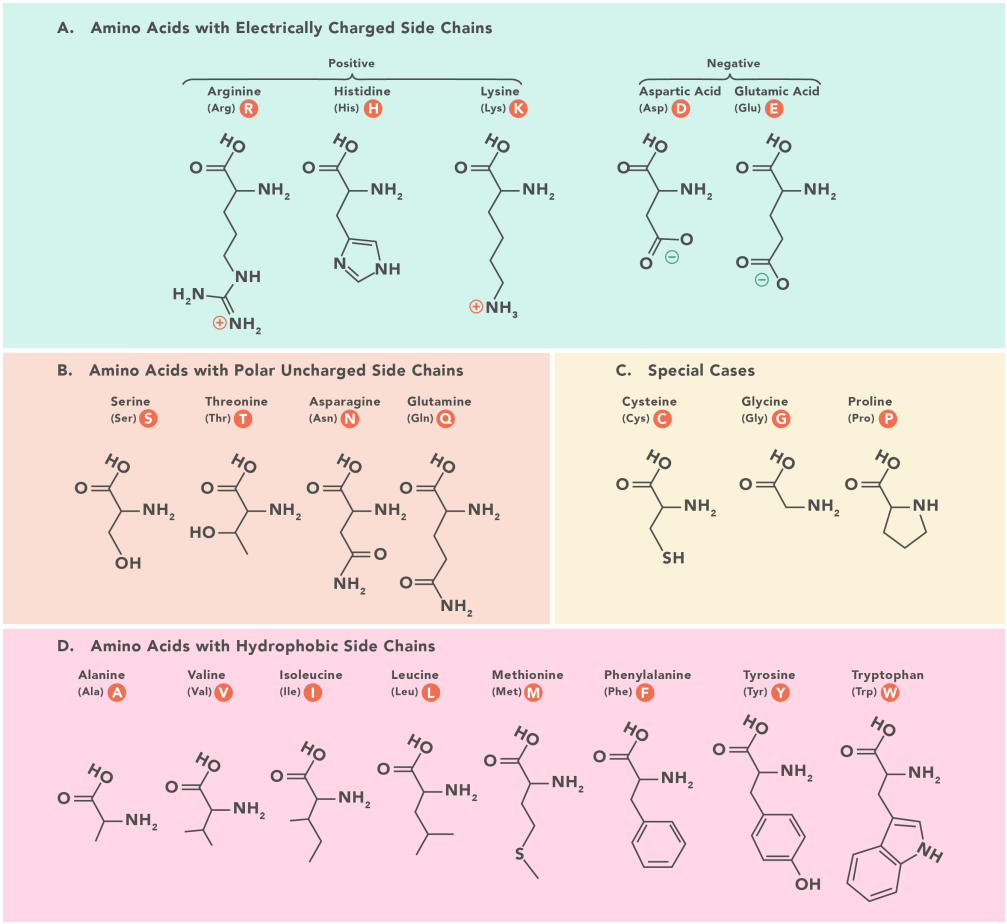
https://alevelbiology.co.uk/notes/functions-of-proteins/

Amino Acid



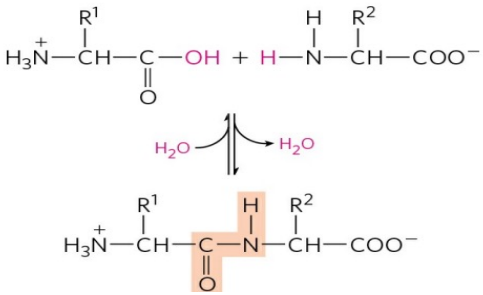
α-carbon atom is thus a chiral center.
> Exception?

Amino acids can be classified based on their **R group and Polarity**.

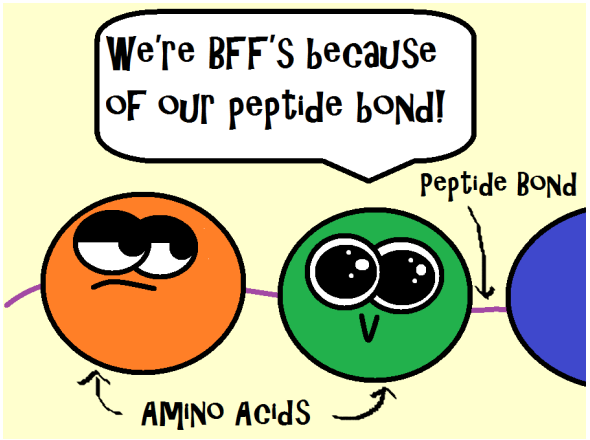


Peptide Bond

- Two amino acid molecules covalently joined through a substituted amide linkage, termed a peptide bond, to yield a dipeptide
- Linkage is formed by the removal of water (dehydration)



- Apart from peptide bonds, Ionic bonds, Disulfide bonds, Hydrogen bonds, and Hydrophobic Interactions are involved in protein folding

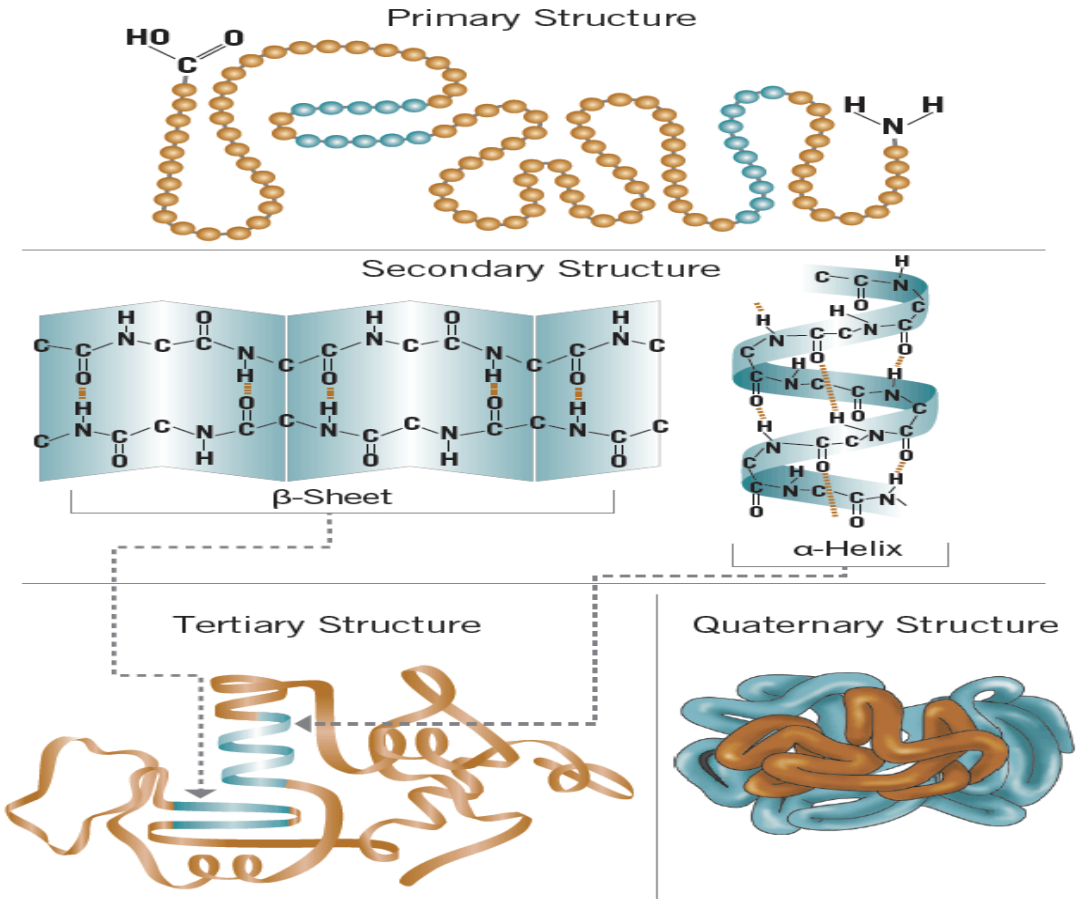


How many water molecules are released in forming a polypeptide containing seven amino acid residues?

Protein Structural Level

- Proteins can be described at several levels of complexity, arranged in a kind of conceptual hierarchy. Mainly four types.

- **Primary Structure**: linking amino acid residues in a polypeptide chain
- **Secondary Structure**: stable arrangements of amino acid residues giving rise to recurring structural patterns
- **Tertiary Structure**: three-dimensional folding of a polypeptide
- **Quaternary Structure**: protein with two or more polypeptide subunits, their arrangement in space



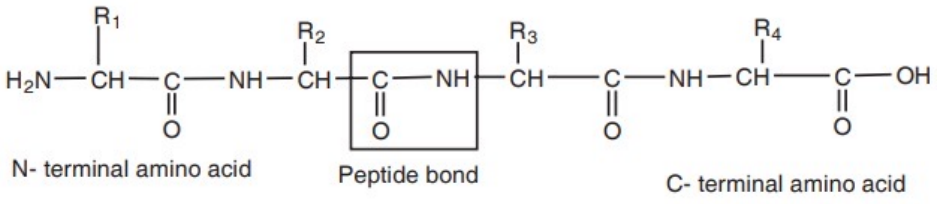
What makes one protein an enzyme, another a hormone, another a structural protein, and still another an antibody? How do they differ chemically?

The most obvious distinctions are **structural**. Each protein has a distinctive number and sequence of amino acid residues, That determines how it folds up into its unique three-dimensional structure, and this, in turn, determines the function of the protein.

Any alteration in the structure or sequencing changes the shape and function of the protein

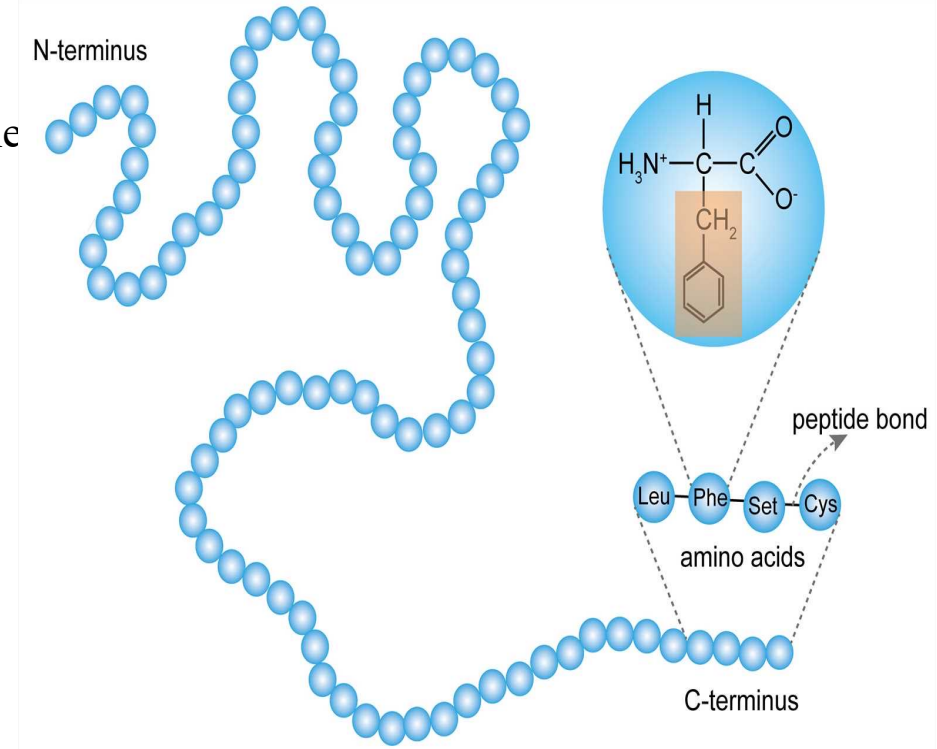
Primary Structure

- Ordering of amino acids to form their chains.
- Determines the final fold and, therefore, the function of the protein.
- Any change in the sequence changes the entire protein.



For example the primary structure of a protein can be written as

H_2N— gly — lys — leu — val — ala — glu — COOH
1 2 3 4 5 6



Anfinsen's Hypothesis

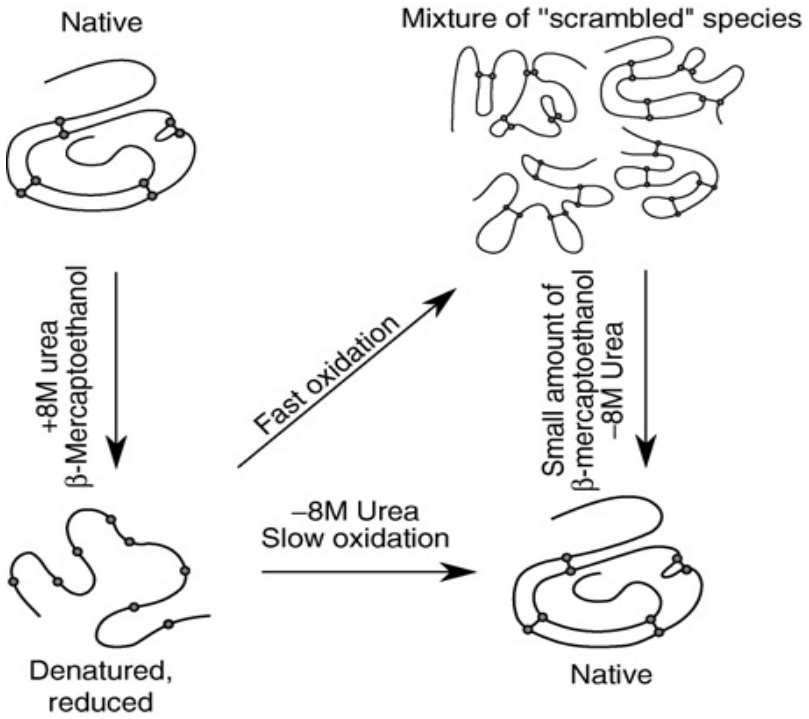
Ingredients: RNase A enzyme, β-mercaptoethanol, 8M Urea

Experiment 1: Addition of both β-mercaptoethanol and 8M Urea
Observation: Denaturation of Disulphide and Hydrogen bonds resulting in the complete unfolding of the protein.

Experiment 2: Simultaneous removal of both β-mercaptoethanol and 8M Urea.
Observation: Reformation of a disulphide linkage. **100% Activity**.

Experiment 3: Sequential removal of β-mercaptoethanol followed by 8M Urea.
Observation: Scrambled Protein formed. Biologically **not active.**

Experiment 4: Addition of small amount of β-mercaptoethanol.
Observation: **100% Activity.**



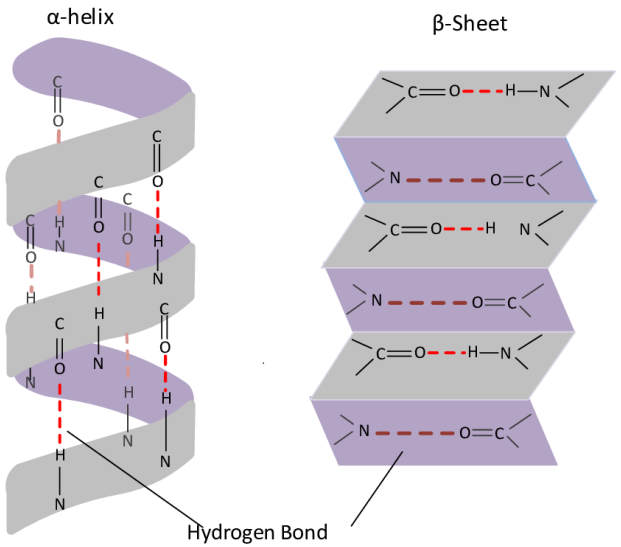
Inference: Primary structure determines the final conformation of the protein.

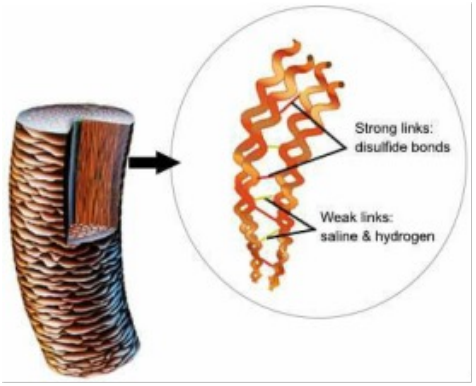
Secondary Structure

•Polypeptide chains usually fold due to the interaction between the amine and carboxyl group of the peptide link.

• They are found to exist in two different types of structures α – helix and β – pleated sheet structures.

• This structure arises due to the regular folding of the backbone of the polypeptide chain due to hydrogen bonding between the -CO group and -NH groups of the peptide bond.





Permanent Hair Waving is Biochemical Engineering!!

- Moist heat stretches α-keratin α-helices to a β conformation, reverting upon cooling.
- Disulfide bond manipulation with reducing and oxidizing agents creates lasting curls or waves, though not truly permanent due to hair growth.

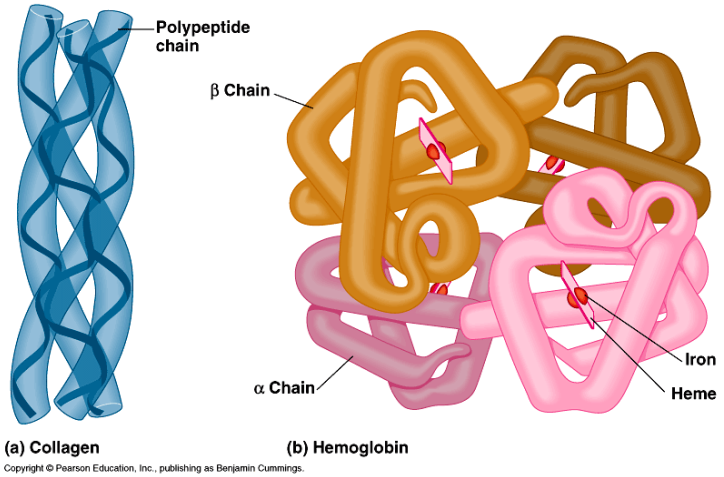
Tertiary and Quaternary Structure

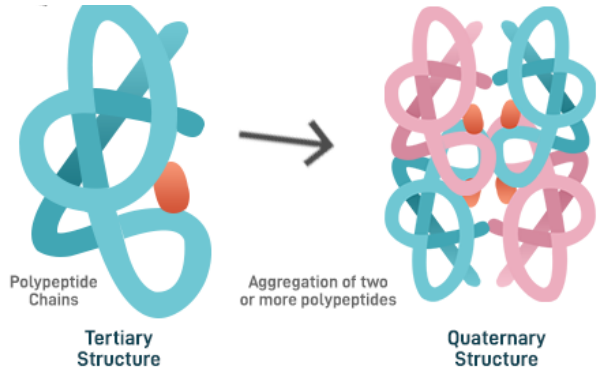
- This structure arises from further folding of the secondary structure of the protein.
- H-bonds, electrostatic forces, disulfide linkages, and Vander Waals forces stabilize this structure.
- It gives rise to two major molecular shapes called **fibrous and globular**.

Fibrous Protein- Keratin

Globular Protein- Albumin

- The spatial arrangement of various tertiary structures gives rise to the **quaternary structure**





Protein Folding

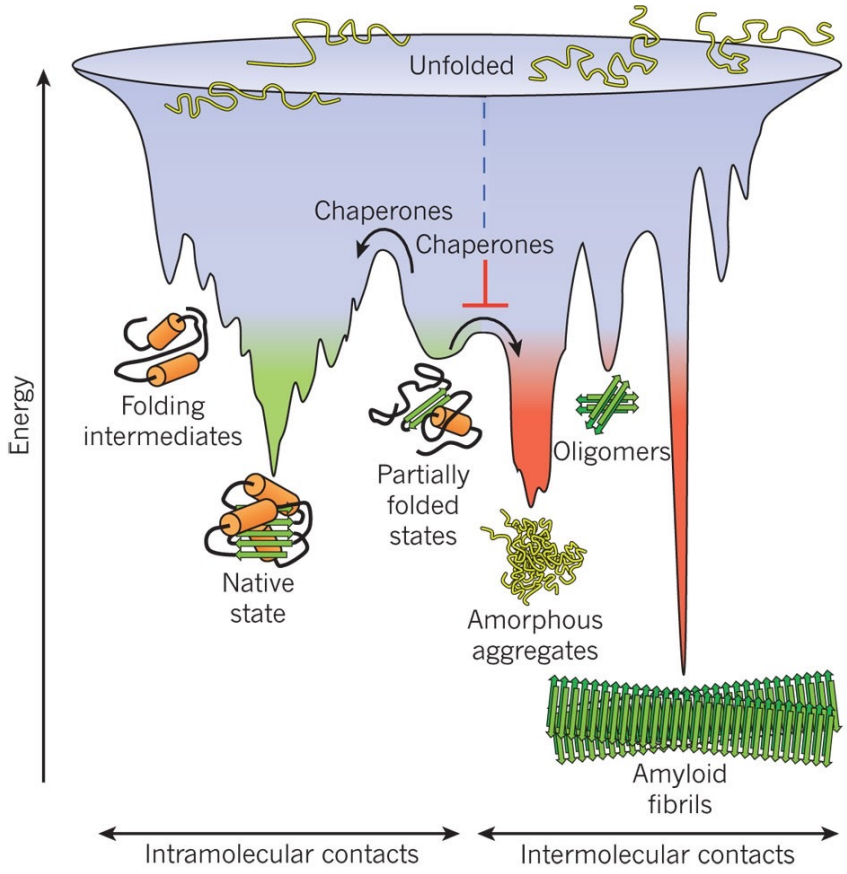
Why do Proteins need to fold?

To carry out their function, for instance, as enzymes or antibodies.

Proteins fold on a defined pathway (or a small number of alternative pathways); they don't randomly search all possible confirmations until they arrive at the most stable (lowest free energy) structure.

Chaperons are a group of proteins that assist a misfolded protein in refolding properly in its native state.
Eg: Bacterial Heat Shock protein

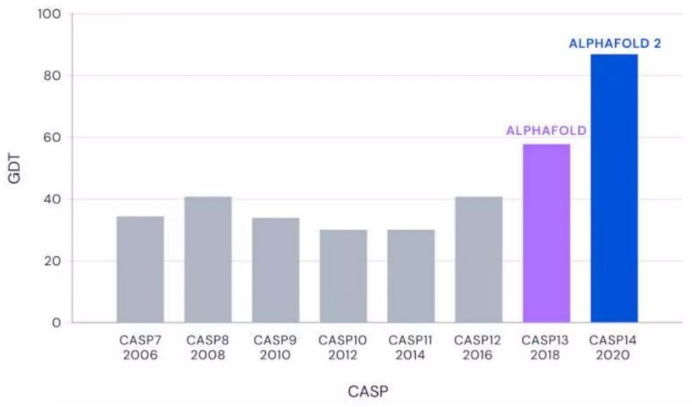
Diseases caused by misfolding of proteins:
Alzheimer's, Cystic Fibrosis, Parkinson's Disease

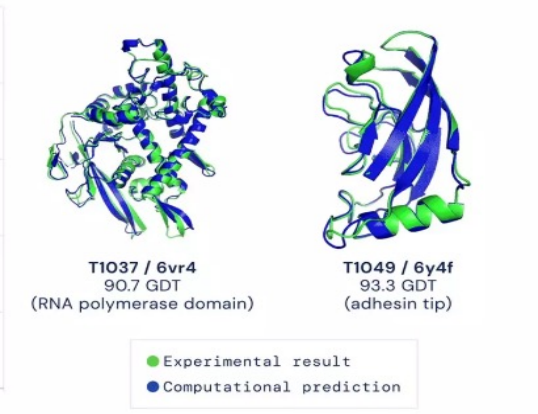


Protein Structure Prediction

Goal: Protein 3D Structure Prediction using Artificial Intelligence
Data: PDB (Publicly available)
Experimental Structure Prediction:

- NMR
- X-Ray crystallography
- Cryo-Electron Microscopy





DeepMind

BBC

AI breakthrough could spark medical revolution

By Paul Rincon
Science editor, BBC News website

22 July | Comments

nature

NEWS | 30 November 2020

'It will change everything': DeepMind's AI makes gigantic leap in solving protein structures

https://www.nextbigfuture.com/2020/12/expert-impressions-of-deep-mind-alphafold-protein-folding-advance.html