



Unit 1: Introduction to Microbial World and You

Microbiology

Microbiology: The study of microorganisms.

Microorganisms: Small living organisms that generally can not be seen with the naked eye. Include:

- Kingdom : Monera (Bacteria)
- Kingdom : Protista (Protozoa, Algae, Slime molds)
- Kingdom : Fungi (Yeasts, Molds)

Virology: Study of non-living infectious particles. Include:

- ◆ Viruses (Infectious particle where a nucleic acid core is surrounded by protein capsid)
- ◆ Viroides (Infectious nucleic acid particle)
- ◆ Prions (Infectious protein particles)

Microbial Nutrition

Microbial Nutrition

- Microbial growth depends on the metabolism of nutrients, and results in the formation of a discrete colony, an aggregation of cells arising from a single parent cell. A nutrient is any chemical required for growth of microbial populations. The most important of these are compounds containing carbon, oxygen, nitrogen, and/or hydrogen.

Nutrients: Chemical and Energy Requirements

- All cells require three things to conduct metabolism: a carbon source, a source of energy, and a source of electrons or hydrogen atoms.

Sources of Carbon, Energy, and Electrons

- Organisms can be categorized into one of four groups based on their source of carbon and their use of either chemicals or light as a source of energy:
 - Photoautotrophs use carbon dioxide as a carbon source and light energy from the environment to make their own food.
 - Chemoautotrophs use carbon dioxide as a carbon source but catabolize organic molecules for energy.
 - Photoheterotrophs are photosynthetic organisms that acquire energy from light and acquire nutrients via catabolism of organic compounds.
 - Chemoheterotrophs use organic compounds for both energy and carbon.
- In addition, organotrophs acquire electrons from organic sources, whereas lithotrophs acquire electrons from inorganic sources.

Oxygen Requirements

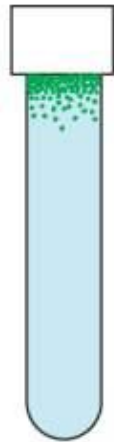
- Obligate aerobes require oxygen as the final electron acceptor of the electron transport chain, whereas obligate anaerobes cannot tolerate oxygen and use an electron acceptor other than oxygen. Toxic forms of oxygen are highly reactive and cause a chain of vigorous oxidation. Four forms of oxygen are toxic:
 - Singlet oxygen (O_2^1) is molecular oxygen with electrons that have been boosted to a higher energy state, typically during aerobic metabolism. Phototropic microorganisms often contain pigments called carotenoids that prevent toxicity by removing the excess energy of singlet oxygen.
 - Superoxide radicals ($O_2^{\cdot-}$) are formed during the incomplete reduction of oxygen during electron transport in aerobes and during metabolism by anaerobes in the presence of oxygen. They are detoxified by superoxide dismutase.
 - Peroxide anion (O_2^{2-}) is a component of hydrogen peroxide, which is formed during reactions catalyzed by superoxide dismutase. The enzymes catalase and peroxidase detoxify peroxide anion.

Oxygen Requirements (Cont.)

- Hydroxyl radicals ($\text{OH}^\bullet$) result from ionizing radiation and from the incomplete reduction of hydrogen peroxide. Hydroxyl radicals are the most reactive of the four toxic forms of oxygen, but because hydrogen peroxide does not accumulate in aerobic cells, the threat of hydroxyl radicals is virtually eliminated in aerobic cells.
- Not all organisms are either strict aerobes or anaerobes. Facultative anaerobes can maintain life via fermentation or anaerobic respiration, though their metabolic efficiency is often reduced in the absence of oxygen. Aerotolerant anaerobes prefer anaerobic conditions, but can tolerate oxygen because they have some form of the enzymes that detoxify oxygen's poisonous forms. Microaerophiles require low levels of oxygen. Capnophiles grow best with high carbon dioxide levels in addition to low oxygen levels.

Oxygen Requirements (Cont.)

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Obligate
aerobe

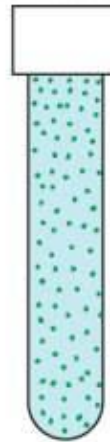
Enzyme content

+ SOD
+ Catalase



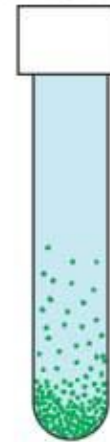
Facultative
anaerobe

+ SOD
+ Catalase



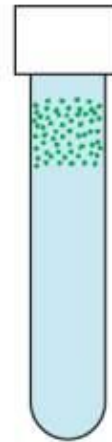
Aerotolerant
anaerobe

+ SOD
- Catalase



Strict
anaerobe

- SOD
- Catalase



Microaerophile

+ SOD
+/- Catalase
(low levels)

Oxygen Requirements (Cont.)

Table 6.4 Oxygen relationships of microorganisms

Group	Relationship to O ₂	Type of metabolism	Example ^a	Habitat ^b
Aerobes				
Obligate	Required	Aerobic respiration	<i>Micrococcus luteus</i> (B)	Skin, dust
Facultative	Not required, but growth better with O ₂	Aerobic respiration, anaerobic respiration, fermentation	<i>Escherichia coli</i> (B)	Mammalian large intestine
Microaerophilic	Required but at levels lower than atmospheric	Aerobic respiration	<i>Spirillum volutans</i> (B)	Lake water
Anaerobes				
Aerotolerant	Not required, and growth no better when O ₂ present	Fermentation	<i>Streptococcus pyogenes</i> (B)	Upper respiratory tract
Obligate	Harmful or lethal	Fermentation or anaerobic respiration	<i>Methanobacterium formicicum</i> (A)	Sewage sludge digestors, anoxic lake sediments

^a Letters in parentheses indicate phylogenetic status (B, *Bacteria*; A, *Archaea*). Representatives of either domain of prokaryotes are known in each category. Most eukaryotes are obligate aerobes, but facultative aerobes (for example, yeast) and obligate anaerobes (for example, certain protozoa and fungi) are known.

^b Listed are typical habitats of the example organism.

Nitrogen Requirements

- Nitrogen is a growth-limiting nutrient for many microorganisms, which acquire it from organic and inorganic nutrients. Though nitrogen constitutes about 79% of the atmosphere, relatively few organisms can utilize nitrogen gas. A few bacteria reduce nitrogen gas to ammonia via a process called nitrogen fixation, which is essential to life on Earth.

Other Chemical Requirements

- In addition to the main elements found in microbes, very small amounts of **trace elements** such as selenium, zinc, etc., are required.
- Most microorganisms also require small amounts of certain organic chemicals that they cannot synthesize. These are called **growth factors**. For example, vitamins are growth factors for some microorganisms.
- Iron plays a major role in cellular respiration, being a key component of cytochromes and iron-sulfur proteins involved in electron transport. Iron-binding agents that cells produce to obtain iron from various insoluble minerals are known as **siderophores**. For example ferric enterobactin, aquachelin.

Physical Requirements

- In addition to chemical nutrients, organisms have physical requirements for growth, including specific conditions of temperature, pH, osmolarity, and pressure.

Temperature

- Since both proteins and lipids are temperature-sensitive, different temperatures have different effects on the survival and growth rates of microbes. Though microbes survive within the limits imposed by a minimum growth temperature and a maximum growth temperature, an organism's metabolic activities produce the highest growth rate at the optimum growth temperature.
- **Minimum Temperature:** Temperature below which growth ceases, or lowest temperature at which microbes will grow.
- **Optimum Temperature:** Temperature at which its growth rate is the fastest.
- **Maximum Temperature:** Temperature above which growth ceases, or highest temperature at which microbes will grow.

Temperature (Cont.)

- Microbes are described in terms of their temperature requirements as (from coldest to warmest):
 - Psychrophiles require temperatures below 20°C. (eg. *Bacillus psychrophilus*, *Micrococcus cryophilus*)
 - Mesophiles grow best at temperatures ranging between about 20°C and 40°C. (eg. *Escherichia coli*, *Neisseria gonorrhoeae*)
 - Thermophiles require temperatures above 45°C. (eg. *Thermoplasma acidophilum*, *Bacillus stearothermophilus*)
 - Hyperthermophiles require temperatures above 80°C. (eg. *Pyrococcus abyssi*, *Pyrolobus fumarii*)

Temperature (Cont.)

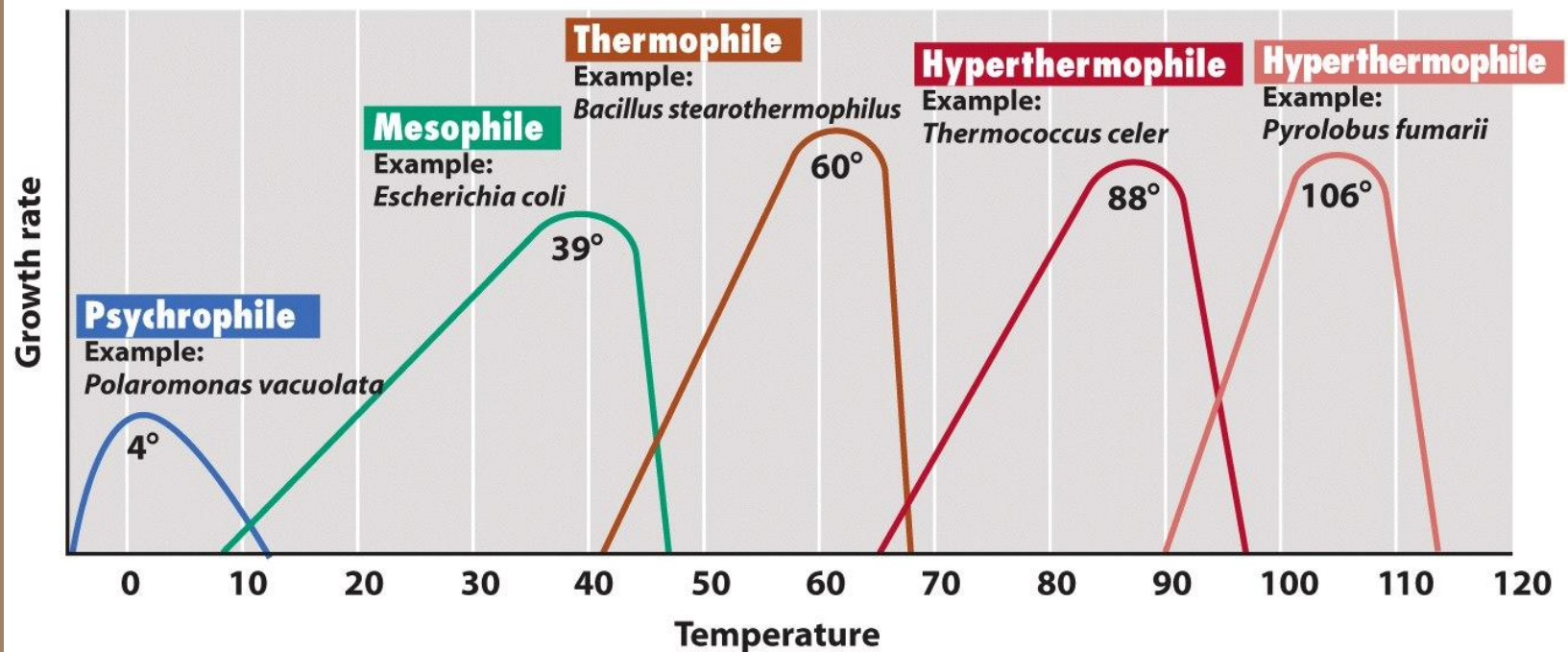


Figure 6-17 Brock Biology of Microorganisms 11/e
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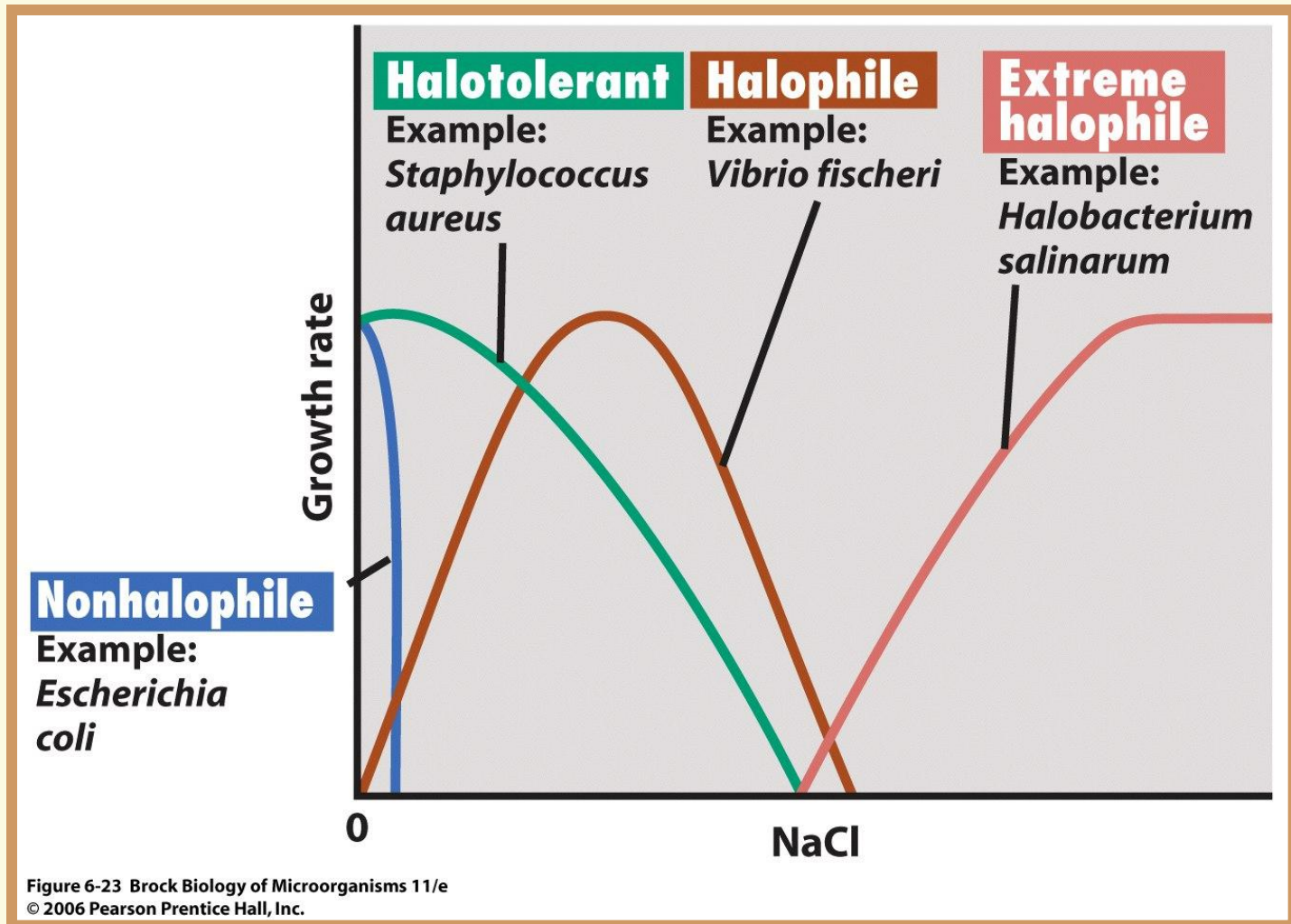
pH

- Organisms are sensitive to changes in acidity because hydrogen ions and hydroxyl ions interfere with hydrogen bonding within the molecules of proteins and nucleic acids; as a result, organisms have ranges of acidity that they prefer and can tolerate.
 - Most bacteria and protozoa are called neutrophiles because they grow best in a narrow range around a neutral pH, between 6.5 and 7.5.
 - By contrast, other bacteria and many fungi are acidophiles, and grow best in acidic environments where pH can range as low as 0.0. (*Helicobacter pylori*, *Thiobacillus thiooxidans*)
 - In contrast, alkaliphiles live in alkaline soils and water up to pH 11.5. (*Vibrio cholera*)

Physical Effects of Water

- Microorganisms require water to dissolve enzymes and nutrients and to act as a reactant in many metabolic reactions. Osmotic pressure restricts cells to certain environments. Whereas the cell walls of some microbes protect them from osmotic shock, osmosis can cause other cells to die from either swelling and bursting, or shriveling (crenation).
 - Obligate halophiles require high osmotic pressure such as exists in salt water. (**extreme halophiles e.g. *Halobacterium*, *Dunaliella***)
 - Facultative halophiles do not require but can tolerate salty conditions. (**eg. *Pseudomonas*, *Vibrio***)
- Water exerts pressure in proportion to its depth, and the pressure in deep ocean basins and trenches is tremendous.
 - Organisms that live under extreme pressure are called barophiles. Their membranes and enzymes depend on pressure to maintain their three-dimensional functional shapes, and typically they cannot survive at sea level.

Physical Effects of Water (Cont.)



Ecological Associations

- Relationships in which one organism harms or even kills another are considered antagonistic. In synergistic relationships, members of an association cooperate such that each receives benefits that exceed those that would result if each lived separately. In symbiotic relationships, organisms live in close nutritional or physical contact, becoming interdependent.
- Biofilms are an example of complex relationships among numerous individuals, which are often different species, that together attach to surfaces and display metabolic and structural traits different from those expressed by any of the microorganisms alone. They often form as a result of quorum sensing, a process in which bacteria respond to the density of nearby bacteria by utilizing signal and receptor molecules.

Culture Media

- **Culture media** supply the nutritional needs of microorganisms (C, N, Phosphorus, trace elements, etc)
- **According to physical state,**
 - **Liquid Media** : also known as Broth eg. Nutrient Broth, Methylene Blue Milk, Thioglycollate Broth)
 - **Semisolid** (Less % of Agar, the solidifying agent eg. Sulfide Indole Motility or SIM medium)
 - **Solid** (Eg. Slant, Stab)
- **According to composition,**
 - **Defined medium** : precise amounts of highly purified chemicals, **synthetic medium** (AGS Medium)
 - **Complex medium** : highly nutritious substances, **undefined medium** (NA medium)

Culture Media (Cont.)

□ In clinical microbiology,

- Selective
- Differential
- Enrichment

□ Selective Medium

Contains compounds that selectively inhibit the growth of a certain microbe and thereby encourages, or **selects**, a specific microbe.

Eg. Mannitol Salt Agar [MSA] encourages the growth of *S. aureus*. MSA contains 7.5% NaCl which inhibits the growth of other Gram +ve bacteria



Growth of *Staphylococcus aureus* on MSA results in a color change in the media from pink to yellow.

Culture Media (Cont.)

□ Differential medium

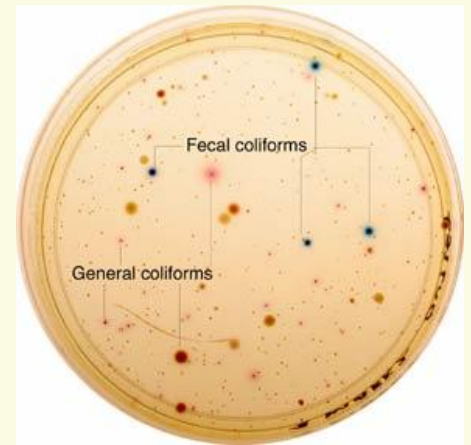
Differential shows up as **visible changes** or variations in colony size or color, in media color changes, or in the formation of gas bubbles and precipitates.

Eg. Spirit Blue Agar (SBA), EMB, MacConkey Agar etc.

□ Enrichment medium

Is used to encourage the growth of a particular microorganism in a mixed culture.

Ex. Manitol Salt Agar for *S. aureus*, Blood agar, chocolate agar, Slenite F broth



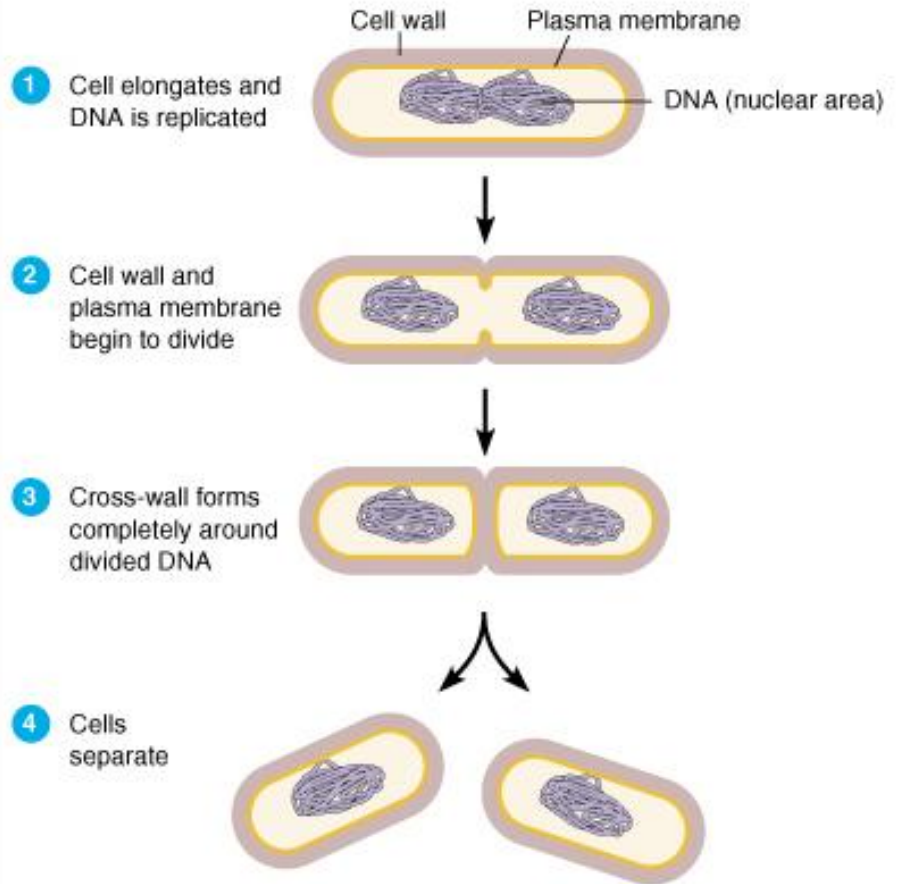
SBA to detect the digestion of fats by lipase enzyme. Positive digestion (hydrolysis) is indicated by the dark blue color that develops in the colonies.



Microbial Growth

Microbial Growth

- Microbiologists use the term growth to indicate an increase in a population of microbes rather than an increase in size.
- Most unicellular microorganisms reproduce by binary fission, a process in which a cell grows to twice its normal size and then divides in half to produce two equally sized daughter cells.



(a)

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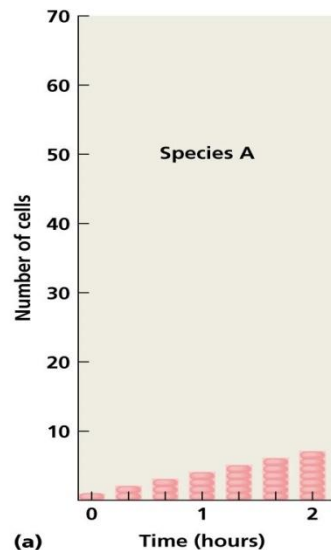
Mathematical Considerations in Population Growth

- With binary fission, any given cell divides to form two cells; then each of these new cells divides in two, to make four, and then four becomes eight, and so on. This type of growth, called logarithmic growth or exponential growth, produces dramatically greater yields than simple addition, known as arithmetic growth. Microbiologists use scientific notation to deal with the huge numbers involved in expressing microbial population size.

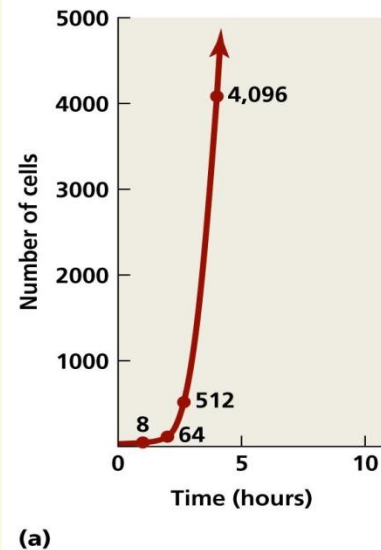
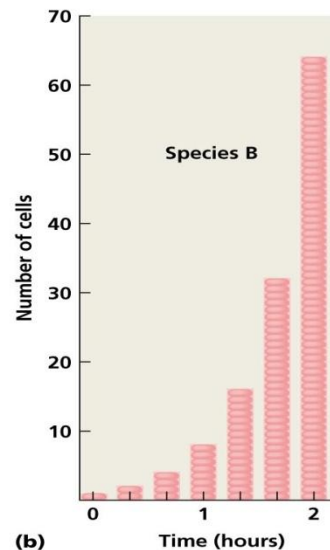
Arithmetic Numbers of Cells	Numbers Expressed as a Power of 2	Visual Representation of Numbers
1	2^0	●
2	2^1	● ●
4	2^2	● ● ● ●
8	2^3	● ● ● ● ● ● ● ●
16	2^4	● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●
32	2^5	● ●

Generation Time

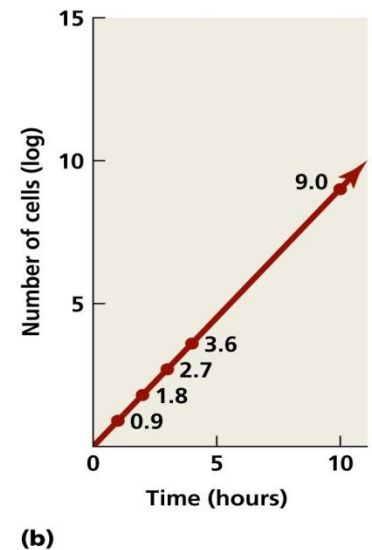
- The time required for a bacterial cell to grow and divide is its generation time. Viewed another way, generation time is the time required for a population of cells to double in number. Most bacteria have a generation time of 1-3 hours.



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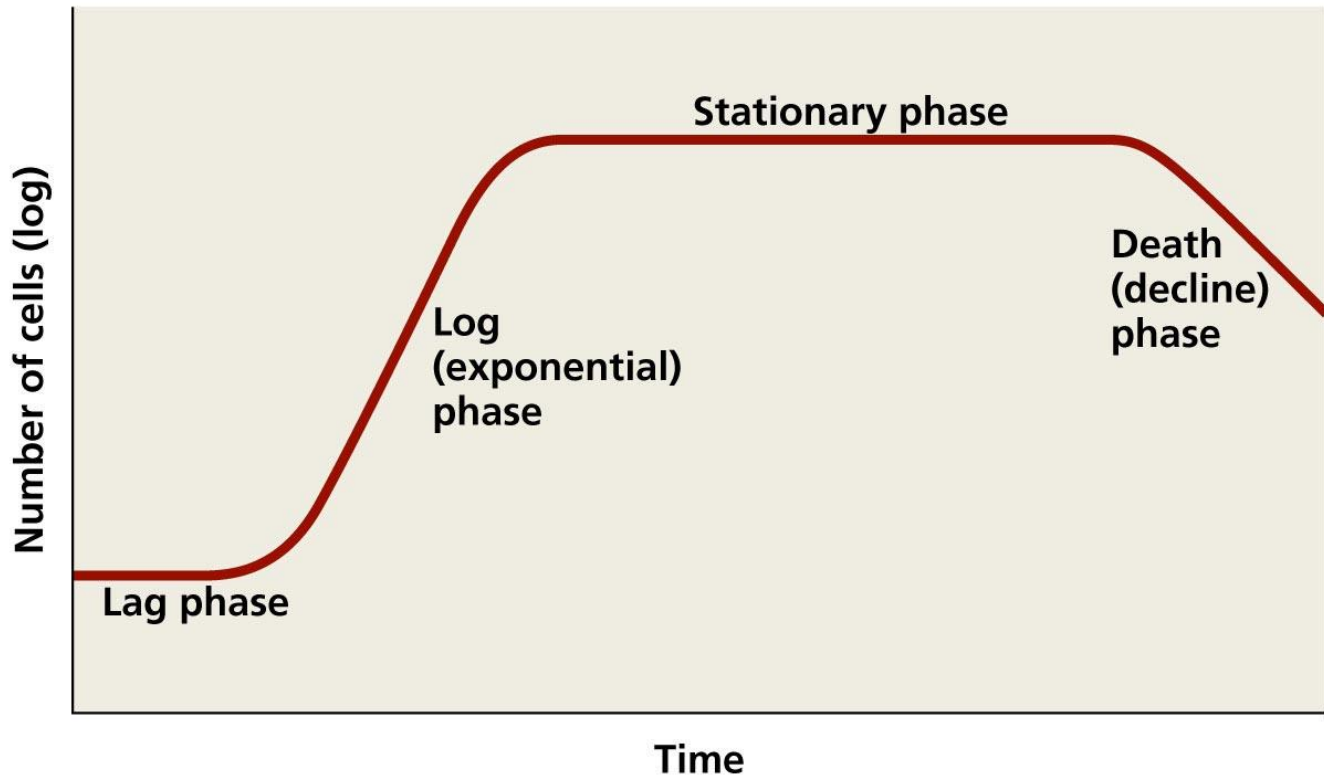
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Phases of Microbial Growth

- A graph that plots the number of bacteria growing in a population over time is called a growth curve. When microbial growth is plotted on a semilogarithmic scale (which uses a logarithmic scale for the y-axis), the plot of the population's growth results in a straight line. When bacteria are grown in a broth, the typical microbial growth curve has four distinct phases:
 - During lag phase, cells are recovering from a period of no growth and are making macromolecules in preparation for growth
 - During log phase cultures are growing maximally
 - Stationary phase occurs when nutrients are depleted and wastes accumulate (Growth rate = death rate)
 - During death phase death rate is greater than growth rate

Phases of Microbial Growth (Cont.)



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Measuring Microbial Growth

- Because of each cell's small size and incredible rate of reproduction, it is not possible to count everyone in a population. Thus, microbiologists estimate population size by counting the number in a small, representative sample, and then multiplying. Microbiologists use either direct or indirect methods to estimate the number of cells. Among the many direct methods are the following:
 - In viable plate counts, microbiologists base an estimate of the size of a microbial population upon the number of colonies formed when diluted samples are plated onto agar media.
 - In membrane filtration, a large sample is poured through a filter small enough to trap cells.
 - In microscopic counts, a sample is placed on a cell counter, a glass slide with an etched grid, and viewed through a microscope. A microbiologist can count the number of bacteria in several of the large squares and then calculate the mean number of bacteria per square.

Measuring Microbial Growth (Cont.)

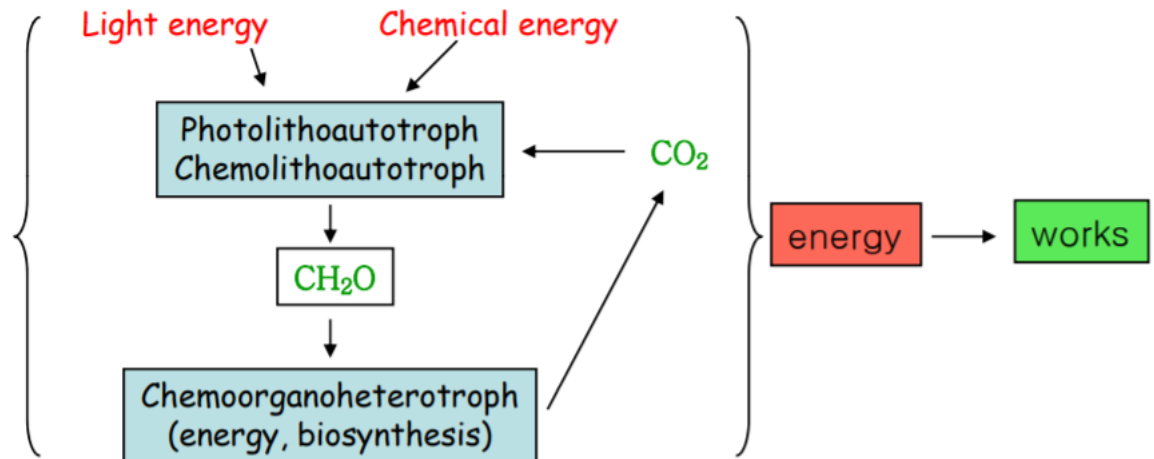
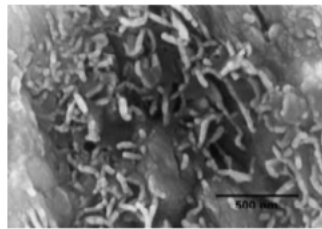
- Electronic counters are devices that count cells as they interrupt an electrical current flowing across a narrow tube held in front of an electronic detector. Flow cytometry is one variation.
 - The most-probable number (MPN) method is a statistical estimating technique based on the fact that the more bacteria in a sample, the more dilutions are required to reduce their number to zero.
- Among the indirect methods are measurements of metabolic activity, measurements of a population's dry weight, and measurement of the turbidity of a broth, especially by a device known as a spectrophotometer.

Microbial Metabolism

Microbial Metabolism

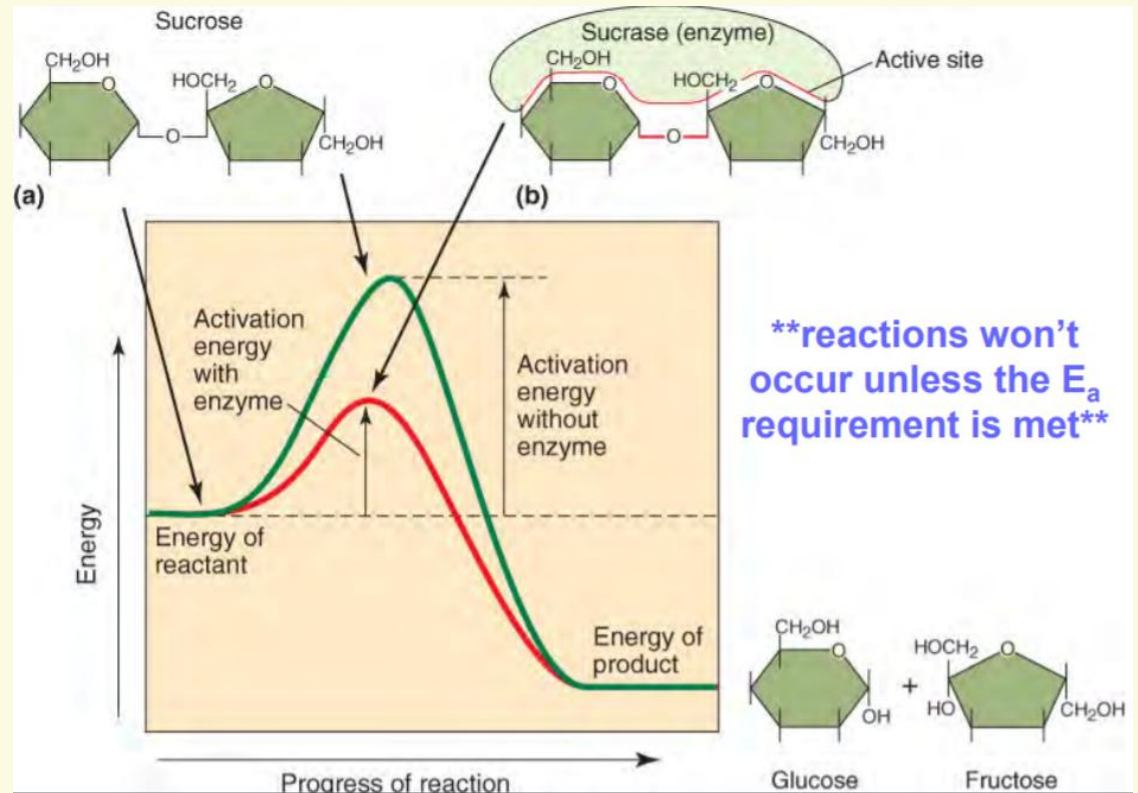
- Metabolism : “metaballein” = change
- Microbial metabolism : all chemical changes occurring in a microbe during its growth and development for healthy and stable maintenance and development for healthy and stable maintenance
- Required for activities such as movement, growth, synthesis, foodstuff, reproduction
 - highly organized and responsive to cellular control in its local environment
 - reactions of metabolism are used efficiently, economically
 - reactions won't occur unless the enzyme that catalyzes the reaction is present & active

Microbial Metabolism (Cont.)



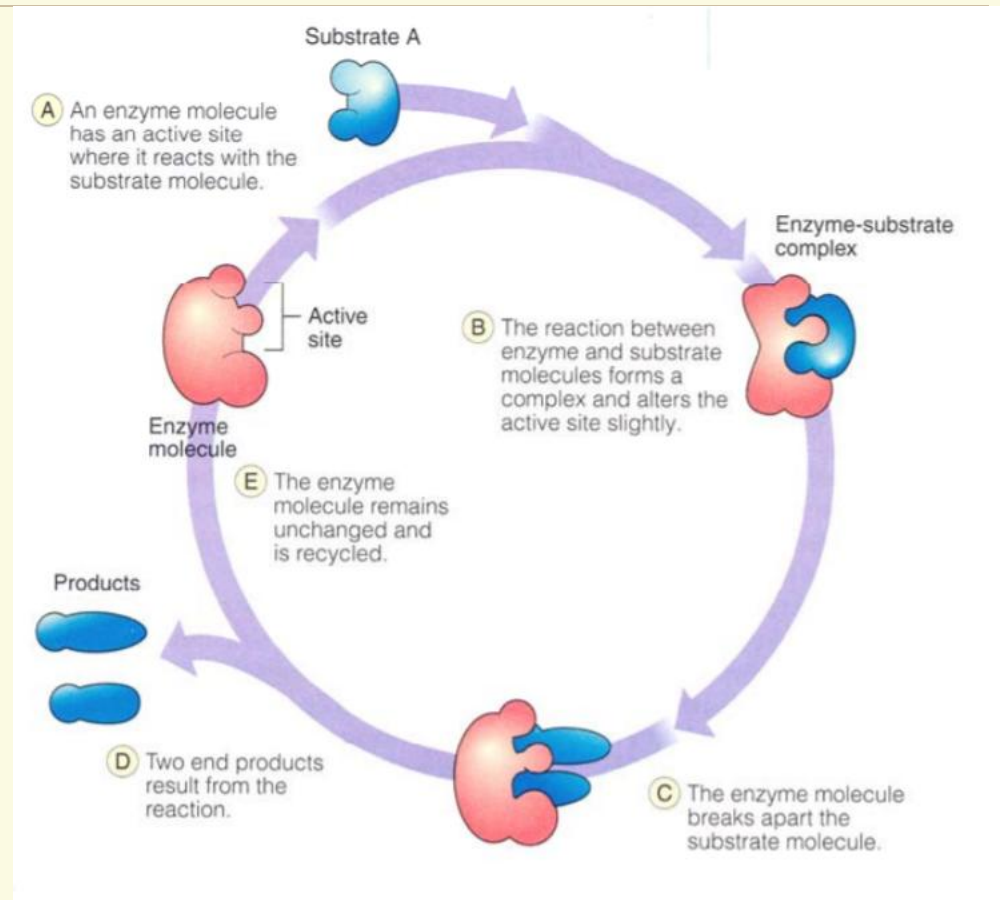
Enzyme

- Proteins that accelerate the rate of a reaction without being changed themselves
- Lower the activation energy (E_a)



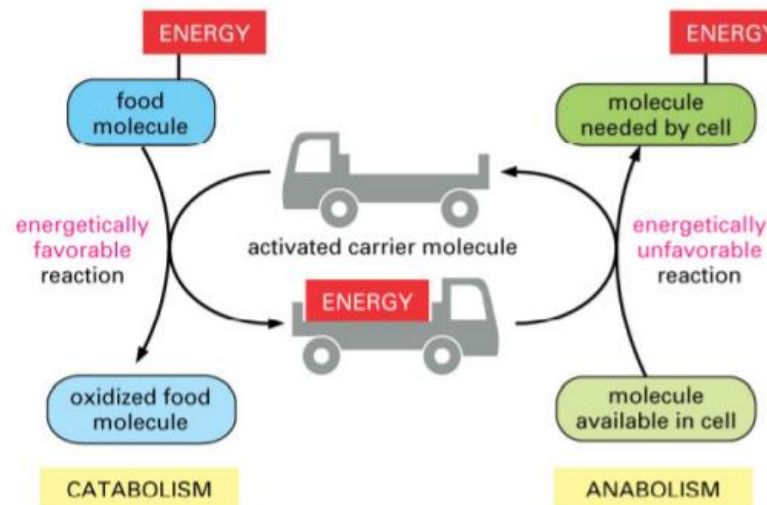
Enzyme reaction

- Enzyme provide a site for substrate binding → active site
- Enzyme-substrate complex is formed at transition state
- End products is released



Energy: ATP Production

- Major goal of metabolism :
 - supply energy-storing substances and release when needed
(**photosynthesis**) vs (**respiration**)
- ATP : energy carrier molecule → adenosine triphosphate
→ universal energy currency

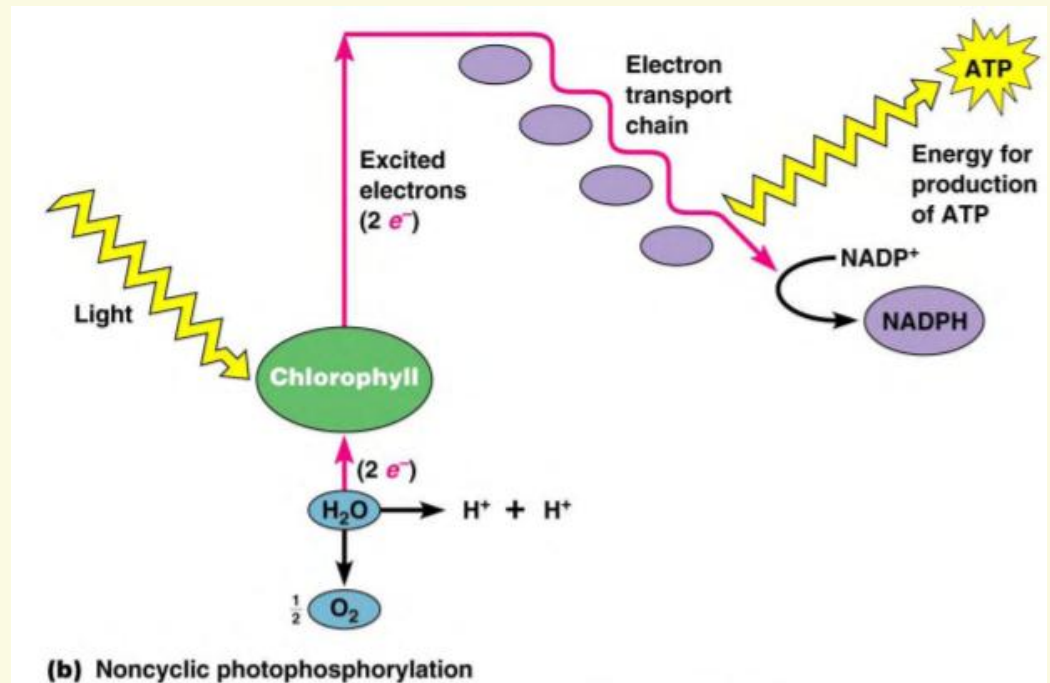


Photosynthesis

- Autotrophs can produce organic molecules from CO_2 , an inorganic carbon source.
- All heterotrophs require an organic source of carbon
- Organic molecules, directly or indirectly, come from autotrophs The source of energy for autotrophic processes can be:
 - LIGHT: photoautotrophs that carry out photosynthesis
 - CHEMICAL: chemoautotrophs that use various molecules as a source of high energy e^-

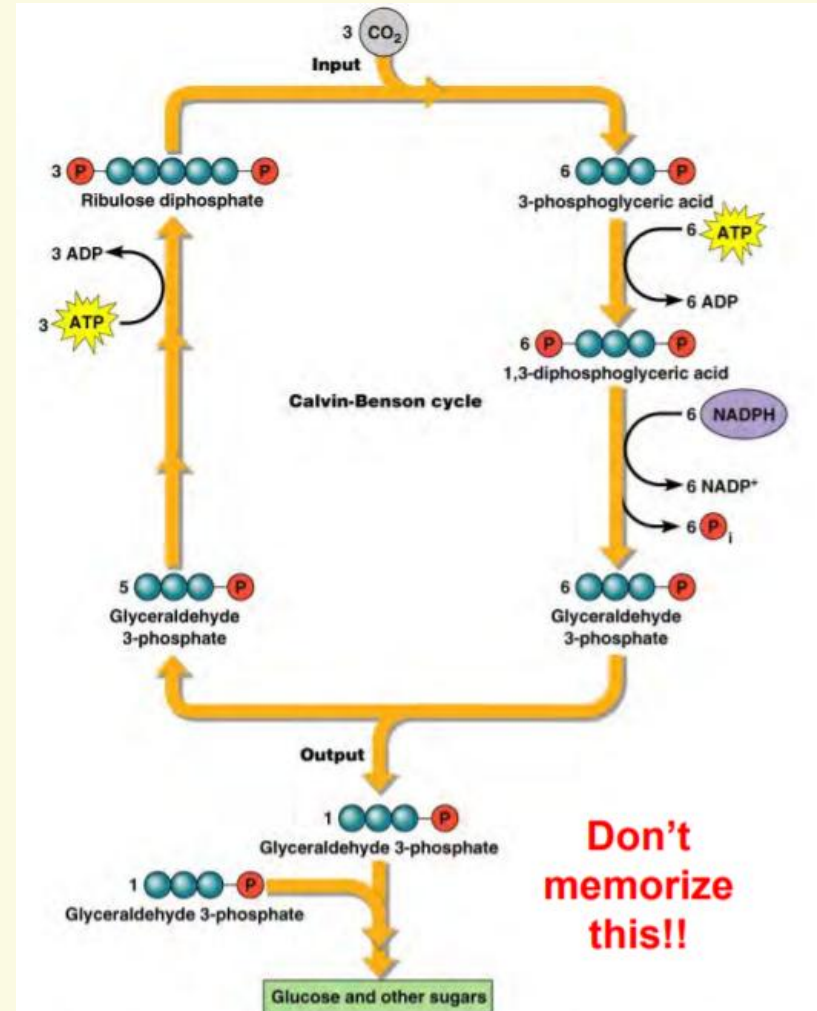
Light Reactions

- Electrons (from H_2O) energized by sunlight:
- Fuel the synthesis of ATP through electron transport & chemiosmosis (much like respiration)
- Ultimately reduce NADP^+ to NADPH
- ATP & NADPH provide energy to fuel production of sugars in the “dark” reactions



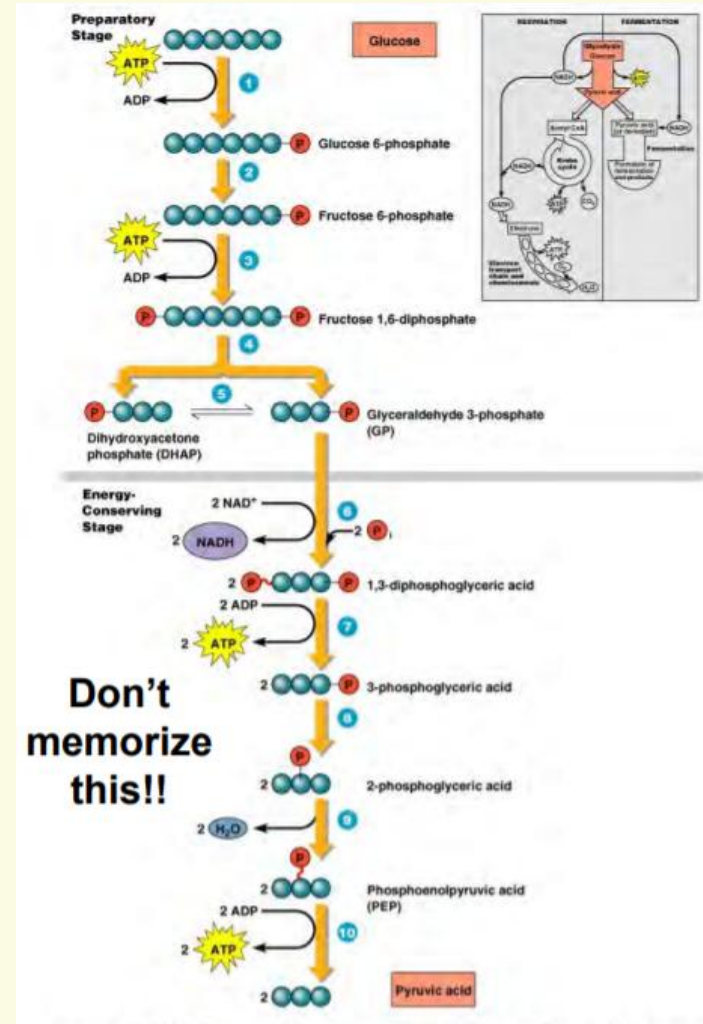
“Dark” Reactions

- Involves an anabolic pathway known as the Calvin-Benson cycle:
 - endergonic reactions of this pathway are fueled by ATP & NADPH from the “light” reactions
 - resulting sugars can be used as a source of energy or to build other organic molecules



Glycolysis

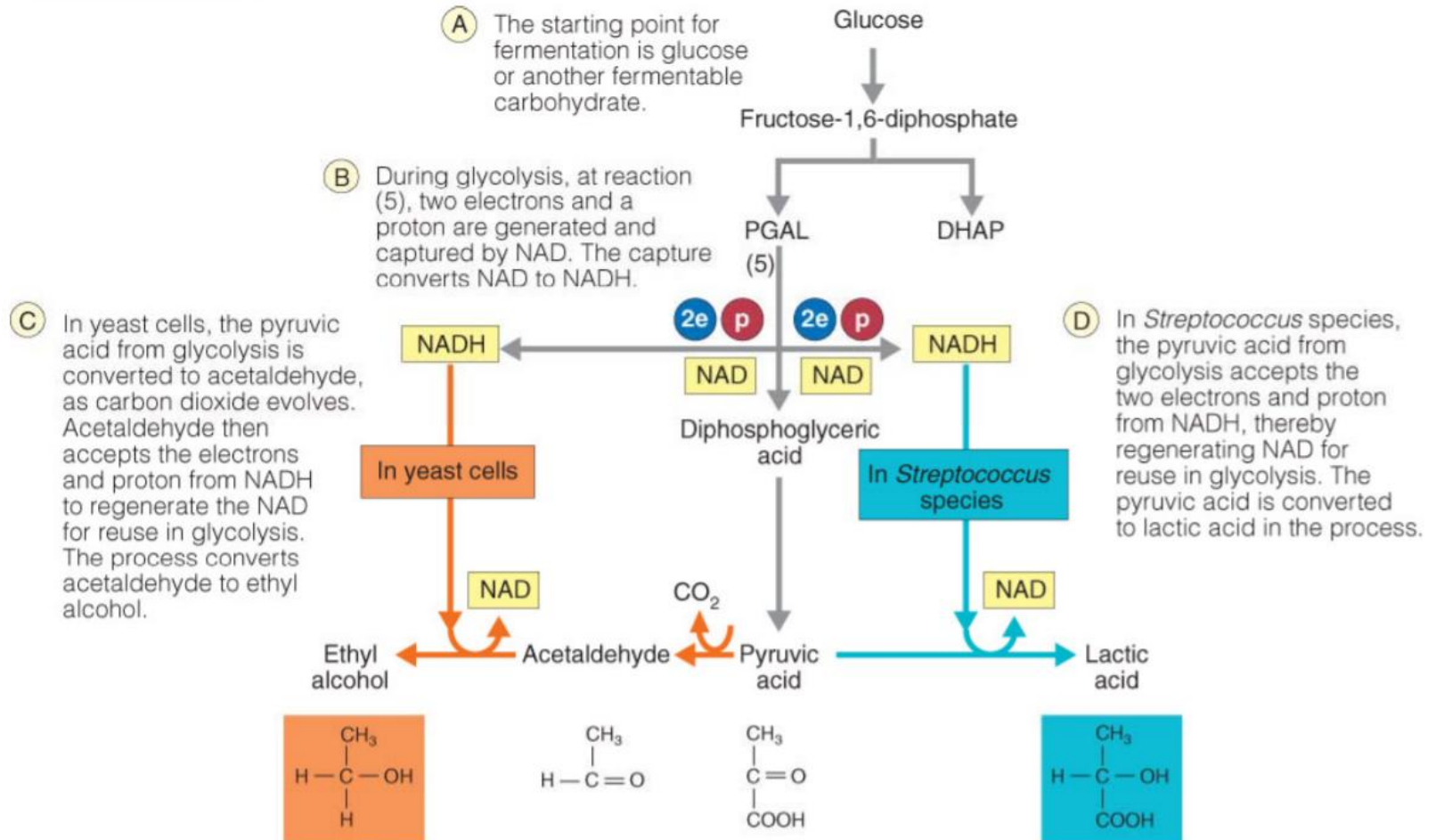
- Primary central pathway for all living organisms
- Starts from six starts from six-carbon organic molecule glucose
- Produce three-carbon molecule, pyruvate, as end product
- Pyruvate is utilized for three different destination
- Take place in the cytoplasm of microbes t
- Not require oxygen
- Catalyzed by enzymes
- 2 molecules of ATP are invested and 4 ATP are produced



Fermentation

- Side step of glycolysis
- Takes place in the absence of oxygen
- Pyruvate is transformed into other organic products → alcohol, acid, CO₂
- Different organisms recycle NAD⁺ in different ways, resulting in a variety of fermentation end-products.
 - Yeast : wine
 - Lactobacillus : yogurt

Fermentation (Cont.)



Fermentation (Cont.)

TABLE 5.4

Some Industrial Uses for Different Types Of Fermentations

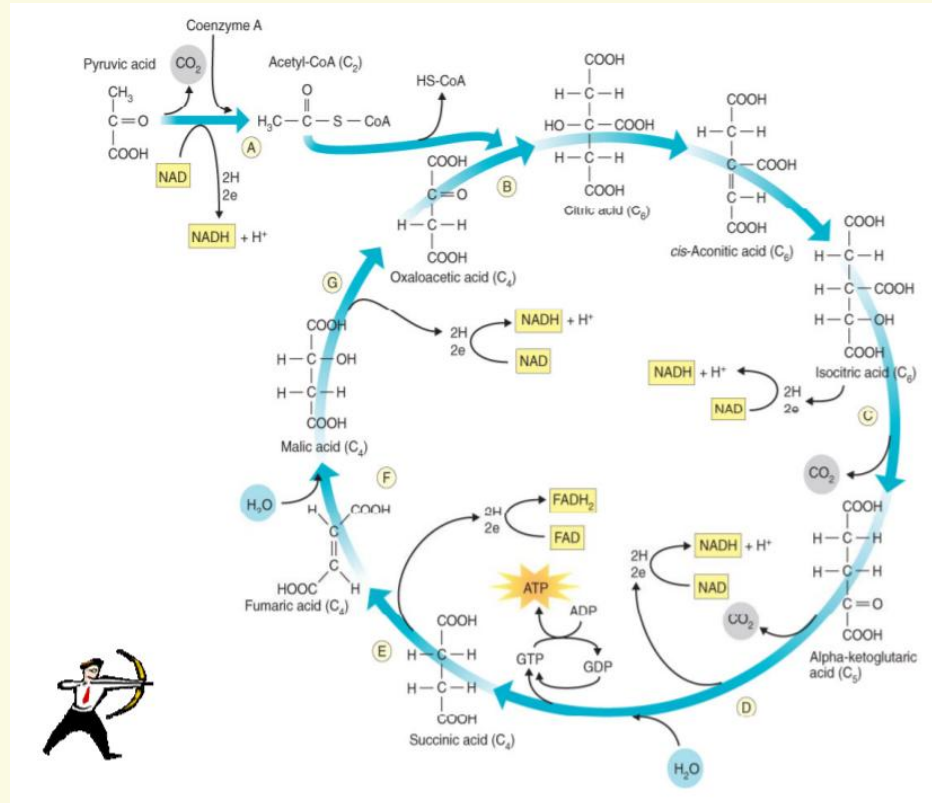
* Fermentation End-Product(s)	Industrial or Commercial Use	Starting Material	Microorganism
Ethanol	Beer	Malt extract	<i>Saccharomyces cerevisiae</i> (yeast, a fungus)
	Wine	Grape or other fruit juices	<i>Saccharomyces cerevisiae</i> var. <i>ellipsoideus</i>
	Fuel	Agricultural wastes	<i>Saccharomyces cerevisiae</i>
Acetic Acid	Vinegar	Ethanol	<i>Acetobacter</i> (bacterium)
Lactic Acid	Cheese, yogurt	Milk	<i>Lactobacillus</i> , <i>Streptococcus</i> (bacteria)
	Rye bread	Grain, sugar	<i>Lactobacillus delbruckii</i> (bacterium)
	Sauerkraut	Cabbage	<i>Lactobacillus plantarum</i> (bacterium)
	Summer sausage	Meat	<i>Pediococcus</i> (bacterium)
Propionic Acid and Carbon Dioxide	Swiss cheese	Lactic acid	<i>Propionibacterium freudenreichii</i> (bacterium)
Acetone and Butanol	Pharmaceutical, industrial uses	Molasses	<i>Clostridium acetobutylicum</i> (bacterium)
Glycerol	Pharmaceutical, industrial uses	Molasses	<i>Saccharomyces cerevisiae</i>
Citric Acid	Flavoring	Molasses	<i>Aspergillus</i> (fungus)
Methane	Fuel	Acetic acid	<i>Methanosarcina</i> (bacterium)
Sorbose	Vitamin C (ascorbic acid)	Sorbitol	<i>Gluconobacter</i>

Aerobic respiration

- After glycolysis, energy in pyruvate & NADH is used to produce much more ATP by respiration:
- KREBS CYCLE
 - Breaks down pyruvate to 3CO_2 ,
 - energy captured as e^- by NADH & FADH_2
- ELECTRON TRANSPORT
 - e^- from NADH, FADH_2 used to produce H^+ gradient
- CHEMIOSMOSIS
 - H^+ gradient used to make ATP

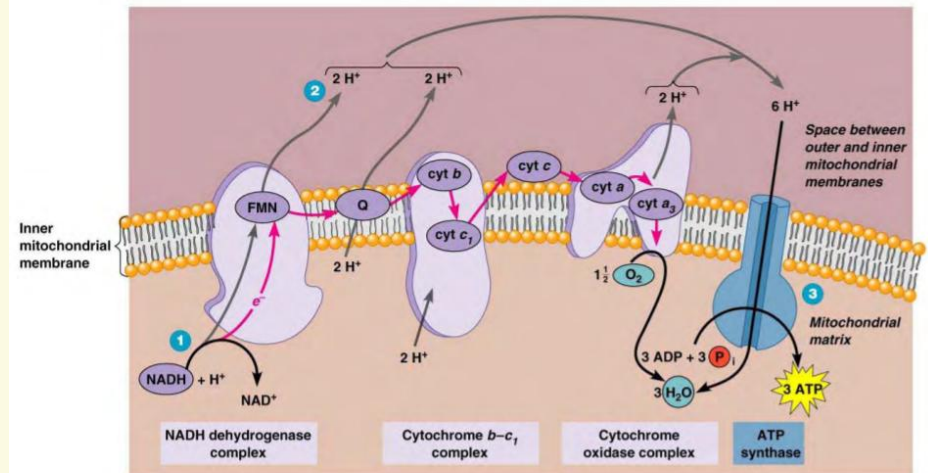
The Krebs cycle

- One cycle : one acetyl-coA $\rightarrow$ two CO_2
- Citric acid cycle, TCA (tricarboxylic acid) cycle
- Produce NADH , FADH_2
produce NADH , FADH_2 ,
 ATP
- Intermediate products $\rightarrow$ precursor of biosynthesis



Electron transport and Chemiosmosis

- Take place in mitochondria or cell membrane
- Series of losses & gains of electron between electron carrier molecules
- Beginning with NADH and FADH_2
- Final electron acceptor : $\text{O}_2 \rightarrow$ produce H_2O
- Released energy is used to make proton gradient cross the membrane
- Proton gradient is utilized to synthesis ATP



Occurs in the mitochondria of eukaryotes and at the plasma membrane of prokaryotes.

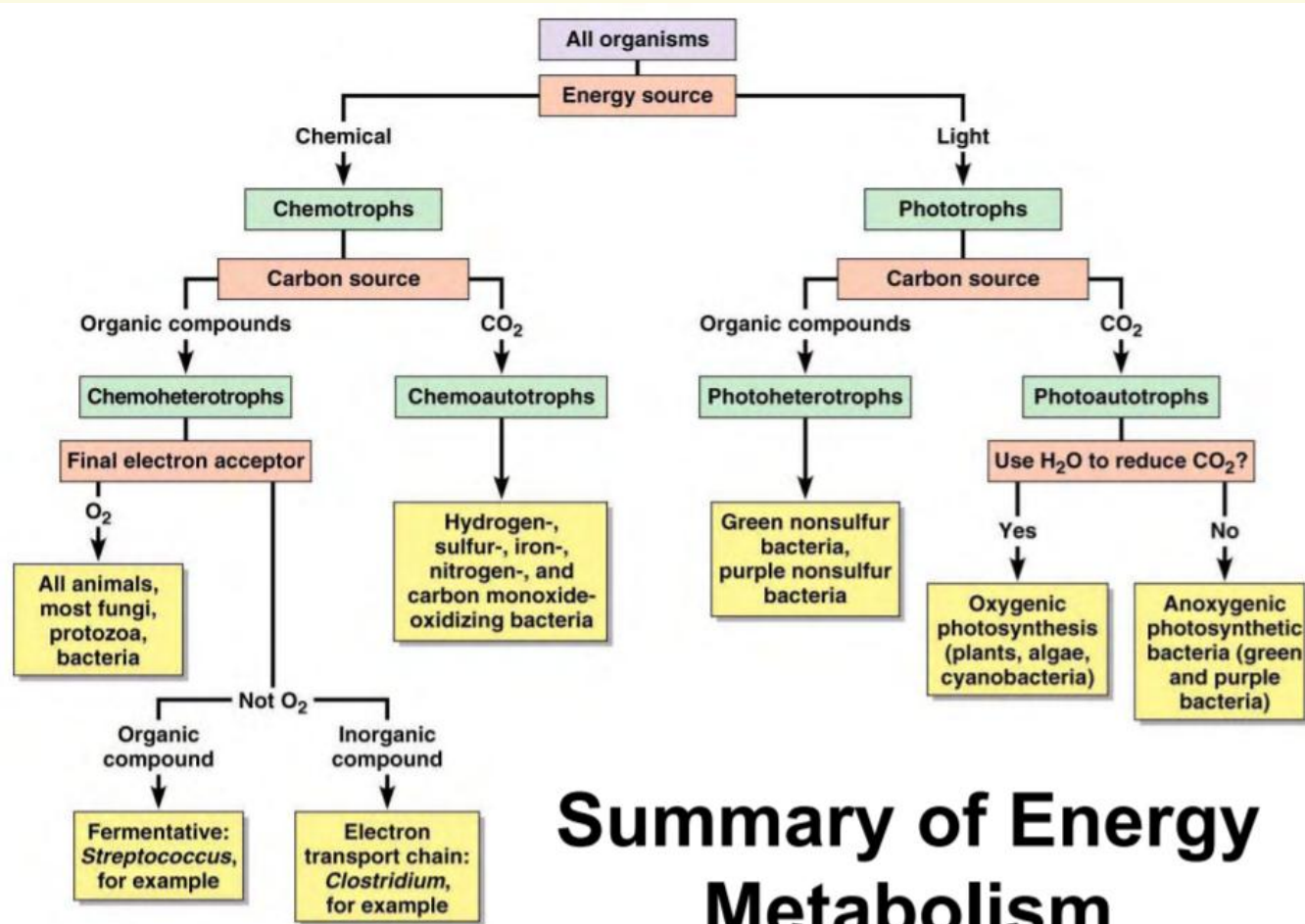
Comparison of Respiration Processes

TABLE 5.5

Aerobic Respiration, Anaerobic Respiration, and Fermentation Compared

Energy-Producing Process	Growth Conditions	Final Hydrogen (Electron) Acceptor	Type of Phosphorylation Used to Generate ATP	ATP Molecules Produced per Glucose Molecule
Aerobic Respiration	Aerobic	Molecular oxygen (O_2)	Substrate-level and oxidative	36 (eukaryotes) 38 (prokaryotes)
Anaerobic Respiration	Anaerobic	Usually an inorganic substance (such as NO_3^- , SO_4^{2-} , or CO_3^{2-}) but not molecular oxygen (O_2)	Substrate-level and oxidative	Variable (fewer than 38 but more than 2)
Fermentation	Aerobic or anaerobic	An organic molecule	Substrate-level	2

Summary of Energy Metabolism



Summary of Energy Metabolism

Photosynthetic & Heterotrophic Microorganisms

Microorganism	Mitochondrion
Nonphotosynthetic Procaryotes	
<i>Bacillus psychrophilus</i>	
<i>Micrococcus cryophilus</i>	
<i>Pseudomonas fluorescens</i>	
<i>Staphylococcus aureus</i>	
<i>Enterococcus faecalis</i>	
<i>Escherichia coli</i>	
<i>Neisseria gonorrhoeae</i>	
<i>Thermoplasma acidophilum</i>	
<i>Bacillus stearothermophilus</i>	
<i>Thermus aquaticus</i>	
<i>Sulfolobus acidocaldarius</i>	
<i>Pyrococcus abyssi</i>	
<i>Pyrodictium occultum</i>	
<i>Pyrolobus fumarii</i>	
Photosynthetic Bacteria	
<i>Rhodospirillum rubrum</i>	
<i>Anabaena variabilis</i>	
<i>Oscillatoria tenuis</i>	
<i>Synechococcus eximius</i>	

Economic Importance of Viruses

Economic Importance of Viruses

- The viruses have both Useful roles and Harmful roles

Useful roles of Viruses

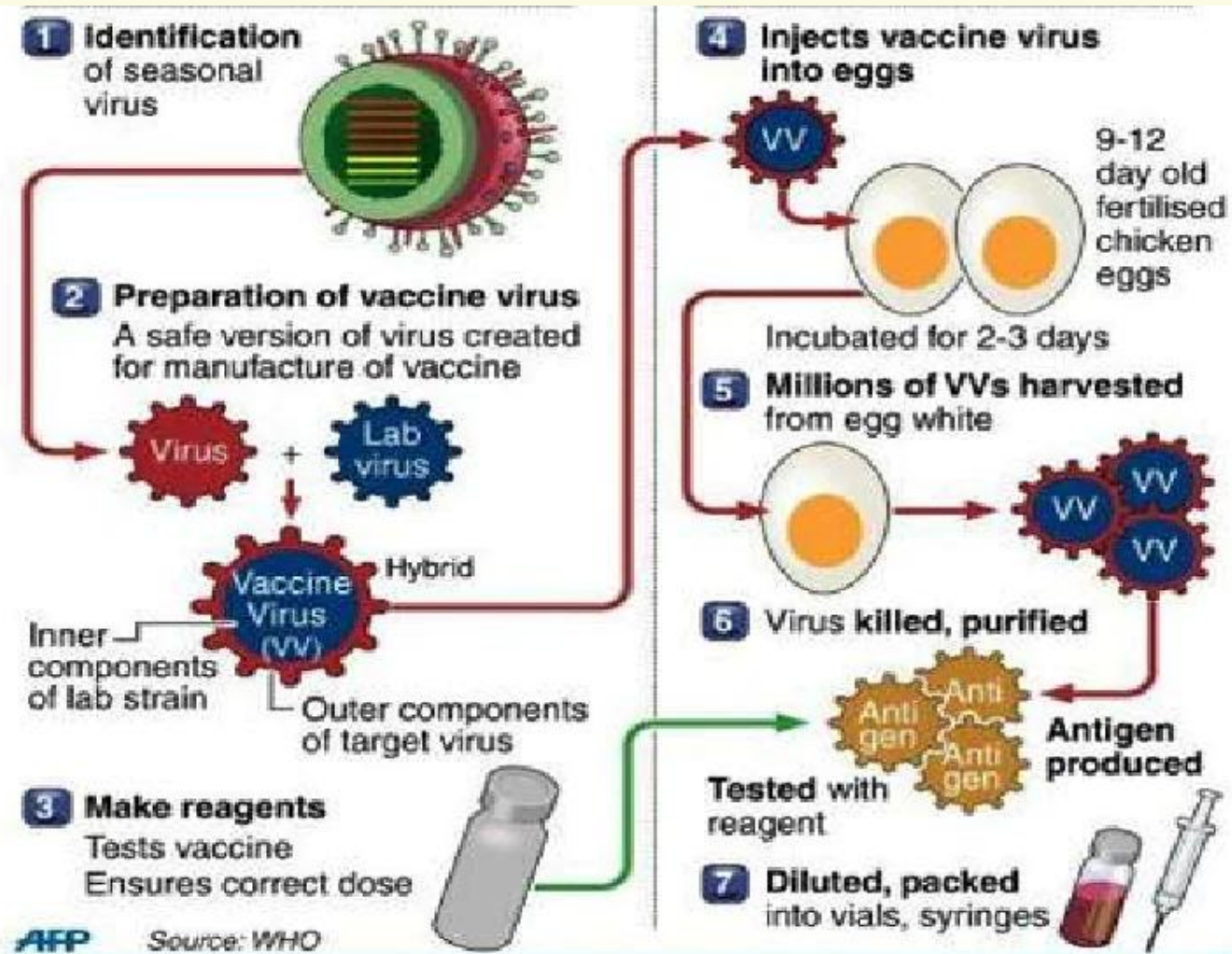
- ❑ **In preparing antidotes/vaccine:** Pox, mumps, polio, jaundice etc diseases can be controlled by penetrating using or dead virus in the human body as vaccines.
- ❑ **In controlling harmful animals and insects:** Some animals and insects which are harmful to humans can be controlled by some special virus. Eg. Baculoviruses are used to control insect pests.
- ❑ **Control of disease:** T2 bacteriophage virus saves humans from dysentery by spoiling some harmful bacteria, like, e-coli. In Virotherapy, viruses use as vectors to treat several diseases, as they can explicitly target cells and DNA. It intimates hopeful use in the treatment of cancer and in gene therapy.
- ❑ **In the laboratory:** Virus is used in the lab, as the simplest model of infection and molecular vector. It is an important subject in genetic engineering.

Viruses in Vaccine

Preparation of Vaccines

- a. **Live attenuated** organisms which have been passed repeatedly in tissue culture or chick embryos so that they have lost their capacity to cause disease, but retained an ability to induce antibody response, such as polio (Sabin), measles, rubella, mumps, yellow fever, BCG, typhoid and plague.
- b. **Inactivated or killed** organisms which have been killed by heat or chemicals but retain an ability to induce antibody response. They are generally safe but less efficacious than live vaccines and require multiple doses; e.g. polio (Salk), influenza, rabies and Japanese encephalitis.

Viruses in Vaccine (Cont.)



Viruses in Medicine

- ❑ Viruses are being used as vectors or carriers that take the required material for treatment of a disease to various target cells. They have been studied extensively in management of inherited diseases and genetic engineering as well as cancers.
- ❑ **Viruses in bacteriophage therapy:** These are highly specific viruses that can target, infect, and (if correctly selected) destroy pathogenic bacteria. Bacteriophages are believed to be the most numerous type of viruses accounting for the majority of the viruses present on Earth. These are basic tools in molecular biology. They have been researched for their use in therapy.
- ❑ **Viruses in nanotechnology:** Nanotechnology deals with microscopic particles. These have various uses in biology and medicine and nanotechnology has been used in genetic engineering. Viruses can be used as carriers for genetically modified sequences of genomes to the host cells.

Viruses in Medicine (Cont.)

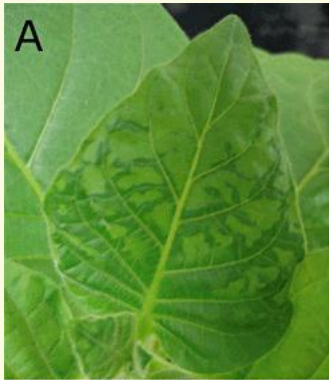
- **Viruses in cancer prevention and control:** Similar modifications (as plants and animals in agriculture) of humans have not been attempted for technical and ethical reasons. But the modification of genes of cells of individuals has been under investigation for many years. This is known as gene therapy.
- **Virus-directed enzyme prodrug therapy (VDEPT):** This is a therapy when the target cells are inserted with an enzyme that can activate an inactive precursor or inactive form of a cytotoxic drug that is administered systemically. Thus, the active, cytotoxic form of the drug is only produced where the relevant enzyme is present and active.
 - Eg., an adenovirus expressing the thymidine kinase (TK) enzyme of herpes simplex virus can be combined with systemic administration of ganciclovir, which is converted by the TK to its active form only in cells where this enzyme is present. This is used in HIV treatment.

Harmful roles of Viruses

- ❑ Different diseases like common Cold, Influenza, Mumps, Pox, Polio, Yellow fever, Harpish, Aids etc. are caused by the attack of the virus.
- ❑ Human viruses, especially those that caused to deaths, can have larger negative economic effects. For example, Africa's Ebola virus occurred in economic losses of over \$1.6 billion.
- ❑ The virus destroys plenty of bacteria which useful for humans.
- ❑ Viruses can cause a destructive influence on human societies. They can be weaponized for biological warfare.

Top 10 plant viruses

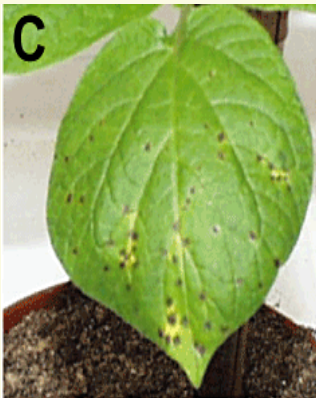
Rank	Virus	Author of virus description
1	<i>Tobacco mosaic virus</i> (TMV)	Karen-Beth G. Scholthof
2	<i>Tomato spotted wilt virus</i> (TSWV)	Scott Adkins
3	<i>Tomato yellow leaf curl virus</i> (TYLCV)	Henryk Czosnek
4	<i>Cucumber mosaic virus</i> (CMV)	Peter Palukaitis
5	<i>Potato virus Y</i> (PVY)	Emmanuel Jacquot
6	<i>Cauliflower mosaic virus</i> (CaMV)	Thomas Hohn and Barbara Hohn
7	<i>African cassava mosaic virus</i> (ACMV)	Keith Saunders
8	<i>Plum pox virus</i> (PPV)	Thierry Candresse
9	<i>Brome mosaic virus</i> (BMV)	Paul Ahlquist
10	<i>Potato virus X</i> (PVX)	Cynthia Hemenway



TMV



TSWV



PVY



PPV

Economic Importance of Bacteria

- The bacteria have both Useful roles and Harmful roles

Roles of Bacteria in Agriculture

Table 1.7: Economic importance of Bacteria

Beneficial aspects	Bacteria	Role
1. Soil fertility		
Ammonification	1. <i>Bacillus ramosus</i> 2. <i>Bacillus mycoides</i>	Convert complex proteins in the dead bodies of plants and animals into ammonia which is later converted into ammonium salt
Nitrification	1. <i>Nitrobacter</i> 2. <i>Nitrosomonas</i>	Convert ammonium salts into nitrites and nitrates
Nitrogen fixation	1. <i>Azotobacter</i> 2. <i>Clostridium</i> 3. <i>Rhizobium</i>	(i) Converting atmospheric nitrogen into organic nitrogen (ii) The nitrogenous compounds are also oxidized to nitrogen (iii) All these activities of bacteria increase soil fertility

Roles of Bacteria in Antibiotic Production

2. Antibiotics

1. Streptomycin	<i>Streptomyces griseus</i>	It cures urinary infections, tuberculosis, meningitis and pneumonia
2. Aureomycin	<i>Streptomyces aureofaciens</i>	It is used as a medicine to treat whooping cough and eye infections
3. Chloromycetin	<i>Streptomyces venezuelae</i>	It cure typhoid fever
4. Bacitracin	<i>Bacillus licheniformis</i>	It is used to treat syphilis
5. Polymyxin	<i>Bacillus polymyxa</i>	It cure some bacterial diseases

Roles of Bacteria in Industry

3. Industrial Uses		
1. Lactic acid	<i>Streptococcus lactis</i> and <i>Lactobacillus bulgaricus</i>	Convert milk sugar lactose into lactic acid
2. Butter	<i>Streptococcus lactis</i> , <i>Leuconostoc citrovorum</i>	Convert milk into butter, cheese, curd and yoghurt
3. cheese	<i>Lactobacillus acidophobus</i> , <i>Lactobacillus lactis</i>	
4. Curd	<i>Lactobacillus lactis</i>	
5. Yoghurt	<i>Lactobacillus bulgaricus</i>	
6. Vinegar (Acetic acid)	<i>Acetobacter aceti</i>	This bacteria oxidizes ethyl alcohol obtained from molasses by fermentation to vinegar(acetic acid)

(Continued)

Roles of Bacteria in Industry (Cont.)

7. Alcohol and Acetone (i) Butyl alcohol (ii) Methyl alcohol	<i>Clostridium acetobutylicum</i>	Alcohols and acetones are prepared from molasses by fermentation activity of the anaerobic bacterium.
8. Retting of fibres	<i>Clostridium tertium</i>	The fibres from the fibre yielding plants are separated by the action of <i>Clostridium</i> is called retting of fibres.
9. Vitamins	<i>Escherichia coli</i>	Living in the intestine of human beings produce large quantities of vitamin K and vitamin B complex.
	<i>Clostridium acetobutylicum</i>	Vitamins B ₂ is prepared by the fermentation of sugar.
10. Curing of Tea and Tobacco	<i>Mycococcus candisans</i> , <i>Bacillus megatherium</i>	The special flavor and aroma of the tea and tobacco are due to fermentation.

Harmful Roles of Bacteria

- ❑ **1. Food poisoning:** Bacterial toxins present in food causes food poisoning. This leads into nausea, vomiting, abdominal discomfort diarrhea and even death. The food poisoning bacteria are *Clostridium botulinum*, *Salmonella enteritis*, *Staphylococcus aureus* etc.
- ❑ **2. Spoilage of food:** Souring of milk, rotting of vegetables and meat are caused by many saprotrophic bacteria.
- ❑ **3. Destruction of domestic articles:** *Spirochaete cytophaga* cause cellulose degradation thereby destroying textiles, wooden articles and canvas.
- ❑ **4. Reduction of Soil fertility:** Denitrifying bacteria like *Thiobacillus denitrificans*, *Micrococcus denitrificans*, *Pseudomonas aeruginosa* convert soil nitrates and ammonia into free nitrogen and thus reduce the soil fertility.

Harmful Roles of Bacteria (Cont.)

- ❑ **5. Human Pathogen:** While only about 5% of bacterial species are pathogenic, bacteria have historically been the cause of a disproportionate amount of human disease and death. Eg. *Vibrio cholerae*
- ❑ **6. Plant Pathogen:** Most plant pathogenic bacteria belong to the following genera: *Erwinia*, *Pectobacterium*, *Pantoea*, *Agrobacterium*, *Pseudomonas*, *Ralstonia*, *Burkholderia*, *Acidovorax*, *Xanthomonas*, *Clavibacter*, *Streptomyces*, *Xylella*, *Spiroplasma*, and *Phytoplasma*.
- ❑ **7. Animal Pathogen:** About 60% of the bacteria commonly causes infectious diseases. Moreover, *Pasteurella multocida*, which causes pasteurellasis, a kind of zoonosis, was isolated from dogs and cats; *Aeromonas hydrophila* is a common fish pathogen etc.
- ❑ **8. Biowar/Bioterrorism:** An attack with bioweapons (antibiotic resistant strains mould) leads to spread of communicable diseases like anthrax and plague etc. Eg. *Bacillus anthracis*.

