IB Biology/Option F - Microbes and Biotechnology

Option F: Microbes and Biotechnology

Diversity of Microbes

F.1.1 Outline the classification of living organisms into three domains.

- Three domains of living organisms

1. Archaea - very primitive; live in extreme habitats
2. Eubacteria - more advanced
3. Eukaryota - all life forms with eukaryotic cells (have a nucleus)

- Use of ribosomal RNA sequences for classification
  - rRNA is found in all cells
  - rRNA is easy to isolate
  - analyzed to determine the exact sequence of nucleotide bases
  - The bases are a complementary copy of DNA
  - Can be compared by the use of computers and statistics

F.1.2 Explain the reasons for the reclassification of living organisms into three domains

- There were found to be several differences between the domains now known as Archaea and Eubacteria.
  - The major reason was due to differences in the genes that transcribe rRNA.
  - Other reasons (see F.1.3) include cell wall differences, lipid bonding and rRNA sequences.

F.1.3 Distinguish between the characteristics of the three domains.

Domain	Histones	Introns	Ribosome Size	Cell Wall made of peptidoglycan	Cell Membrane
Archaea	Proteins similar to histones	No	70S	Not present	Ether-linked glycerides, chirality of glyceral, saturated, branched, L-form of glycerol
Eubacteria	No	No	70S	Present	Ester-linked glycerides, unbranched, saturated or monounsaturated, D-form of glycerol
Eukaryota	Yes	Yes (most)	80S	Cell wall not always present; not made of peptidoglycan	Ester-linked glycerides, unbranched polyunstaturated, fluid, embeded with proteins and glycoproteins, D-form of glycerol

F.1.4 Outline the wide diversity of habitat in the Archaea as exemplified by methanogens, thermophiles and halophiles.

- Methanogens
  - Obligate anerobes (must be without oxygen)
  - Produce methane as waste product
  - Found in the guts of cows, termite guts, waste landfills and marshes
- Thermophiles
  - Live at temperatures close to boiling
  - Tend to be extreme thermophiles (60°C to 100°C)
  - Found in deep sea vents and hot springs
- Halophiles

- Live in saline habitats with high salt concentrations
- Tend to be extreme halophiles (very high concentrations)
- Found in the Great Salt Lake, The Dead Sea, and on Saltines

F.1.5 Outline the diversity of Eubacteria, including shape and cell wall structure

- Shapes of Eubacteria
  - Coccus - round, spherical
  - Bacillus - rod-shaped
  - Spirilla - spiral
  - Vibrio - comma-shaped
- Cell Wall Structure
  - Gram Negative
    - 2 cell membranes, one single thin peptidoglycan, lipopoysaccharides outside of wall
  - Gram Positive
    - 1 cell membrane, several layers peptidoglycan

F.1.6 State, with one example, that some bacteria form aggregates that show characteristics not seen in individual bacteria

Some bacteria form aggregates that show characteristics not seen in individual bacteria

Vibrio fischeri

- Single individuals do not emit light unless they become part of a population with a high density
- *V. fischeri* releases a regulatory substance into its surroundings
- In dense populations, the concentration of the substance becomes high enough to trigger bioluminescence
- Happens when *V. fischeri*are living in mucus matrix in a squid

Another example is *Streptococcus mutans* which forms biofilms on teeth, commonly known as plaque.

F.1.7 Compare the structure of the cell walls of Gram-positive and Gram-negative Eubacteria.

- Gram-positive
  - Simple, one-cell membrane
  - Several layer of peptidoglycan
  - No outer membrane
- Gram-negative
  - Complex cell wall
  - Small amount of peptidoglycan
  - Thin peptidoglycan layer
  - Inner and outer membrane with peptidoglycan in between

F.1.8 Outline the diversity of structure in viruses including: naked capsid versus enveloped capsid; DNA versus RNA; and single stranded versus double stranded DNA or RNA.

- Capsid Proteins
  - Naked Capsid - no membrane/envelope outside protein coat
  - Enveloped Capsid - cell membrane from host surrounds protein coat
- Genetic material
  - DNA (double or single stranded) or RNA (double or single stranded)

Outline the diversity of microscopic eukaryotes, as illustrated by *Saccharomyces, Amoeba, Plasmodium, Paramecium, Euglena* and *Chlorella*

Organism	Nutrition	Locomotion	Cell Wall	Chloroplasts	Cilia or Flagella
Saccharomyces	heterotroph (extracellular digestion)	absent	made of chitin	absent	absent
Amoeba	heterotroph (intracellular digestion)	slides using pseudopodia (amoeboid movements)	absent	absent	absent
Plasmodium	heterotroph (intracellular digestion)	glides on substrate	absent	absent	absent
Paramecium	heterotroph (intracellular digestion)	swimming (cilia)	absent	absent	cilia
Euglena	autotroph and heterotroph	swimming (flagella)	absent	present	flagellae
Chlorella	autotroph	none	made of cellulose	present	absent

Microbes and the Environment

F.2.1 List the roles of microbes in ecosystems, including producers, nitrogen fixers and decomposers.

- Producers
  - Microscopic algae and some bacteria use chlorophyll to trap sunlight
  - Chemosynthetic bacteria use chemical energy
  - Change inorganic molecules into organic molecules that can be used by other organisms for food
- Nitrogen fixers
  - Bacteria which remove nitrogen as from the atmosphere and fix it into nitrates which are usable by producers.
- Decomposers
  - Breakdown detritus (organic molecules) and release inorganic nutrients back into the ecosystem

F.2.2 Draw and label a diagram of the nitrogen cycle

F.2.3 State the roles of *Rhizobium, Azotobacter, Nitrosomonas, Nitrobacter* and *Pseudomonas denitrificans* in the nitrogen cycle.

- Nitrogen Fixation
  - Mutalistic: *Rhizobium* lives in symbiosis with legumes (its root nodules) and fixes nitrogen for them
  - Free-living: *Azotobacter* fixes nitrogen and lives freely in the soil without a host
- Nitrification
  - *Nitrosomonas* converts ammonia (NH_3) into nitrite (NO_2-)
  - *Nitrobacter* changes nitrite into nitrate (NO_3-) which is usable by plants
- Denitrification
  - Conversion of nitrates to nitrogen gas
  - *Pseudomonas denitrificans* removes nitrates and nitrites and puts nitrogen gas back in atmosphere

F.2.4 Outline the conditions that favour denitrification and nitrification.

- Conditions favouring nitrification
  - available oxygen/aerated soils
  - neutral pH
  - warm temperature

- Conditions favouring denitrification
  - No available oxygen/anaerobic soils (flooding or compacted soil)
  - High nitrogen input

F.2.5 Explain the consequences of releasing raw sewage and nitrate fertilizer into rivers

- Raw Sewage
  - Raw sewage consists of organic matter and may contain pathogens, which are dangerous if drunk/bathed in => amount of saprotrophs increase to break down organic matter => a biochemical oxygen demand (BOD) occurs due to high levels of oxygen used =>deoxygenation of water => oxygen-dependent organisms are forced to emigrate/die => death and decay => decomposition => ammonia, phosphorus and minerals released => nitrification => eutrophication occurs due to high nutrient levels => algae proliferate => provided no algal bloom occurs, the rivers recovers eventually
- Nitrate Fertilizer
  - Rivers leech off nitrate from soil => if application of nitrate fertilizer is great enough, eutrophication occurs => algae proliferate (increasing oxygen levels) => if nitrate levels in excess, algal bloom occurs => due to large amount of algae, some are deprived of sunlight and die => saprotrophs are needed to break down the organic matter => this creates a biochemical oxygen demand (BOD) => deoxygenation occurs => oxygen-dependent organisms are forced to emigrate/die=> increase in ammonia and phosphorus levels => nitrification => eutrophication => algae proliferate => provided no new algal bloon occurs, river recovers eventually.
- Simpler Module:
  - High and excess nitrates and phosphates fertilize the algae in water
  - Increased growth of algae (algal bloom)
- Algae decomposed by aerobic bacteria which use up oxygen in water, resulting in deoxygenation
- The high use of oxygen is called biochemical oxygen demand (BOD)

F.2.6 Outline the role of saprotrophic bacteria in the treatment of sewage using trickling filter beds and reed bed systems.

- Trickling Filter System
  - Bed of stones 1-2 meters wide
  - A biofilm of aerobic saprotrophs are on the rocks, which feed on organic mater, cling to the stones and act on the sewage trickled over (this is done to aerate the sewage), until it is broken down.
  - Cleaner water trickles out the bottom of the bed to another tank where the bacteria are removed and the water treated with chlorine to disinfect it
- Reed Bed System
  - Artificial wetland used to treat waste water
  - Waste water provides both the water and nutrients to the growing reeds
  - The reeds are harvested for compost and the organic waste is broken down by saprotrophic bacteria
  - Nitrification of ammonia to nitrite and nitrite to nitrate
  - Nitrates and phosphates released are used as fertilizer by the reeds
  - Remaining nitrates are denitrified

F.2.7 State that biomass can be used as raw material for the production of fuels such as methane and ethanol.

- Biomass (organic matter) can be used as raw material for the production of fuels such as methane and ethanol. Examples include manure and cellulose.

F.2.8 Explain the principles involved in the generation of methane from biomass, including the conditions needed, organisms involved and the basic chemical reactions that occur.

- One group of Eubacteria are needed to convert the organic mater into organic acids and alcohol
- A second group of Eubacteria convert these into acetate, carbon dioxide and hydrogen
- Methanogenic bacteria are needed to create the methane, by two chemical reactions:
  - carbon dioxide + hydrogen -> methane + water
  - acetate -> methane + carbon dioxide (breakdown of acetate)
- Conditions required:
  - No free oxygen (anaerobic)
  - Constant temperature of about 35°C
  - pH not too acidic

Microbes and biotechnology

F.3.1 State that reverse transcriptase catalyzes the production of DNA from RNA.

- Reverse transcriptase catalyzes the production of DNA from RNA and is used by retroviruses.

F.3.2 Explain how reverse transcriptase is used in molecular biology.

- RNA and reverse transcriptase enter the host cell, injected by the virus
- Reverse transcriptase makes a DNA copy of itself
- DNA of virus injects into nucleus and integrates into the DNA of the host cell
- Can be used to remove introns from DNA
  - Conversion of mRNA (made from DNA and with introns removed) to cDNA after extracted

F.3.3. Distinguish between somatic and germ line therapy.

- Somatic: consists of replacing bodily cells.
  - Somatic gene therapy cures the disease in the individual; however, it can still be passed to offspring.
- Germ-line therapy: consists of treating the gametes
  - Germ-line therapy stops spread of genetic disease to offspring; however, individual remains afflicted.

F.3.4 Outline the use of viral vectors in gene therapy.

- Viral vectors take out harmful genes and put the normal genes in the cells
- Retroviral therapy has more permanent change and work better
- SCIDS
  - First successful example of gene therapy
    - Replaced gene allows for the production of ADA

F.3.5 Discuss the risks of gene therapy.

- Gene therapy is a very dangerous process; the viral vectors can trigger a cancer-causing gene.
- Genes can be over-expressed and make too much protein.
- Virus vector might place the new gene in the wrong location in the DNA molecule.
- Might stimulate an immune reaction.
- Virus vector might be transferred from person to person.
- Does not always work, therefore raising the hopes of patients/families and then drop their hopes.
- Potential Alternative: Adenoviruses do not incorporate themselves into the human genome

Microbes and Foods Production

F.4.1 Explain the use of *Saccharomyces* in the production of beer, wine and bread.

- Beer
  - Sweet liquid wort is made from malt
  - Hops are added and liquid is boiled and cooled
  - Wetted barley allowed to germinate: amlyase is formed.
  - Amylase catalyses starch into maltose.
  - Fermentation by yeast produces beer containing ethanol and CO_2
- Wine
  - Crushed grapes and yeast are put into a tank
  - Yeasts respirate aerobically until oxygen is depleted
  - The yeasts then switch to fermentation (anaerobic)
  - Ethanol stays in the tank, while CO_2 escapes
  - Process ends when ethanol concentration reaches ax. 15%, killing the yeast, or when substrates have been used up.
- Bread
  - Fermentation of sugars in the dough by yeast
  - CO^2 makes the dough rise
  - Baking in the oven kills the yeast, stops fermentation and evaporates the ethanol

F.4.2 Outline the production of soy sauce using *Aspergillus oryzae*.

- Soak soy beans, boil and drain
- Mix a mash of soy beans with toasted wheat
- Add a culture *Aspergillus oryzae*
- Incubate for 3 days at 30°C
- Add salt and water and fermentation of starch and proteins to alcohol, organic acids, sugars and amino acids occurs for 3-6 months.
- Filter and pasteurize; liquid produced is the soy sauce product.

F.4.3 Explain the use of acids and high salt or sugar concentrations in food preservation.

- Food preservation with acid:
  - Microbes cannot live in low pH levels
  - Common examples include vinegar and production of yoghurt.
- Food preservation with high sugar/salt concentrations:
  - high concentrations of either will kill any microbes in food samples, since the high concentration draws out water through osmosis.
  - Common examples include honey, jam, salted meat.

F.4.4 Outline the symptoms, method of transmissions and treatment of one named example of food poisoning.

- Transmission of *Salmonella* food poisoning
  - Lives in the intestinal tract and is transmitted after ineffective hand washing
  - Can be found in the feces of some pets and be transferred to food
  - Eating contaminated foods not properly cooked
  - Uncooked meat cut on a cutting board which if not washed can cause transfer of *Salmonella*
  - Raw eggs
- Treatment of *Salmonella* food poisoning

- Treat the dehydration by drinking lots of water
- Serious dehydration is treated with intravenous
- Antibiotics can be given if the infection is serious and has spread from intestine to the blood

Metabolism of Microbes (AHL)

F.5.1 Define the terms photoautotroph, photoheterotroph, chemoautotroph, and chemoheterotroph.

- Photoautotroph:
  - An organism that uses light energy to generate ATP and produce organic compounds from inorganic substances.
- Photoheterotroph:
  - An organism that uses light energy to generate ATP and obtains organic compounds from other organism.
- Chemoautotroph:
  - An organism that uses energy from chemical reactions to generate ATP and produce organic compounds from inorganic substances.
- Chemoheterotroph:
  - An organism that uses energy from chemical reactions to generate ATP and obtain organic compounds from other organisms.

F.5.2 State one example of a photoautotroph, photoheterotroph, chemoautotroph and chemoheterotroph.

- Photoautotroph - Cyanobacteria (e.g. *Anabaena*)
- Photoheterotroph - *Rhodospirillum*; *Rhodobacter*
- Chemoautotroph - *Nitrobacter*
- Chemoheterotroph - *Mycobacterium tuberculosis*; *Lactobacillus*

F.5.3 Compare photoautotrophs with photoheterophs in terms of energy sources and carbon sources.

- Both create ATP from light
- Photoautotrophs use CO_2 as their carbon source
- Photoheterotrophs use organic molecules as their carbon source

F.5.3 Compare chemoautotrophs with chemoheterotrophs in terms of energy sources and carbon sources.

- Chemoautotrophs get their energy from chemicals and carbon from inorganic compounds
- Chemoheterotrophs get their energy and carbon from organic compounds

F.5.4 Draw and label a diagram of a filamentous cyanobacterium.

- Using Anabaena as an example, there are two types of cells:
  - Photosynthetic cells contain genetic material, cell walls and photosynthetic membranes.
  - Heterocysts act as nitrogen-fixers; are much larger and fewer than the photosynthetic cells.

F.5.5 Explain the use of bacteria in the bioremediation of soil and water.

- Bioremediation
  - Use of microbes, fungi, plants or enzymes to remove environmental contaminants from water and soil.
  - The bacteria break down the chemicals or convert them so that they can be filtered out
  - Oil Spills:
    - Microbes oxidate hydrocarbons; takes a long time and some hydrocarbons are very difficult to oxidate.
  - Pesticide Pollution:
    - Microbes gradually break down pesticides
  - Selenium pollution:

        - Microbes absorb selenium ions and oxidate them into metallic selenium, which is far less toxic.
    - Solvent pollution:
        - Microbes dechlorinate these solvents in anaerobic conditions, releasing far less toxic substances.
- Examples
    - *Pseudomonas* using oil for energy
    - *Dehalococcoides ethenogenes* breaking down chlorinated solvents in soil

Microbes and Disease (AHL)

F.6.1 List six methods by which pathogens are transmitted and gain entry to the body.

1. Food - ingestion of food with bacteria can cause food poisoning
2. Water - polluted or unclean water can cause disease
3. Air/Droplets - water droplets in the area can carry organisms
4. Animal vectors - insects and other animals can carry disease
5. Puncture wounds/Cuts - break the skin barrier and allow entry of bacteria or viruses.
6. Sexual contact - with an infected person can transmitt disease

F.6.2 Distinguish between intracellular and extracellular bacterial infection using *Chlamydia* and *Streptococcus* as examples.

- Intracellular Bacterium - *Chlamydia*
    - Rely on host's metabolism for certain of metabolic processes.
    - Live within the epithelial cells of that line the genital tract
    - Does not produce toxins nor directly damage cells, but can cause long-term problems (such as pelvic inflammatory disease or infertility)
    - Is not targeted by the immune system due to its hidden nature
- Extracellular Bacterium - *Streptococcus*
    - Lives inside the host, but in the intercellular spaces and use the nutrients available there.
    - Produces toxins and damage cells.
    - *Streptococcus* produces toxins that kill host cells and molecules called invasins which split open and dissolve host cells
    - Is targeted immediately by the immune system and antibodies are made to fight the infection

F.6.3 Distinguish between endotoxins and exotoxins.

- Endotoxins
    - Lipopolysaccharides (heat-stable) in the walls of Gram-negative bacteria that cause fever and aches.
- Exotoxins
    - Specific proteins secreted by bacteria that cause symptoms such as muscle spasms (tetanus) and diarrhea.

F.6.4 Evaluate methods of controlling microbial growth by irradiation, pasteurization, antiseptics and disinfectants.

- Irradiation
    - Ionizing radiation
        - Some microbes are resistant (e.g. *Clostridium botulinum*)
        - Free radicals may alter the flavour
        - Some consumers are afraid to use products of 'radiation'
- Pasteurization
    - Application of high temperature, which is very quickly cooled down and repeated.

    - Very effective, can kill all pathogens if done at high enough temperatures at long enough periods
    - Usually, however, this is not done as it alters the flavour of e.g. milk
- Antiseptics
    - Kill/prevent microbial growth; prevent infection
    - Mild chemicals that are less effective than disinfectants but not damaging to skin and mucous membranes
    - Too toxic to be taken through consumption
- Disinfectants
    - Extremely effective sterilisation; does not kill endospores, however.
    - Cannot be used on living tissue, nor through consumption.
    - Useful for sterilisation of medical tools, floors, furniture, etc

F.6.5 Outline the mechanism of the action of antibiotics, including the inhibition of synthesis of cell walls, proteins and nucleic acids.

- Antibiotics - antimicrobial agents produced by microbes which inhibit or kill other microbes
- Cell wall synthesis inhibition (e.g. Penicillin)
    - Antibiotics inhibit the production of peptidoglycan for the cell walls of bacteria
    - Without cell walls, the new bacteria cannot survive
- Protein synthesis inhibition (e.g. Erythromycin, Streptomycin)
    - Block some stage of protein synthesis by attacking the bacterial ribosomes.
    - Does not attack the ribosomes of human cells because bacterial ribosomes (70S) differ from those of humans (80S)
    - Nucleic acid inhibition (e.g. Rifampin)
    - Affect the synthesis of DNA/RNA or attach to DNA/RNA so that they cannot be read
    - Interferes with the growth of bacterial cells

F.6.6 Outline the lytic life cycle of the influenza virus

1. Virus attaches to cell surface by means of specific receptors (e.g. glycoproteins)
2. Virus is taken up in membrane-enclosed endosome during endocytosis
3. Uncoating occurs in endosome and viral RNA (genome) is released into the cytoplasm
4. RNA of viral genome transported into the nucleus, where it is copied and replicated by the viral enzyme into RNA, acting as template for more RNA and a messenger
5. Some RNA transported into cytoplasm and translated into viral proteins which are transported back into the nucleus to assemble the capsid
6. Viral envelope proteins assemble in cell membrane and the capsid buds off of these points, using the cell membrane as its envelope
7. Lysis, or the bursting of the cell, occurs and releases new virus particles to attack other cells.

F.6.7 Define epidemiology.

- Epidemiology is the study of the occurrence, distribution and control of disease.

F.6.8 Discuss the origin and epidemiology of one example of a pandemic.

- Spanish Flu of 1918
    - Killed 40-50 million people
    - Origin believed to be in China
    - Travel of soldiers for WWI aided spread of flu
    - Hang washing encouraged, public gathering banned

F.6.9 Describe the cause, transmission and effects of malaria, as an example of disease caused by a protozoan.

- Cause

    - Four species of the genus *Plasmodium* (*falciparum, vivax, ovale, malariae*)
- Transmission
    - Transmitted from one person to the next by a female *Anopheles* mosquito which feeds on human blood (males only feed on plants)
    - Plasmodia reproduce in the gut of the female mosquito
    - Egg sac ruptures and releases cells called sporozoites which travel to the salivary glands
    - Sporozites enter bloodstream with mosquito bite and travel to the liver
    - Develop in liver cells, which change form, and then invade red blood cells
    - Another *Anopheles* female mosquito feeds on an infected individual, transferring *Plasmodium falciparum* into the gut of "Anopheles".
- Symptoms/Effects
    - Presents as symptoms of anemia, bouts of fever chills, shivering, joint pain, and headache.
    - Cycle begins again when new mosquito bites a person infected with malaria.

F.6.10 Discuss the prion hypothesis for the cause of spongiform encephalopathies.

- States that the causal agent for spongiform encephalopathies in humans has no nucleic acid and consists only of misfolded proteins (PrP^{SC}).
- The infecting agent is a prion and the abnormal protein alone causes the disease.
    - Scientists have not found any nucleic acids in prion particles.
- Abnormally shaped prions that can cause normal proteins (PrP^{C}) to change to an abnormal shape, resulting in cell death.
- Chronic, degenerative diseases of the nervous system that form holes in brain tissue (hence the name), causing symptoms such as memory loss, personality changes, speech lapses and ultimately death.
- Examples include scrapies in sheep, BSE in cattle and CJD in humans.

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