

LIFS 1901 Notes

by CHEN, Ruiping

All living things generally share these 7 characteristics

Cell – Organisms are made up of **cells** and are organized into levels

Metabolism – acquire and use energy

Reproduce – makes more of itself

Respond to stimuli – able to sense the surroundings

Homeostasis – to maintain your internal state

Growth and Development – increase in size or number of cells vs changes that take place from conception to maturity

Adaptation – Have the capacity to adapt to the environment through evolution

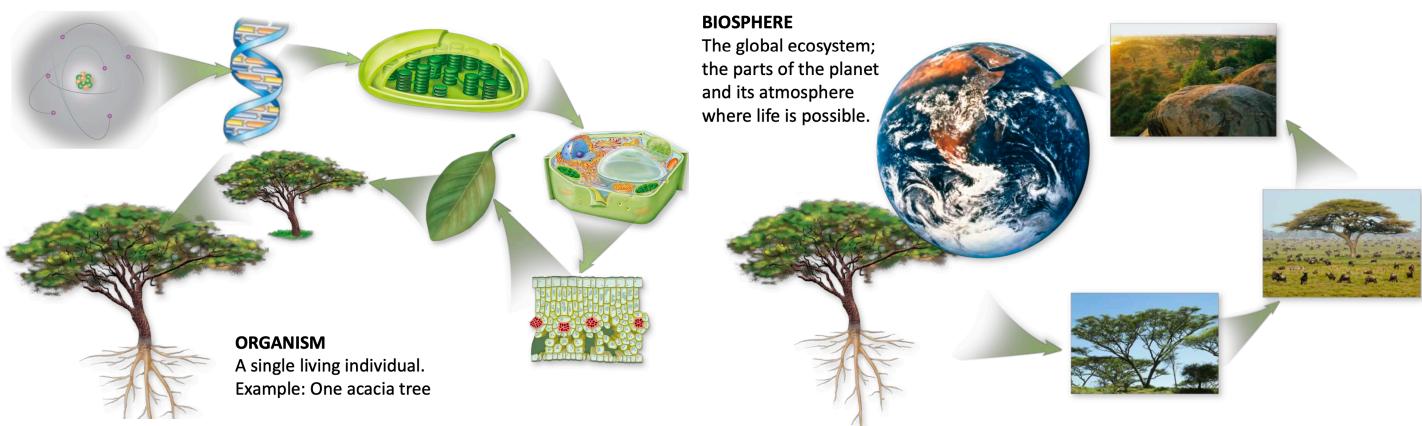
Parasites are considered **living**, but **viruses** are considered **non-living**.

Living things are organized in a hierarchy of 12 levels.

atom < molecule < organelle < **cell** (50–200 μ m)

< tissue < organ < organ system < **organism**

< population < community < ecosystem < **biosphere**



Chemical cycling & energy flow (one-way, through the food chain)

The 8-level Classification of Living Things (Taxonomy)

Domain 域 > Kingdom 界 > Phylum 门 > Class 纲 > Order 目 > Family 科 > Genus 属 > Species 种
DKPCOFGS

3 Domains

Bacteria 细菌域: Single cells. Bacteria are found nearly everywhere.

Archaea 古菌域: Single cells. Many live in extreme environments, e.g. salty, acidic, lack oxygen conditions.

Bacteria (Eubacteria) + Archaea (Archaeobacteria) = **Prokaryotes** 原核生物

Eukarya 真核生物域: Eukaryotic cells. Single-celled and multi-celled species of protists, fungi, plants and animals.

Kingdom Protista 原生生物

Kingdom Plantae 动物界

Kingdom Animalia 植物界

Kingdom Fungi 真菌界

Archaea and Eukarya are more close to each other.

The Linnaean system – Binomial in Latin

Species = genus, specific epithet

Genus capitalized, both words in italics

e.g. Species: *Homo sapiens* (Genus: *Homo*)

A species: One or more groups of individuals that potentially interbreed, produce fertile offspring, and do not interbreed with other groups.

The Process of Science

Observation → Question → Research topic area → Hypothesis → Prediction → Test with experiment → Analyze data → Conclusion → Communication

Inductive reasoning (Bottom-up logic) & **Deductive reasoning** (Top-down logic)

Inductive: specific observations → general conclusions

Deductive: general principles → specific conclusions

Inductive reasoning is not always reliable, while deductive reasoning is generally considered more reliable.

Animal models

Chimpanzee

Mouse (>90%)

Zebrafish (84%)

Fruit fly (77%)

Roundworm (65%)

Control Group/Experimental Group

Data must be repeatable

Cation 阳离子

Anion 阴离子

3 Types of bonding

Ionic bonds / Covalent bonds / Hydrogen bonds

Electronegativity is the measure of an atom's ability to attract electrons in a chemical bond.

Cohesive forces / Adhesive forces

Polar/Nonpolar Covalent bonds

due to the polarity of water molecules, allows them to surround and separate ions and polar molecules

NaCl in water: Ionized and polar molecules form hydrogen bonds and are hydrophilic
solute 溶质 + solvent 溶剂 = solution 溶液

Cohesion causes water to have a high surface tension

Ionization of water

pH = $-\log [H^+]$

pH of blood ~ 7.4

Bicarbonate Buffer in Blood: HCO_3^-

Acid: $H^+ + HCO_3^- = H_2O + CO_2$

Base: $OH^- + HCO_3^- = H_2O + CO_3^{2-}$

Macromolecules are made from monomers

Triglyceride(甘油三酯) = 3 Fatty Acid(脂肪酸) + Glycerol(丙三醇)

$H_2CO-CO-[CH_2]_n-CH_3$

$HCO-CO-[CH_2]_n-CH_3$

$H_2CO-CO-[CH_2]_n-CH_3$

Carbohydrate

C:H:O=1:2:1

simple	monosaccharide	glucose/fructose/galactose 单糖 葡萄糖/果糖/半乳糖
	disaccharide	maltose/sucrose/lactose 二糖 麦芽糖/蔗糖/乳糖
complex	polysaccharide	starch/glycogen/cellulose/fiber (insoluble) 多糖 淀粉/糖原/纤维素

Starch stored in plants, glycogen stored in animals

Cellulose in cell walls

Lipid

Triglyceride/phospholipid/steroid/wax (hydrophobic, insoluble)

Saturated (solid) / monounsaturated / polyunsaturated (liquid) fat

Margarine 人造黃油

Steroid 类固醇

All have a backbone of four fused carbon rings

cholesterol 胆固醇 → steroids like sex hormone

Phospholipid

Hydrophilic head Hydrophobic tail

$\{N(CH_3)_3-CH_2-CH_2\}-\{PO_4\}-CH_2-HCO-CO-[CH_2]_n-CH_3$
 $-H_2CO-CO-[CH_2]_n-CH_3$

Protein

Composed of amino acid(氨基酸) monomers

$NH_2-CH_2-\underline{COOH} + NH_2-CH(CH_3)-COOH \rightarrow NH_2-CH_2-\underline{CO-NH-CH(CH_3)-COOH} + \underline{H_2O}$

O=C-N-H: peptide bond(肽键)

Amino group

H₂N-CHR-COOH (side chain R)

20 amino acids, 11 are non-essential (-ine)

4 levels of protein structure

Primary structure: sequence of amino acids

Secondary structure: helix/pleated sheet, H bonds

Tertiary structure: 3D, polypeptide chain, S bonds, H bonds, hydrophobic interactions

Quaternary structure: two or more polypeptides join to form a single protein

Prion – misfolded protein – mad cow disease

Nucleic Acid

DNA → mRNA → protein

Nucleotide 核苷酸

triphosphate + 5-carbon sugar + nitrogenous base

PO₄-[C5]-Base

Base: DNA: A/C/G/T, RNA: A/C/G/U, A=T, C≡G

Purine 嘌呤: A/G

Pyrimidine 嘧啶: C/T/U

Adenine 腺嘌呤, Thymine 胸腺嘧啶, Guanine 鸟嘌呤, Cytosine 胞嘧啶, Uracil 尿嘧啶

P group in 5', -OH group in 3'

5' 3'

S-T=A-S

P P

S-C≡G-S

P P

S-A=T-S

3' 5'

mRNA, tRNA, rRNA

Found by James Watson and Francis Crick

Adenosine Triphosphate 腺苷三磷酸

Base-[C5]-P-P~P

Small cells have a higher surface-volume ratio

microvilli 微绒毛

alveoli 肺泡

Electron microscope: SEM, TEM

More than 1000x

Scanning/transmission Electron microscope

Eukaryote 真核细胞

process membrane-enclosed structures including the nucleus

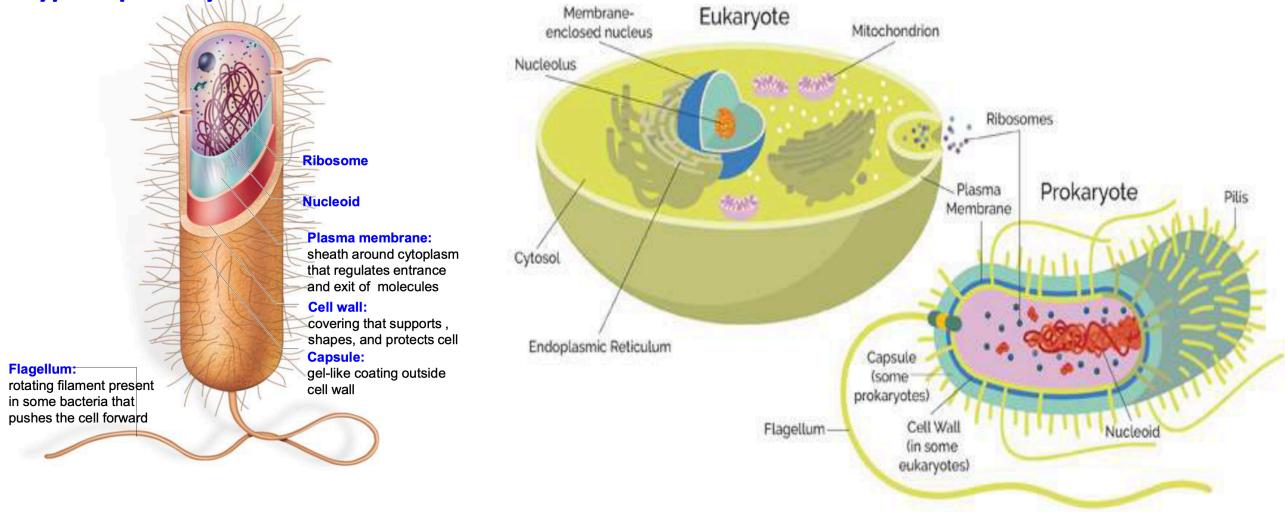
All cells except bacteria and archaea

Prokaryote 原核细胞

Lack membrane-enclosed structures, lack the nucleus 细胞核

Contain a nucleoid 类核

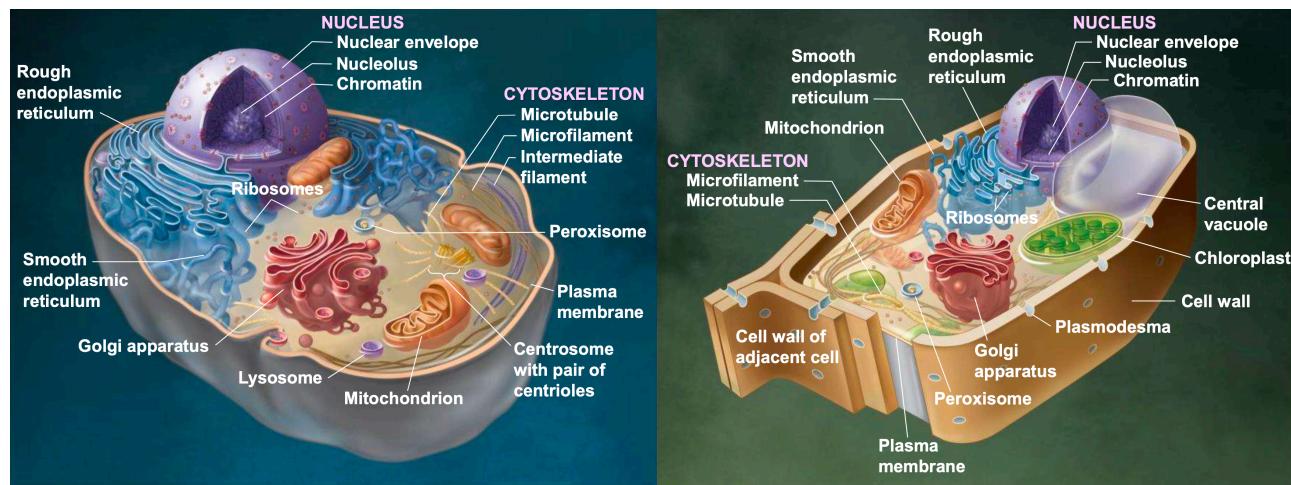
A typical prokaryote



Prokaryote: nucleoid, circular DNA

Eukaryote: nucleus, organelles, linear DNA

Both: cells, cell membrane, ribosomes 核糖体



Cytoplasm 细胞质

Nucleus 细胞核

nucleolus 核仁 (inside nucleus)

nuclear envelope 核膜 (double plasma membrane)

nuclear pores 核孔 allowing RNA and proteins to move in and out

chromatin 染色质

Ribosome 核糖体

Peroxisome

Centrosome 中心体

Centriole 中心粒

Lysosome 溶酶体

Mitochondrion 线粒体

double-membrane

matrix 基质

cristae 嵴

Golgi Apparatus 高尔基体

Smooth Endoplasmic Reticulum 滑面内质网

Rough Endoplasmic Reticulum 粗面内质网 (ribosomes attached)

Chloroplast 叶绿体 (植物)

stroma 基质

granum 基粒

thylakoid 类囊体

Central Vacuole 中央液泡 (植物)

Cytoskeleton 细胞骨架

Ribosomes use mRNA as a template to make proteins – the protein factories

Endomembrane System 内质膜系统

Protein synthesis → modification → packaging

Ribosome: make proteins

no membrane, not an organelle

RER: synthesizes proteins

SER: synthesizes lipids and also performs various other functions

Golgi Apparatus: modify and tag proteins to 3 destinations: cell membrane / secreted out / makes lysosome

Lysosome: containing digestive enzymes – recycling plant

chloroplast & mitochondria: double membrane

Chloroplast: Sun + CO₂ + H₂O → [C] + O₂ (photosynthesis)

Chlorophyll 叶绿素

[C] + O₂ → CO₂ + H₂O + ATP

Cytoskeleton

shaper/mover/cell division

Motor protein

Myosin – interacts with actin (muscles)

Kinesin (move to plus end), **Dynein** (move to minus end) – walk along microtubules to transport vesicles and organelles

Flagella – using dynein to bend: dynein side arms reach to their neighbors

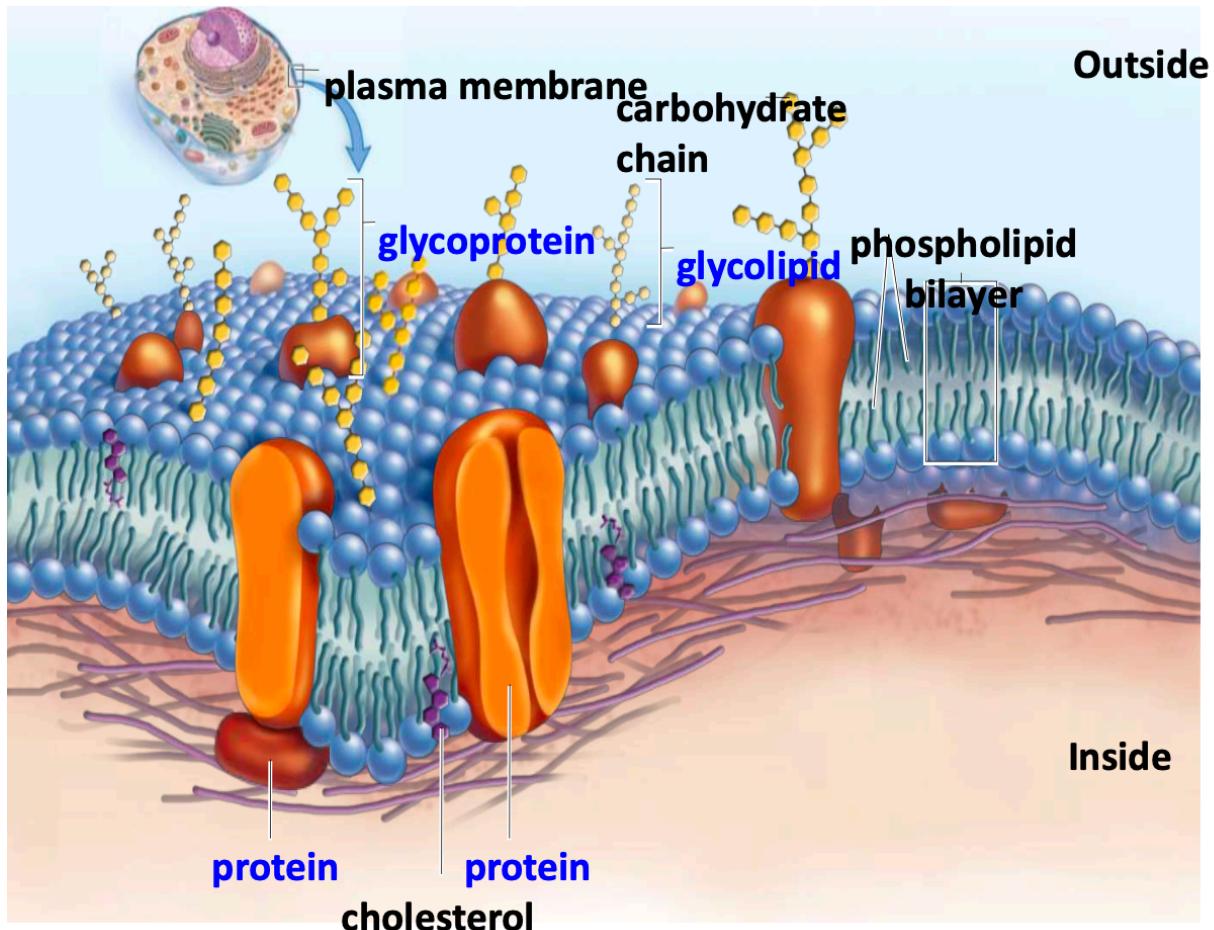
Microtubule 微管 – shaper/cell division, constantly (de)polymerize to change the cell's shape, position cell organelles

made of tubulin 微管蛋白

Actin Filament (Microfilament) 微丝

two actin chains twisted in helix

dense web under plasma membrane / found in microvilli to provide support



Actin subunits allow cells to change shape quickly to form pseudopods

Intermediate Filament 中间丝 (动物) – shaper, surrounding nucleus

high strength, permanent, made from keratin (角蛋白) – in hair and fingernails

Plasma membrane = cell membrane = cytoplasmic membrane

Phospholipid bilayer

glycoprotein

glycolipid

cholesterol

integral protein

peripheral proteins: Located on the inner or outer surface of the membrane.

Fluid–mosaic model

Diffusion and Osmosis

Isotonic, hypotonic, and hypertonic solution

Simple diffusion – selectively permeable

can:

hydrophobic molecules: O₂, CO₂, N₂, steroid

small uncharged molecules: H₂O, glycerol, urea

cannot:

large uncharged polar molecules

ions

Bulk transport

endocytosis 胞吞

exocytosis 胞吐

phagocytosis 吞噬

pinocytosis 胞饮

Receptor-mediated endocytosis

Channel protein – specific molecule/ion (e.g. aquaporin) passive transport

Carrier protein: passive/active transport (e.g. Sodium–Potassium pump, 3Na^+ , 2K^+)

Junction proteins

Extracellular matrix

collagen fibre

Adheren junction

found in tissues that require stretching: skin

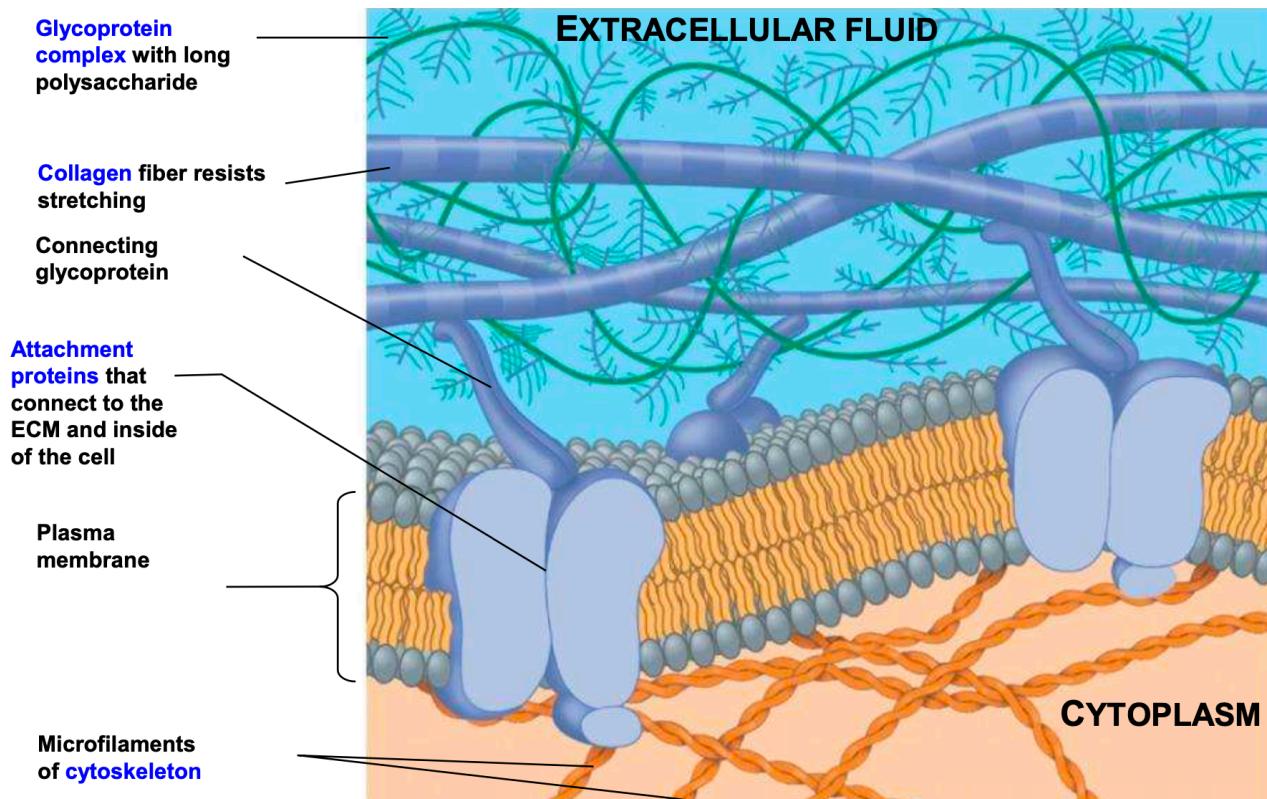
Desmosome – provides strong adhesion between cells

Tight junction – tight junction proteins so that no liquid leaks out

found in kidneys/intestines

Gap junction – communication channels – small molecules and ions, electricity

Plasmodesmata (plant cells)



Metabolism: all reactions that take place in order for things to live

Catabolism: the breakdown of molecules (usually release energy)

Anabolism: the synthesis of all compounds needed by the cell (requires energy)

Phosphorylation: $\text{ADP} + \text{Pi} \rightarrow \text{ATP}$

ATP: Adenosine triphosphate

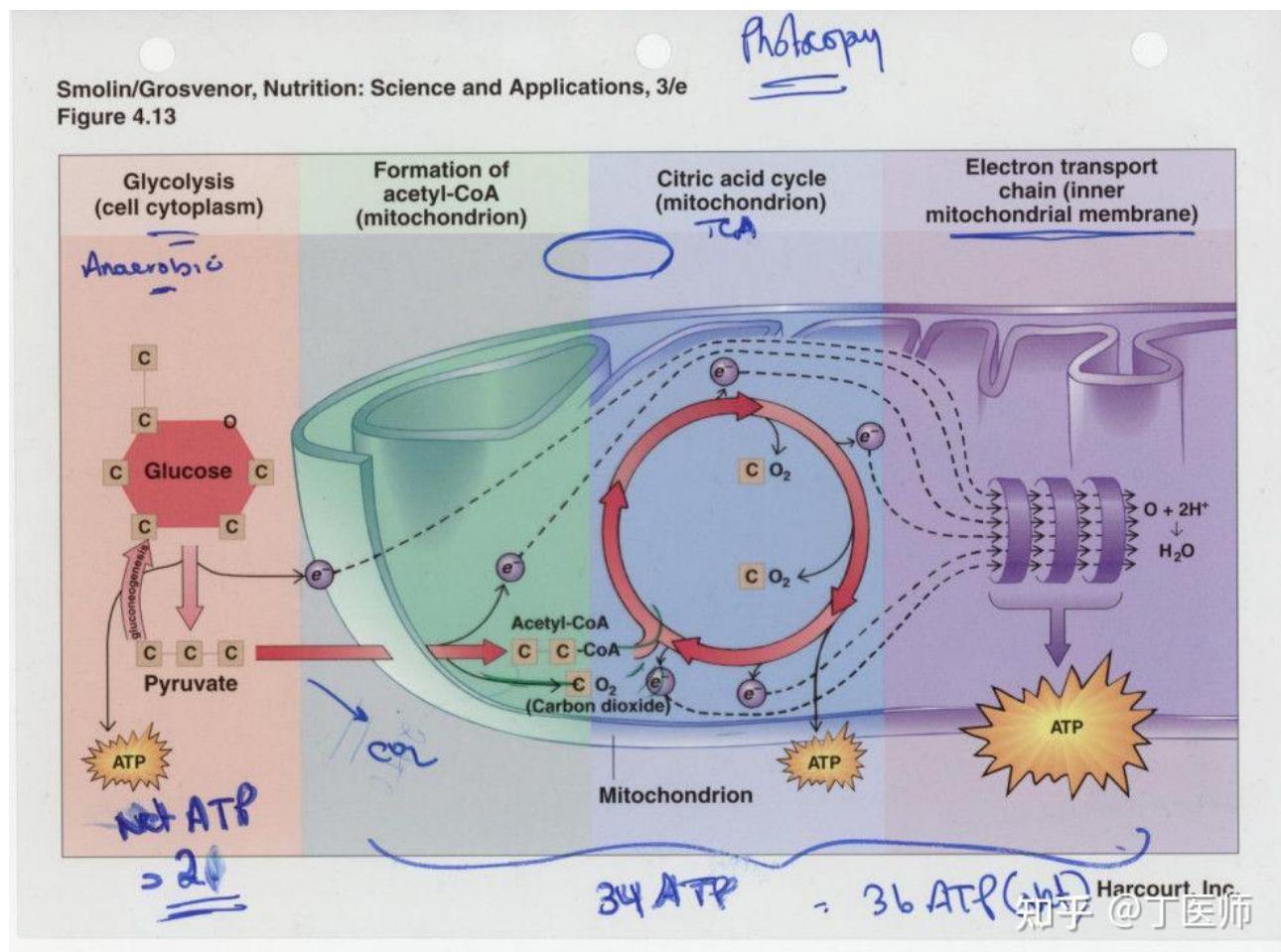
Enzymes can denature

Enzymes named [substrate] + -ase

Cofactors – non-protein helpers

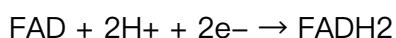
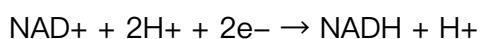
Coenzyme – organic cofactors

Biochemical pathways are regulated by feedback inhibition



2 ways: Competitive/noncompetitive inhibitor

Poisons and drugs are often enzyme inhibitors



Aerobic respiration

Glucose (6C)

↓ Glycolysis (cytoplasm) [$2\text{NAD}^+ \rightarrow 2\text{NADH}$] [$-2\text{ATP} + 4\text{ATP} \rightarrow 2\text{ATP}$]

2 Pyruvate(丙酮酸) (3C) + 2ATP + 2e-

↓ Pyruvate Oxidation (mitochondrial matrix) [$2\text{NAD}^+ \rightarrow 2\text{NADH}$]

2 Acetyl (2C) CoA + 2CO2 + 2e-

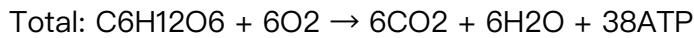
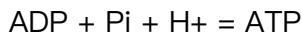
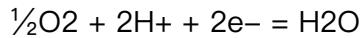
↓ Citric Acid Cycle (Tricarboxylic Acid Cycle/Kreb's Cycle) (cristae)



↓ Oxidative Phosphorylation = Electron Transport Chain + Chemiosmosis (inner membrane)

Pumping H⁺ into intermembrane space to create a proton gradient

A membrane protein that acts as a molecular rotary motor

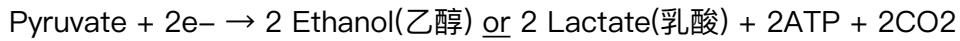


CO₂: step2, 3

ATP: step1, 3, 4(many)

NADH: step1, 2, 3(many)

Anaerobic respiration – fermentation(发酵)



Lactate fermentation (animal, certain bacteria)

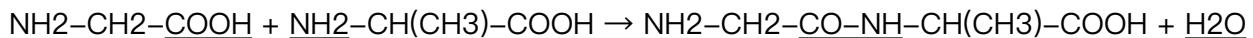
Alcoholic fermentation (yeast and other fungi)

After Midterm

Recap:

Protein

Composed of amino acid(氨基酸) monomers



O=C-N-H: peptide bond(肽键)

Amino group

H₂N-CHR-COOH (side chain R)

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Nucleic Acid

DNA → mRNA → protein

Nucleotide 核苷酸

triphosphate + 5-carbon sugar + nitrogenous base

PO₄-[C5]-Base

Base: DNA: A/C/G/T, RNA: A/C/G/U, A=T, C≡G

Purine 嘌呤: A/G

Pyrimidine 嘧啶: C/T/U

Adenine 腺嘌呤, Thymine 胸腺嘧啶, Guanine 鸟嘌呤, Cytosine 胞嘧啶, Uracil 尿嘧啶

P group in 5', -OH group in 3'

5' 3'

S-T=A-S

P P

S-C≡G-S

P P

S-A=T-S

3' 5'

mRNA, tRNA, rRNA

Found by James Watson and Francis Crick

Adenosine Triphosphate 腺苷三磷酸

Base-[C5]-P-P~P

Protein are the direct determinants of life

1 polypeptide ~ 360 amino acids (avg.)

DNA is the ultimate determinant of life

Chromosome

DNA associated with proteins is packed into a **chromosome**

1 chromosome = 1 double-stranded DNA

1 prokaryotic cell has **1 circular** chromosome = 1 circular DNA

1 eukaryotic cell has **n linear** chromosomes = n linear DNA

Regularly – chromosomes extended & spreading in nucleus, indistinguishable

Cell dividing – no nucleus, chromosomes condensed, distinguishable

DNA/chromosome length and number in 1 cell

	Basepairs per chromosome	Chromosomes per cell
E. Coli (大肠杆菌)	10^6	1
Brewer's yeast	10^5	16
Fruit fly	10^7	8
Human	10^8	46
Loblolly pine	10^9	24

3-nucleotide unit = codon = triplet code

The genetic code table of **coding strand**

	T	C	A	G	
T	TTT Phe	TCT Ser	TAT Tyr	TGT Cys	T
	TTC Phe	TCC Ser	TAC Tyr	TGC Cys	C
	TTA Leu	TCA Ser	TAA stop	TGA stop	A
	TTG Leu	TCG Ser	TAG stop	TGG Trp	G
C	CTT Leu	CCT Pro	CAT His	CGT Arg	T
	CTC Leu	CCC Pro	CAC His	CGC Arg	C
	CTA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CTG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	ATT Ile	ACT Thr	AAT Asn	AGT Ser	T
	ATC Ile	ACC Thr	AAC Asn	AGC Ser	C
	ATA Ile	ACA Thr	AAA Lys	AGA Arg	A
	ATG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GTT Val	GCT Ala	GAT Asp	GGT Gly	T
	GTC Val	GCC Ala	GAC Asp	GGC Gly	C
	GTA Val	GCA Ala	GAA Glu	GGA Gly	A
	GTG Val	GCG Ala	GAG Glu	GGG Gly	G

DNA

5'-ATGGAC...CAGTGA-3' (non-template strand = coding strand)

3'-TACCTG...GTCACT-5' (template strand = non-coding strand)

↓ Transcription (5'→3')

RNA

5'-UACCU...GUCACU-3' (RNA strand)

↓ Translation (5'→3')

Protein

NH₃+-Met-Asp...-Gln-CO₂- (polypeptide)

Gene = Heritable section of DNA that determines the character of living organisms = Instructions for protein production

Gene Expressed = Gene's instructions used by the cell = Synthesis of its encoded polypeptides

Transcription

Each gene can be transcribed many times

1. Promoter sequence attracts RNA polymerase (**Initiation**)
2. RNA polymerase unwinds DNA from 5' to 3' (**Elongation**)
3. Produce RNA
4. DNA rewound after RNA polymerase left
5. RNA polymerase comes across a terminator and falls off the DNA (**Termination**)
6. RNA product transported out of the nucleus if involved in protein synthesis (eukaryotes)

Terminator sequence = inverted complementary sequences, making RNA stick to itself to escape from RNA polymerase

RNA

Messenger RNA (mRNA)

Coding for proteins, template for translation

Ribosomal RNA (rRNA)

Forming ribosomes together with ribosomal proteins

Transfer RNA (tRNA)

Transferring amino acids for translation

Nucleotide of rRNA and tRNA do not form codons

Backbone Sugars

Deoxyribose (DNA)

C₄O–2'C–H, less reactive, more stable → master copy, permanent

Ribose (RNA)

C₄O–2'C–OH, more reactive, less stable → working copy, disposable

Nucleoside triphosphate (activated nucleotide)

P₃–[C₅]–A/C/G/U (P₂ removed during transcription)

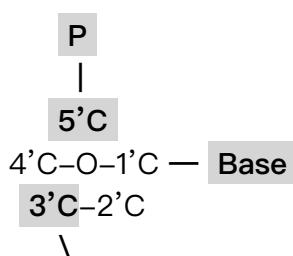
P₃ = Triphosphate

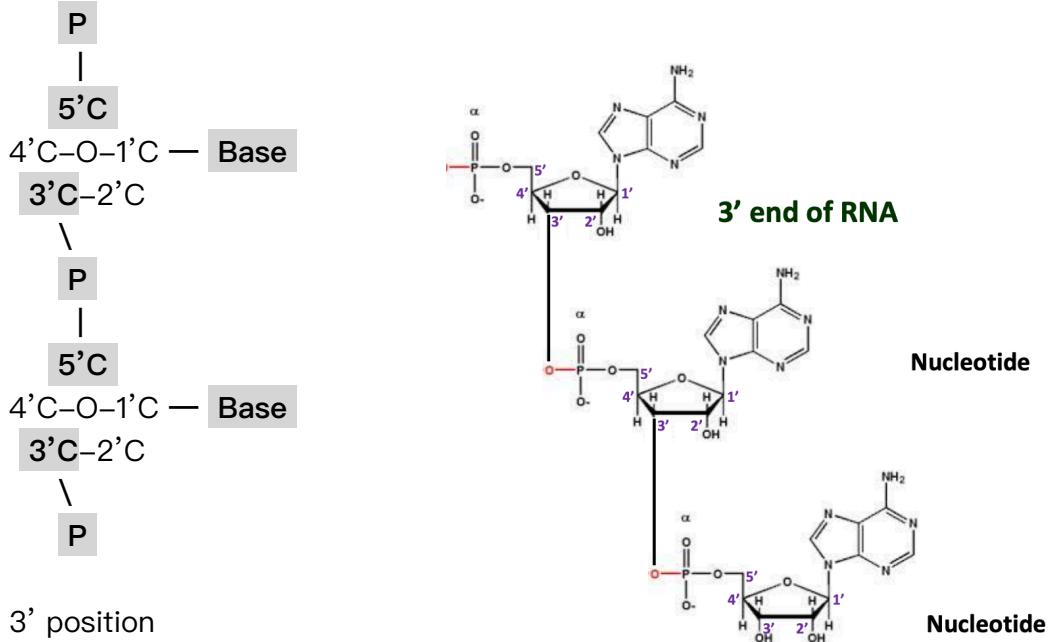
[C₅] = Ribose

A/C/G/U = Nitrogenous Base

PO₃–[C₅]–A/C/G/U = Nucleotide

5' position





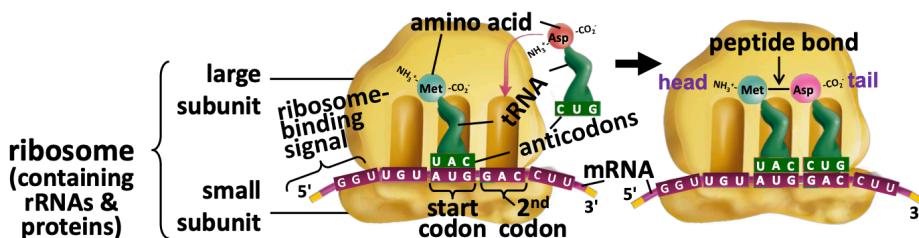
Transfer RNA (tRNA)

Mediator between mRNA and amino acid

Having a specific anticodon to basepair with a specific codon on the mRNA

Carrying the corresponding amino acid on the other side

Translation



1. Ribosome recognizes ribosome-binding sequence and the start codon (AUG) on mRNA
 2. A tRNA with anticodon (UAC) for the start codon carrying amino acid (Met) is recruited to the ribosome-mRNA complex
 3. A tRNA with anticodon for the 2nd codon carrying the corresponding amino acid is recruited to the ribosome-mRNA complex
 4. A peptide bond is formed between the first and the 2nd amino acid
 5. The ribosome shifts downstream along the mRNA to locate the 3rd codon
 6. Repeat 3, 4, 5
 7. Ribosome arrives at a stop codon and releases the mRNA
- Polypeptide product
(Head = amino) NH₃⁺-Met-Val-...-Asp-CO₂⁻ (Tail = carboxyl)

Ribosome = 3 rRNA + >50 Protein Molecules

Regulatory Elements of a Non-protein-coding Gene

Transcription promoter

Transcription start site (TSS)

Transcription terminator

Transcription termination site (TTS)

Transcribed region = from TSS to TTS

Product = RNA

Regulatory Elements of a Protein-coding Gene (10^2 bp in prok., 10^3–5 in euk.)

Transcription promoter (TP, determine the rate of transcription = number of mRNAs)

Transcription start site (TSS)

Ribosome binding site (RBS, determine the rate of translation = number of proteins per mRNA)

Start codon (ATG)

Stop codon (TAA/TAG/TGA)

Transcription terminator

Transcription termination site (TTS)

Protein coding region = from start codon to stop codon (inclusive)

In a multicellular organism, every cell contains all the genes of that organism.

	Genes in one set	Total length of DNA per set of genes (bp)	Avg. distance between two genes (bp)
E. Coli (大肠杆菌)	4300	$\sim 10^6$	1100
Brewer's yeast	6600	$\sim 10^7$	1800
Fruit fly	15600	$\sim 10^8$	8300
Human	21000	$\sim 10^9$	140000
Loblolly pine	50000	$\sim 10^{10}$	440000

There are high proportions of repeat sequences (junk DNA) in eukaryotic genomes

Regulation of gene expression in response to external signals

Eg1: No lactose \rightarrow lacZ gene not expressed

LacI repressor protein binds between the promoter and TSS

Lactose binds to the repressor to change its shape so that it cannot bind to lacZ DNA

Eg2: UV \rightarrow production of pigment

Regulation of gene expression

RNA/Protein production (transcription) (usual)

RNA/Protein sequence modification (RNA splicing)

RNA/Protein transportation

RNA/Protein degradation

During embryonic development of an organism:

Different parts receive different signals, expressing different subsets of genes, thus differentiating.

Stem cell = Undifferentiated cells

Cell division

Binary fission

G1 phase = growth

S phase = DNA replication and growth

G2 phase = growth

M phase = mitosis = cell division

Diploid = having 2 sets of chromosomes

Human body cell contains:

23 different chromosomes, 2 copies of each chromosome

1 chromosome = 2 chromatids(染色单体) + centromere(着丝粒)

Mitosis(有丝分裂)

1. Chromosomes replicated
2. Chromosomes condense
3. Centrosomes move to poles and send out spindle-like microtubule fibers
4. Nuclear envelope disintegrates
5. Spindle fibers attach to the centromere, aligning chromosomes at the equatorial area
6. Centromere protein degrades, chromosomes pulled toward opposite poles
7. Nuclear envelope re-forms around each collection of chromosomes to form 2 nuclei
8. Chromosomes de-condense
9. Plasma membrane constricts and separates the cell into 2 portions

Programmed cell death

Damaged beyond repair

Dividing out of control

Infected by virus

Fertilized egg

↓ DNA replication

↓ Cell division

↓ Cell differentiation

↓ Cell death

Adult organisms (10^{14} cells)

Some cells stop dividing in adult organisms, e.g. neurons, heart muscle cells

Asexual reproduction = ... from one existing individual (favorable condition)

Sexual reproduction = fusion of cells produced by 2 separate individuals (unfavorable condition)

Almost all **multicellular eukaryotes** – Sexual reproduction

Most **unicellular eukaryotes** – Both asexual and sexual reproduction, depending on the environmental conditions

All prokaryotes – Asexual reproduction

All prokaryotes are unicellular

Sex cells are haploid = containing 1 set of chromosomes

Meiosis(減数分裂) = Reductive cell division

Chromosomes already replicated

1. Chromosomes condense
2. Centrosomes move to poles and send out spindle-like microtubule fibers
3. Homologous chromosomes pair up
4. Exchange of chromosome segment
5. Nuclear envelope disintegrates
6. Spindle fibers attach to the centromere, aligning **paired** chromosomes at the equatorial area
7. **Paired chromosomes lose bonding**, pulled toward opposite poles
8. Nuclear envelope re-forms around each collection of chromosomes to form 2 nuclei
9. Chromosomes de-condense
10. Plasma membrane constricts and separates the cell into 2 portions
11. **A further division similar to mitosis**

Overall outcome of meiosis

1 germline cell(生殖细胞) → 4 sex cells

Each sex cell is haploid = has 1 set of chromosomes

Contain recombinant chromosomes

Difference among living individuals

Regular individuals of the same species have

Same assemblage of genes

Same assemblage of chromosomes

Small differences in DNA sequences

Allele(等位基因) = same locus with different DNA sequences

Difference of DNA sequences between 2 unrelated humans = 0.1% = 3×10^6 bp, most of which are outside genes

Difference of DNA sequences between humans and chimps = 1.25%

Mutation

Mutation in a somatic cell is inherited by all tissue cells that it generates

Mutation in a germline cell is inherited by its descendants

Point mutation = small mutation involving 1 or a few bp

In protein-coding region

Base substitution

ATGCAAAGTCAC...

Met-Gln-Ser-His-...

Missense mutation = 1 amino acid change

ATGCAACGTCAC...

Met–Gln–Arg–His–...

Silent mutation = no amino acid change

ATGCAAAGCCAC...

Met–Gln–Ser–His–...

Nonsense mutation = protein truncation

ATGTAAAGCCAC...

Met

Base deletion/insertion

Frameshift mutation = deletion/insertion of a non–3n of bp

Insertion

ATGCAAGAGTCAC...

Met–Gln–Glu–Ser–...

Deletion

ATGCAAGTCAC...

Met–Gln–Val–...

In regulatory region

Promoter mutation

stronger/weaker binding to RNA polymerase

higher/lower transcription level

increase decrease in gene expression level

Ribosome binding site mutation

Change in a large chromosome segment

Gene loss (deletion) or gain (duplication)

non–viability or inferiority

e.g. Cri du chat syndrome

DNA rearrangement

Translocation/Inversion/...

reduced fertility

Change in chromosome number

Euploid(整倍体) = Diploid

Aneuploid(非整倍体)

e.g. Trisomic (21) = Down syndrome

Polyplloid(多倍体)

non–viability or inferiority

reduced fertility e.g. seedless watermelon

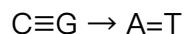
bigger than diploid

reproducing asexually only

Internal mutation mechanisms

Point mutations

1. Spontaneous changes in nitrogenous bases



2. Reaction with water

$C \equiv G \rightarrow A=T$

3. Reactive oxygen species

$C \equiv G \rightarrow A=T$

4. Mistakes made by DNA polymerase

misincorporation of nucleotide (1 in 10^{6-9})

slipping/jumping along DNA (causing small DNA deletion or duplication)

Large chromosome mutations

5. Unequal exchanges of chromosomal segments = unequal crossovers

Gene disruptions and large chromosome mutations

6. Transposition of transposon

Chromosome number mutations

7. Failure of spindle function during cell division

Aneuploidy/Polyplody

8. Failure of cell division after DNA replication

Polyplody

9. Cell fusion

Polyplody

External mutation mechanism

Chemical mutagens

1. DNA adduct formation (point mutations)

chemicals react with nitrogenous bases

e.g. PAHs(多环芳香烃)/Nitrosamines(亚硝胺)

2. Spindle disruption (chromosome number mutations)

e.g. vinblastine & vincristine from periwinkle

Physical mutagens

3. Ionizing radiations (point mutations & large chromosome mutations)

γ -, X-radiations, breaking bonds wherever they hit

4. UV radiations (CC/CT/TC \rightarrow TT point mutations)

dimerization of adjacent pyrimidines

Biological mutagens

5. viruses (gene disruptions & large chromosome mutations)

insert their DNA into the host cell genome randomly, causing disruption

Viruses = small particles made up of biological molecules

Size = 0.03–0.2 μm

Virus = genome + protein coat (+ envelope) (+ spikes)

Genome = DNA or RNA, 10^{3-5} b(p), 2–300 genes

Viruses multiply only when they are inside host cells

DNA virus

replicated by host-cell DNA polymerase

multiple copies of viral DNA genome

Retrovirus(逆转录病毒)

turn into DNA by virus-encoded reverse-transcriptase

inserted into host-cell genome by virus-encoded integrase
transcribed by host-cell RNA polymerase
multiple copies of viral RNA genome

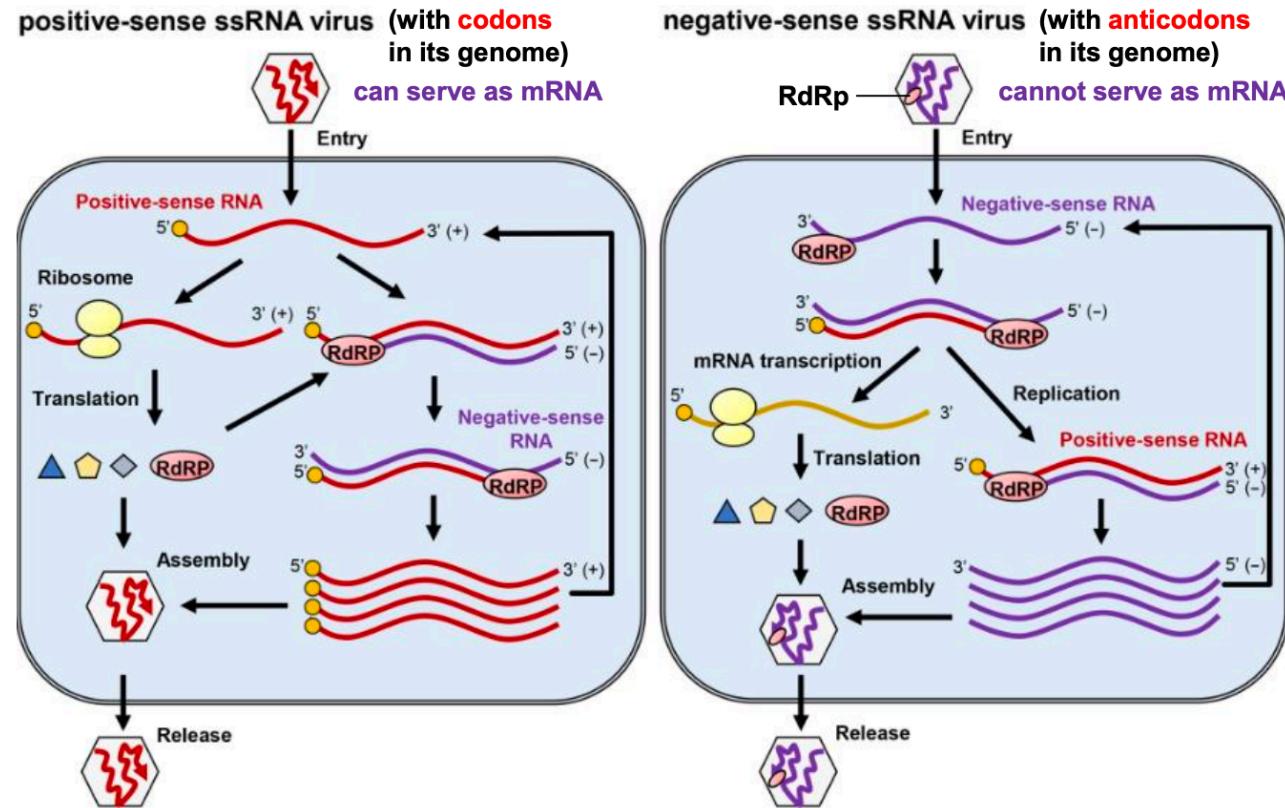
Other RNA virus

virus-encoded RNA polymerase which synthesizes RNA using RNA as the template (RNA-dependent RNA polymerases, aka RdRP)

Immune response of the host

Eliminate viral particles and virus-infected cells

Antibodies & killer T cells



B cells & antibody

1. Have receptors that can bind different foreign molecules
2. Continuously circulate in the body and check for foreign molecules
3. Once bound, B cells divide repeatedly to produce many clones
4. B cell clones produce and release antibodies that can bind the particular foreign molecules
5. These antibodies coat the foreign molecules
6. Scavenger cells swallow and destroy foreign items
7. Some B cell clones differentiate into long-life memory B cells that when they encounter the same foreign molecules, they can divide and release antibodies rapidly.

Killer T cells

1. All cells present the peptides degraded from proteins on their surfaces using **presenter protein MHC-I**
2. Killer T cells with different receptors are constantly made
3. Circulate in the body and check with MHC-I-presented peptide
4. Once bound, the killer T cell kills the cell

5. Divide repeatedly to produce many clones
6. Circulate in the body, looking for cells with the same peptides
7. Some Killer T cell clones differentiate into long-life memory killer T cells that when they encounter the same foreign peptides, they can divide rapidly.

Protein vaccine (sp, B)

spike proteins on the surface of the virus
generating memory B cells having receptors that can bind the virus surface
not including killer T cell response
have relatively mild side effects

Inactivated vaccine (mp, B)

virus particles inactivated by chemicals
multiple protein targets
have relatively mild side effects

mRNA vaccine (sp, B+T)

mRNA of gene coding for a virus surface protein, packaged in a liposome
Inducing memory B cells & memory killer T cells
only one protein target

DNA vaccine

DNA of gene coding for a virus surface protein, packaged in a liposome
unable to enter the cell nucleus

Virus vectored DNA vaccine (sp, B+T)

DNA of gene coding for a virus surface protein, packaged in a virus vector
Inducing memory B cells & memory killer T cells
only one protein target

Attenuated vaccine

viral particles with changes in genome
still able to infect cells, producing less progeny virus
Inducing memory B cells & memory killer T cells
most effective, but dangerous

Antivirals = anti-virus drugs

Chemicals inhibiting virus-specific biological activities

Reverse transcriptase(逆转录酶) & integrase of retroviruses(逆转录病毒整合酶)

RdRp of RNA viruses other than retroviruses

Viral proteases(病毒蛋白酶)

Virus-specific antibodies

Stimulators of anti-virus immune responses

e.g. interferons