AQUATIC MICROBIOLOGY AQS205

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WEEK 1 INTRODUCTION

- A variety of microorganisms live in fresh water. The region of a water body near the shoreline that is termed the littoral zone is well lighted, shallow, and warmer than other regions of the water. Photosynthetic algae and bacteria that use light as energy thrive in this zone. Further away from the shore is the limnitic zone, which can be colder and sunlight only in the upper 100 feet or so. Photosynthetic microbes also live here. As the water deepens, temperatures become colder and the oxygen concentration and light in the water decrease. Now, microbes that require oxygen do not thrive. Instead, purple and green sulfur bacteria, which can grow without oxygen, dominate. Finally, at the bottom of fresh waters (the benthic zone), few microbes survive. Bacteria that can survive in the absence of oxygen and sunlight, such as methane producing bacteria, thrive.

WEEK 1 INTRODUCTION

- Salt water presents a different environment to microorganisms. The higher salt concentration, higher pH, and lower nutrients, relative to freshwater, are lethal to many microorganisms. But, salt loving (halophilic) bacteria abound near the surface, and some bacteria that also live in freshwater are plentiful (i.e., *Pseudomonas* and *Vibrio*). Also, in 2001, researchers demonstrated that the ancient form of microbial life known as archaebacteria is one of the dominant forms of life in the ocean. The role of archaebacteria in the ocean food chain is not yet known, but must be of vital importance.

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WEEK2 Microbes in Lakes and Streams

- Like all ecosystems, fresh-water ecosystems require energy inputs to sustain the organisms within. In lakes and streams, plants and also certain microbes conduct **photosynthesis** to harvest the Sun's energy. Microbial photosynthesizers include protists (known as algae) and **cyanobacteria** . Other protists and animals feed on these organisms, forming the next link in the **food chain** . Plant material from the land also enters lakes and streams at their edges, providing an important nutrient source for many waterbodies.
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WEEK2 Microbes in Lakes and Streams

- Decomposers form an especially important part of fresh-water ecosystems because they consume dead bodies of plants, animals, and other microbes. These microbial agents of decay are an important part of the ecosystem because they convert detritus (dead and decaying matter) and **organic** materials into needed nutrients, such as nitrate, phosphate, and sulfate. Decomposers and other microbes are thus essential to the major biogeochemical cycles by which nutrients are exchanged between the various parts of the ecosystem, both living and nonliving. Without microbial decomposers, minerals and nutrients critical to plant and animal growth would not be made available to support other levels of the fresh-water food chain.

WEEK2 Microbes in Lakes and Streams

- **Aerobes and Anaerobes.**
- Aerobic decomposers in water need oxygen to survive and do their work. The lapping waves and babbling brook help increase the level of dissolved oxygen that is crucial to so many creatures in lake and stream ecosystems, none more so than the bacteria. If there is not enough oxygen in the water, many parts of the system suffer: the aerobic decomposers cannot digest plant matter, insects cannot develop and mature, and the fish cannot play their part, whether browsing for small food particles or eating other fish. Eventually, the stream or pond will be changed, starting at the microbial level.

WEEK2 **Microbes in Lakes and Streams**

- Microbes and Human Health
- Fresh water is host to numerous microorganisms that affect human health directly.*Polluted drinking water is a major source of illness and death throughout the world, particularly in developing countries. In almost all cases, the organisms responsible cycle from the waterbody through the digestive tract of humans or other animals. Released in fecal waste of the infected host, they enter the water again to complete their life cycle. Most infections derived this way cause diarrhea, abdominal cramping, and potentially more serious symptoms, including fever, vomiting, and intestinal bleeding. Some common microbes in lakes and streams that are responsible for disease include:
- The protist *Giardia lamblia,*found in fresh-water bodies throughout the world. Giardia infection is a common waterborne illness in the United States.
- The bacterium *Vibrio cholerae,*while rare in the United States, remains a significant source of disease and death in countries without advanced sewage treatment and with no potable water supplies. For example, a cholera epidemic in 1991 killed more than a thousand people in Peru (South America), where more than 150,000 cases of the illness were confirmed.
- The bacterium *Escherichia coli,*a very common waterborne pollutant. Humans have a large and harmless population of *E. coli*in their lower, large intestines, and bacteria make up a large fraction of the volume of human feces. When released into drinking water or recreational water sources, *E. coli*can be ingested and enter the upper small intestine, causing diarrhea. Other fecal bacteria known as "coliform" bacteria cause similar symptoms. The level of fecal coliform bacteria in pools, ponds, and other waterbodies is frequently measured during the summer months to assess the safety of recreation in these waters.
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  Read more: http://www.waterencyclopedia.com/La-Mi/Microbes-in-Lakes-and-Streams.html#ixzz6M8T3NgSt

WEEK3 Microorganisms in Water

- Aquatic environments represent the largest part of the biosphere, and many species of microorganisms are found in both marine and freshwater environments. Open oceans contain salt and many marine bacteria, referred to as oligotrophic psychrophiles, which have a requirement for salt and can grow at relatively low temperatures. The surfaces of fish caught from cold water in the open sea contain psychrophilic and psychrotrophic bacterial flora that are capable of breaking down proteins, polysaccharides, and lipids, and can double in numbers at refrigeration temperatures of 0–7 °C in as short a time as 10 h. The implication of this is that a single bacterium on freshly caught fish can multiply to 2^{22} or between 10^7 and 10^8 in just 9 days, and in this situation, cold-stored fresh fish starts giving off off-odors.

WEEK3 Microorganisms in Water

- The sea has been used by man as a dumping ground for sewage and other waste products. Unfortunately, many shellfish used for food grow in these polluted coastal waters and actually feed by filtering out particles from large volumes of seawater. Therefore, there is always a high risk of contamination by enteric organisms from infected individuals, and the microbes concentrate in numbers within the organism as a result of the filter-feeding habits of shellfish. Severe diseases such as hepatitis and typhoid fever, and milder illnesses such as gastroenteritis, have been caused by eating contaminated oysters and mussels that look sound in appearance and taste normal. In warmer seas with unpolluted water, high numbers of the bacterium *Vibrio parahaemolyticus* may also be concentrated through the filter feeding of shellfish. This bacterium then becomes part of the stable commensal enteric flora and has been responsible for episodes of food poisoning associated with seafood.

WEEK3 Microorganisms in Water

- Fresh water from lakes and rivers has a complex flora, which includes genuinely aquatic microbial species as well as those introduced from terrestrial, animal, and plant sources. Like other water sources, fresh water may act as a repository and vehicle for bacteria, protozoa, and viruses of fecal origin, which can also cause diseases.
- Fungi are also found in marine and fresh waters, but they are not as important in their association with food as the groups of microorganisms described above. There are true aquatic fungi, and these include some that are pathogens of molluscs and fish. The most well-adapted aquatic fungi belong to all the major groups of terrestrial fungi, namely: *Ascomycotina, Basidiomycotina, Deuteromycotina*, and *Zygomycotina*. There is the possibility that some of these could be responsible for spoilage of some food commodities, including salad crops cultivated with overhead irrigation from rivers or lakes. The aquatic photosynthetic microorganisms, the cyanobacteria (or blue–green algae), and the eukaryotic dinoflagellates are groups of microorganisms that may also become concentrated in shellfish and can cause severe illness such as paralytic shellfish poisoning.

WEEK4

Table 3.1 Similarities and differences between procaryotic and eucaryotic cell structure

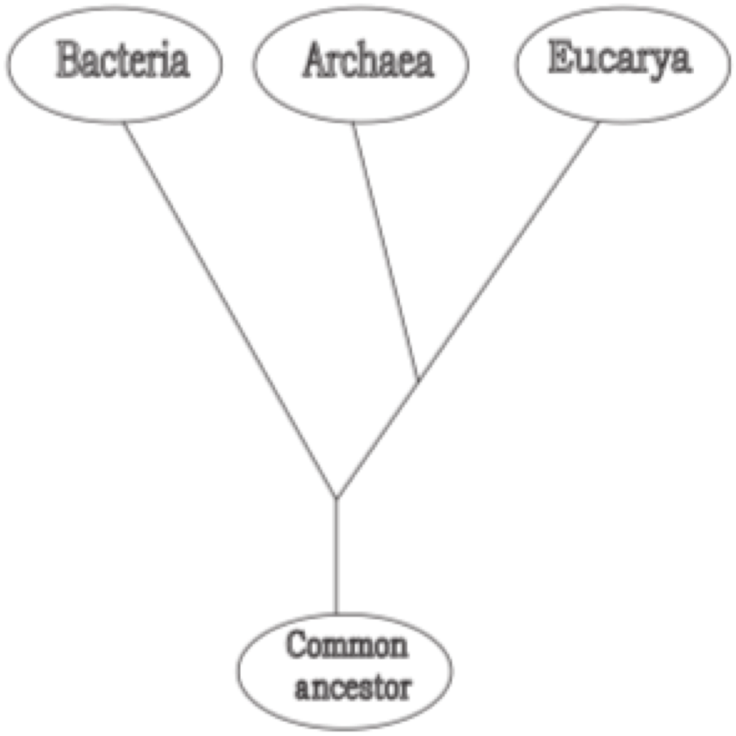
Similarities	
Cell contents bounded by a plasma membrane	
Genetic information encoded on DNA	
Ribosomes act as site of protein synthesis	
Differences	
Procaryotic	**Eucaryotic**
Size	
Typically 1–5 μm	Typically 10–100 μm
Genetic material	
Free in cytoplasm	Contained within a membrane-bound nucleus
Single circular chromosome or nucleoid	Multiple chromosomes, generally in pairs
Histones absent.	DNA complexed with histone proteins
Internal features	
Membrane-bound organelles absent	Several membrane-bound organelles present, including mitochondria, Golgi body, endoplasmic reticulum and (in plants & algae) chloroplasts
Ribosomes smaller (70S), free in cytoplasm	Ribosomes larger (80S), free in cytoplasm or attached to membranes
Respiratory enzymes bound to plasma membrane	Respiratory enzymes located in mitochondria
Cell wall	
Usually based on peptidoglycan (not Archaea)	When present, based on cellulose or chitin
External features	
Cilia absent	Cilia may be present
Flagella, if present, composed of flagellin. Provide rotating motility	Flagella, if present, have complex (9 + 2) structure. Provide 'whiplash' motility
Pili may be present	Pili absent
Outside layer (slime layer, capsule, glycocalyx) present in some types	Pellicle or test present in some types

WEEK 5

Table 3.2 Principal groups of procaryotic and eucaryotic organisms

Procaryotes	Eucaryotes
Bacteria	Fungi
Blue-green 'algae'*	Algae
	Protozoa
	Plants
	Animals

WEEK 6



WEEK 7 The procaryotic cell

- Bacteria are much smaller than eucaryotic cells; most fall into a size range of about 1–5µm, although some may be larger than this. Some of the smallest bacteria, such as the mycoplasma measure less than 1µm, and are too small to be resolved clearly by an ordinary light microscope.
- Because of their extremely small size, it was only with the advent of the electron microscope that we were able to learn about the detailed structure of bacterial cells. Using the light microscope however, it is possible to recognise differences in the shape and arrangement of bacteria. Al- though a good deal of variation is possible, most have one of three basic shapes (Figure 3.2):
- - rod shaped (*bacillus*)
- - spherical (*coccus*)
- - curved: these range from comma-shaped (*vibrio*) to corkscrew-shaped (*spirochaete*)

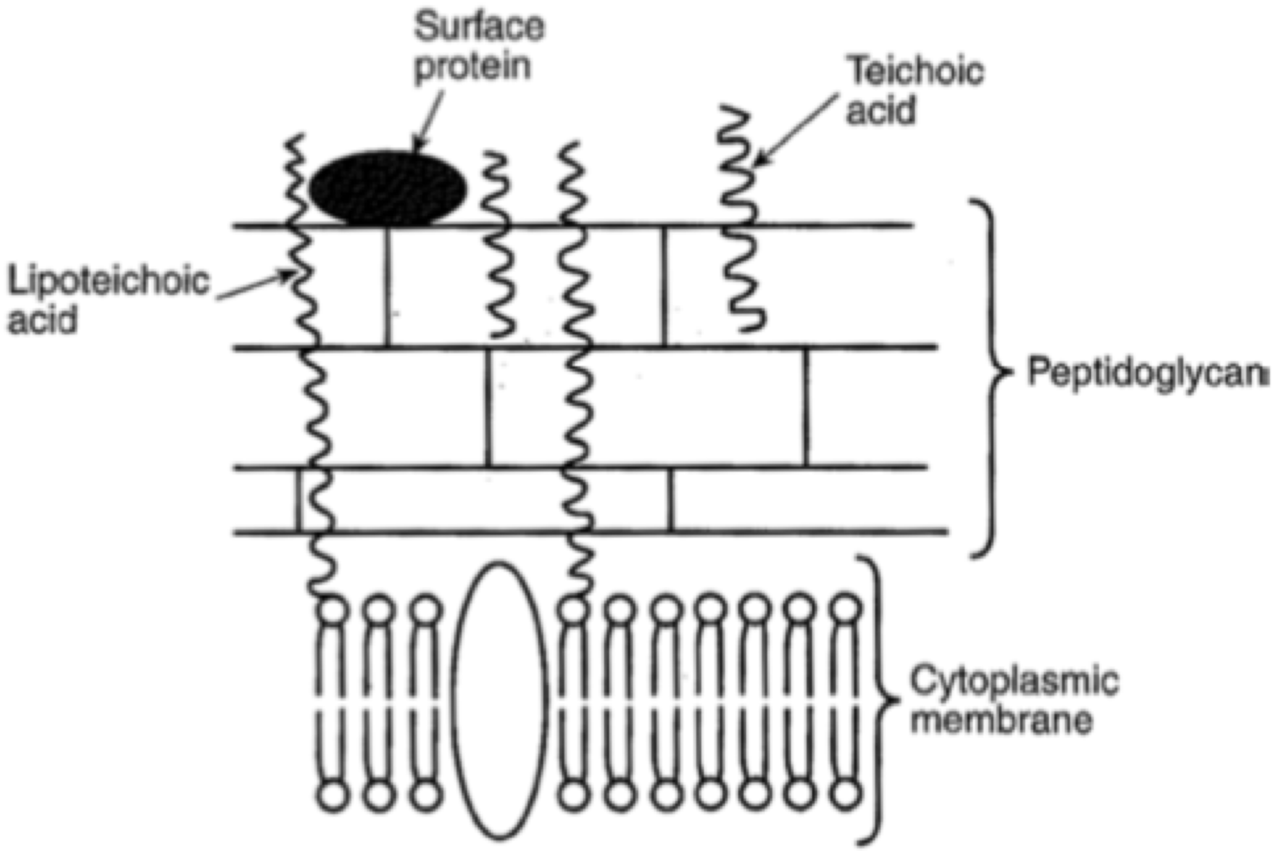
WEEK 7

- **Procaryotic cell structure**
- When compared with the profusion of elaborate organelles encountered inside a typical eucaryotic cell, the interior of a typical bacterium looks rather empty. The only internal structural features are:
- - a bacterial chromosome or *nucleoid*, comprising a closed loop of double stranded, supercoiled DNA. In addition, there may be additional DNA in the form of a *plasmid*

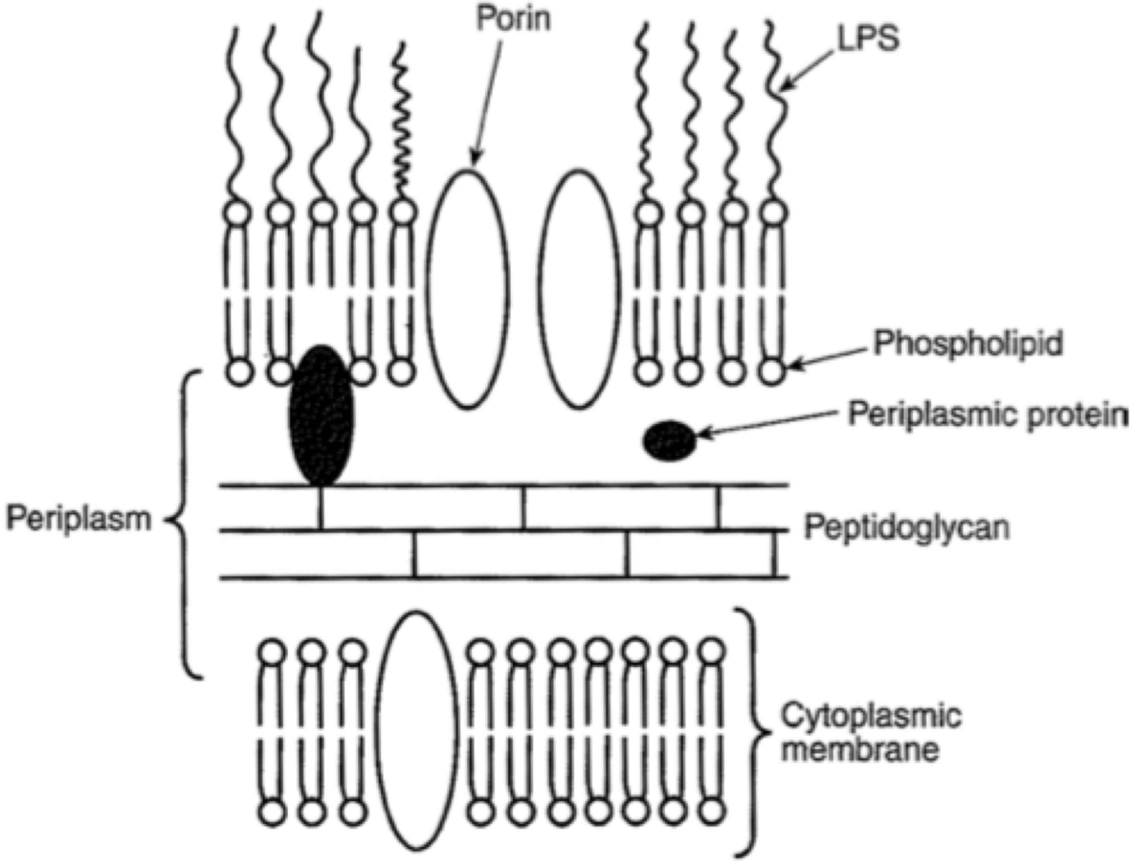
- thousands of granular *ribosomes*

- a variety of granular *inclusions* associated with nutrient storage.

WEEK 7 GRAM POSITIVE CELL WALL



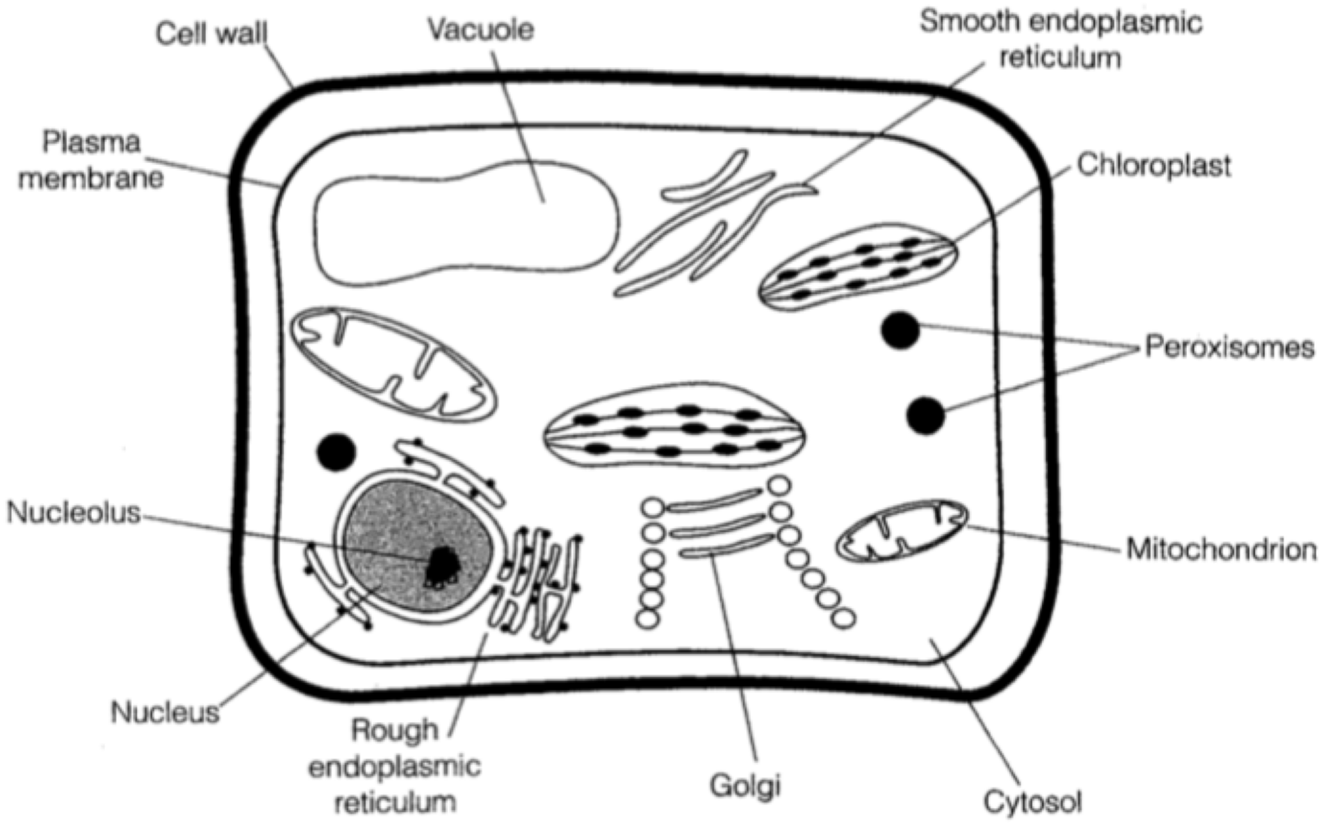
WEEK 7 GRAM NEGATIVE CELL WALL



WEEK 8 The eucaryotic cell

- Within the microbial world, the major groups of eucaryotes are the fungi and the protists (protozoans and algae); all of these groups have single-celled representatives, and there are multicellular forms in the algae and fungi.
- The survey of eucaryotic cell structure begins once more with the genetic material, and works outwards. However, since many internal structures in eucaryotes are en- closed in a membrane, it is appropriate to preface our description by briefly considering eucaryotic membranes. These are, in fact, very similar to the fluid mosaic structure we described earlier in this chapter, as depicted. The main difference is that eucaryotic membranes contain lipids called sterols, which enhances their rigidity. We shall consider the significance of this when we discuss the plasma membrane of eucary- otes below. Cholesterol, which we usually hear about in a very negative context, is a very important sterol found in the membranes of many eucaryotes.

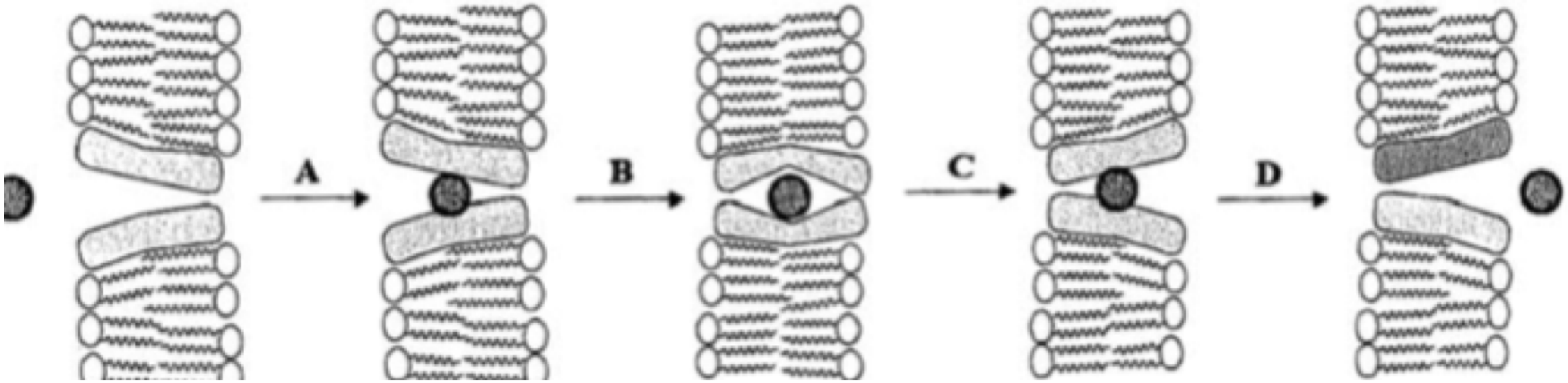
WEEK 8 Eucaryotic Cell Structure



WEEK 9 How do nutrients get into the microbial cell?

- Having found a source of a given nutrient, a microorganism must:
- have some means of taking it up from the environment
- possess the appropriate enzyme systems to utilise it.
- The plasma membrane represents a selective barrier, allowing into the cell only those substances it is able to utilise. This selectivity is due in large part to the hydrophobic nature of the lipid bilayer. A substance can be transported across the cell membrane in one of three ways, known as simple diffusion, facilitated diffusion and active transport.
- In *simple* diffusion, small molecules move across the membrane in response to a concentration gradient (from high to low), until concentrations on either side of the membrane are in equilibrium. The ability to do this depends on being small (H2O, Na+, Cl−) or soluble in the lipid component of the membrane (non-polar gases such as O2 and CO2).

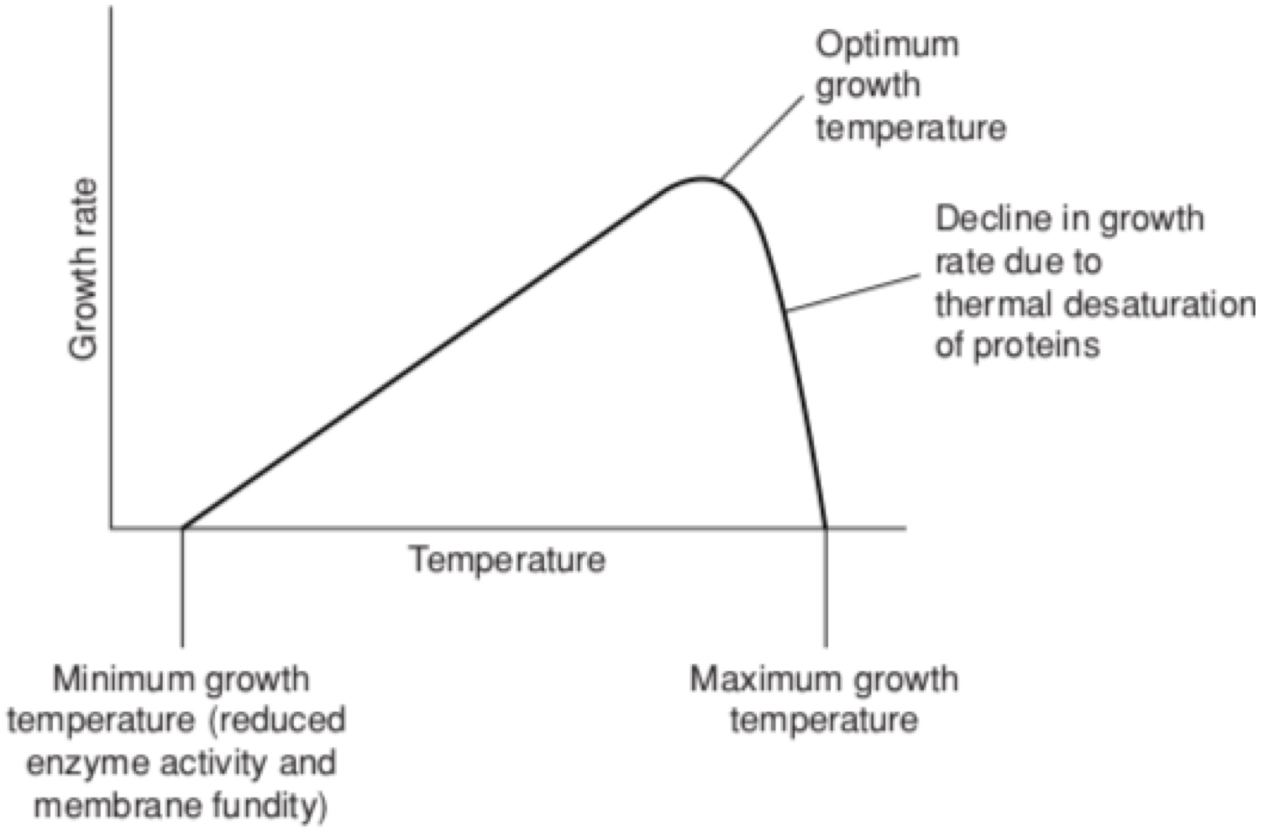
WEEK9 (CONTINUE)



WEEK 10 Factors affecting microbial growth

- **Temperature**
- Microorganisms as a group are able to grow over a wide range of temperatures, from around freezing to above boiling point. For any organism, the *minimum* and *maximum* growth temperatures define the range over which growth is possible; this is typically about 25–30◦C. Growth is slower at low temperatures because enzymes work less efficiently and also because lipids tend to harden and there is a loss of membrane fluid- ity. Growth rates increase with temperature until the *optimum* temperature is reached, then the rate falls again

WEEK 10-


Optimum
growth
temperature
Decline in growth
rate due to
thermal desaturation
of proteins
Growth rate
Temperature
Minimum growth
temperature (reduced
enzyme activity and
membrane fundity)
Maximum growth
temperature

WEEK 10

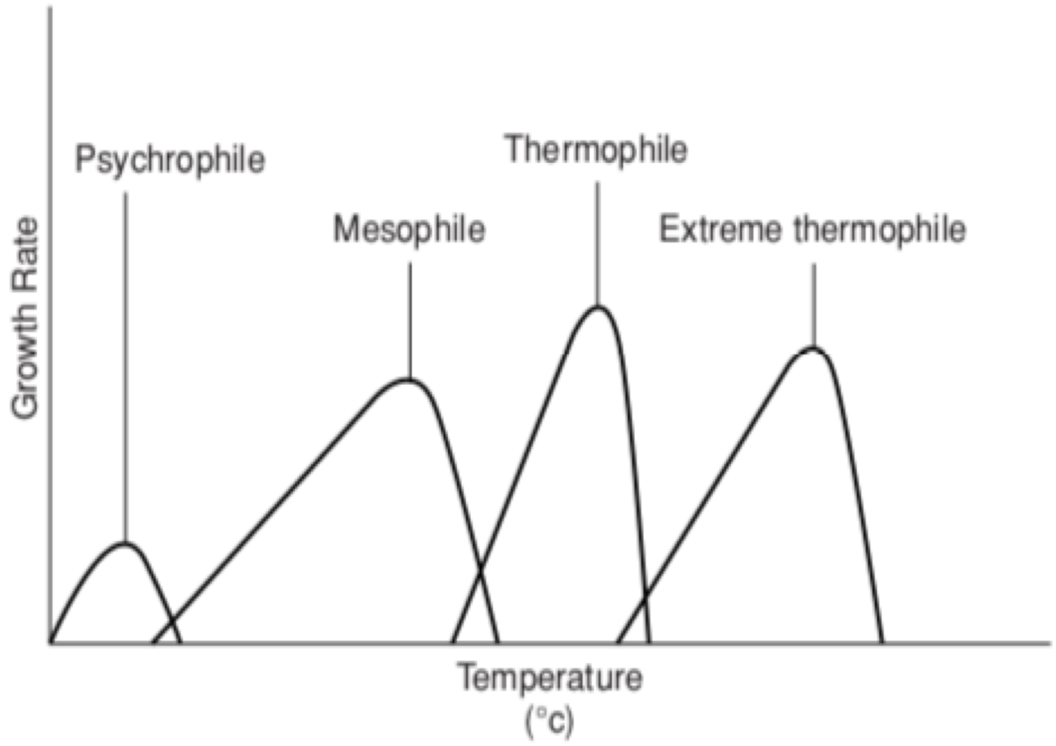


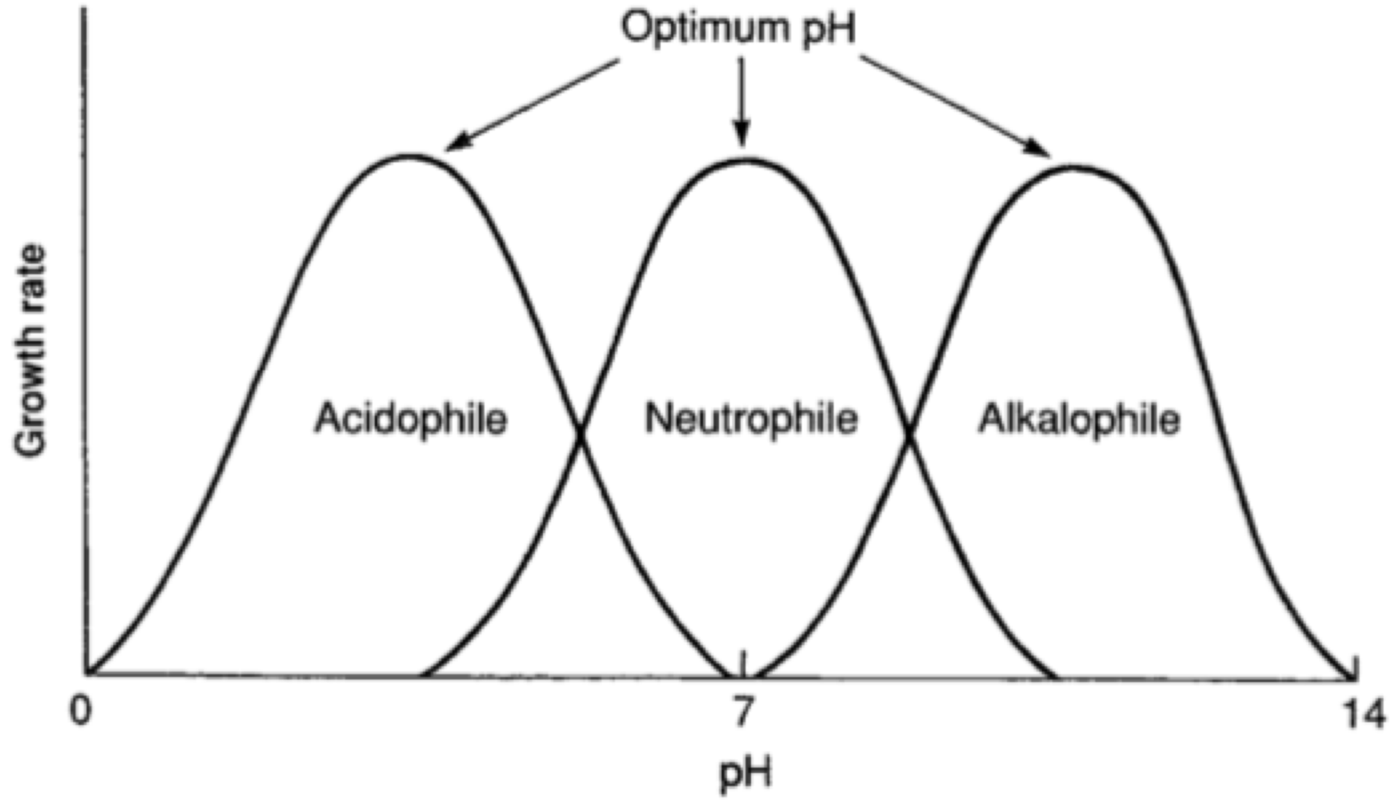
Figure 5.5 Microorganisms can be categorised according to the temperature range at which they grow

WEEK 10-Temperature (continue)

- The majority of microorganisms achieve optimal growth at 'middling' temperatures of around 20–45 ◦ C; these are called *mesophiles* (Figure 5.5). Contrast these with *thermophiles*, which have become adapted to not only surviving, but thriving at much higher temperatures. Typically, these would be capable of growth within a range of about 40–80 ◦C, with an optimum around 50–65 ◦C. *Extreme thermophiles* have optimum values in excess of this, and can tolerate temperatures in excess of 100◦C. In 2003, a member of the primitive bacterial group called the Archaea (see Chapter 7) was reported as growing at a temperature of 121◦C, a new world record! *Psychrophiles* occupy the other extreme of the temperature range; they can grow at 0◦C, with optimal growth occurring at 15◦C or below. Such organisms are not able to grow at tem- peratures above 25◦C or so. *Psychrotrophs*, on the other hand, although they can also grow at 0◦C, have much higher temperature optima (20–30◦C). Members of this group are often economically significant due to their ability to grow on refrigerated foodstuffs.
- In the laboratory, appropriate temperatures for growth are provided by culturing in an appropriate incubator. These come in a variety of shapes and sizes, but all are thermostatically controlled and generally hold the temperature within a degree or two of the desired value.

WEEK 11 pH

- Microorganisms are strongly influenced by the prevailing pH of their surroundings. As with temperature, we can define minimum, optimum and maximum values for growth of a particular type (Figure 5.6). The pH range (between minimum and maximum values) is greater in fungi than it is in bacteria. Most microorganisms grow best around neutrality (pH 7). Many bacteria prefer slightly alkaline conditions but relatively few pH Effect of pH on microbial growth rate. Individual species of microorganism occupy a relatively narrow range of pH. Although for most species this is around neutrality, both acidophilic and alkalophilic forms exist. The shape of the curve reflects the properties of a particular organism’s enzymes and other proteins



WEEK 11 Oxygen

- Oxygen is present as a major constituent (20 per cent) of our atmosphere, and most life forms are dependent upon it for survival and growth. Such organisms are termed *aerobes*. Not all organisms are aerobes however; some *anaerobes* are able to survive in the absence of oxygen, and for some this is actually a necessity.

> An aerobe is an organism that grows in the presence of molecular oxygen, which it uses as a terminal electron acceptor in aerobic respiration.
>
> An anaerobe is an organism that grows in the absence of molecular oxygen

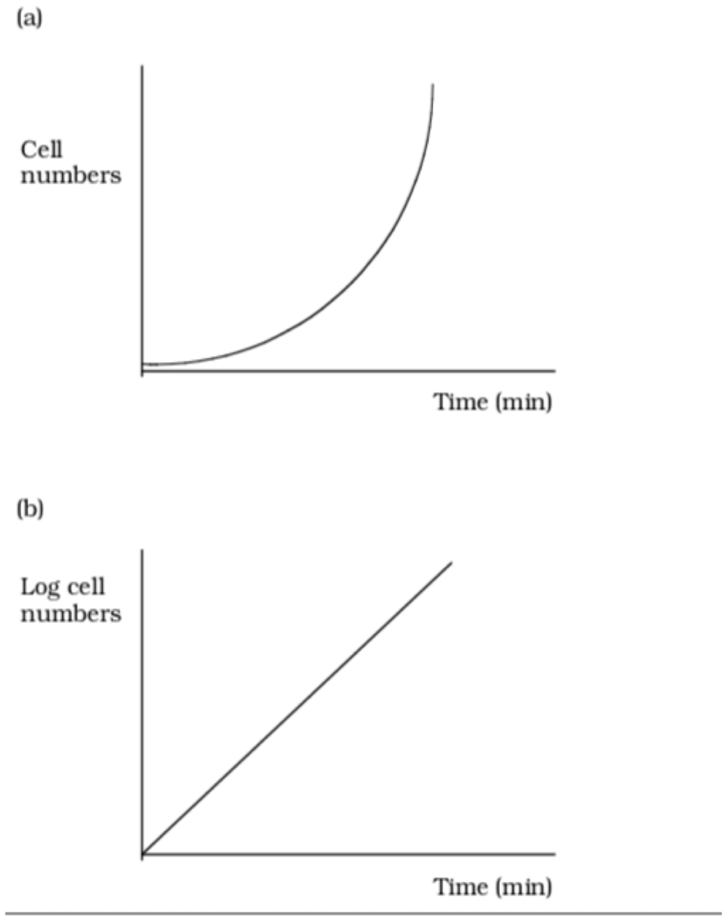
WEEK 11 Carbon dioxide

- Autotrophic organisms are able to use carbon dioxide as a carbon source; when grown in culture, these are provided with bicarbonate in their growth medium or incubated in a CO2-enriched atmosphere. However, heterotrophic bacteria also require small amounts of carbon dioxide, which is incorporated into var- ious metabolic intermediates. This dependency can be demonstrated by the failure of these organisms to grow if carbon dioxide is deliberately removed from the atmosphere.

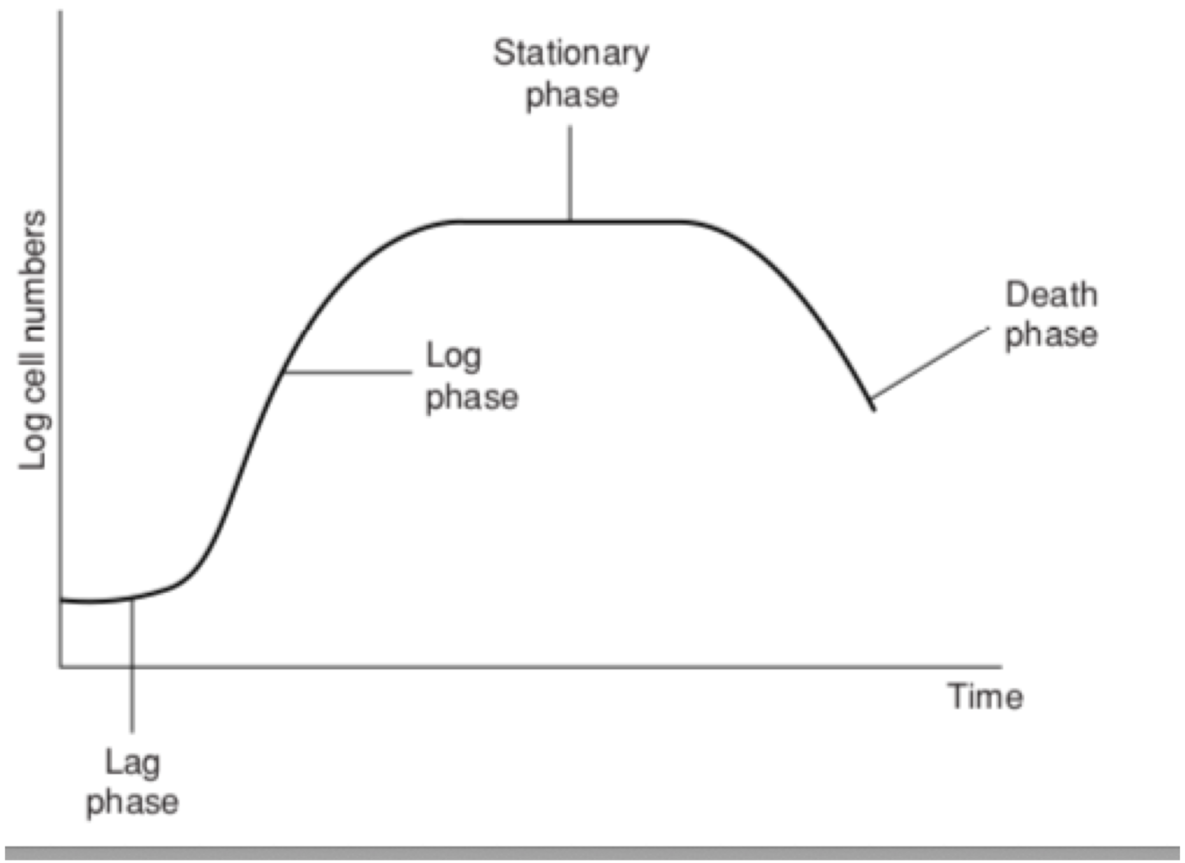
WEEK 12 The kinetics of microbial growth

Unicellular organisms divide by *binary fission*; each cell grows to full size, replicates its genetic material then divides into two identical daughter cells. By identical means, two cells divide into four, four into eight and so on, leading to an exponential increase in cell numbers:

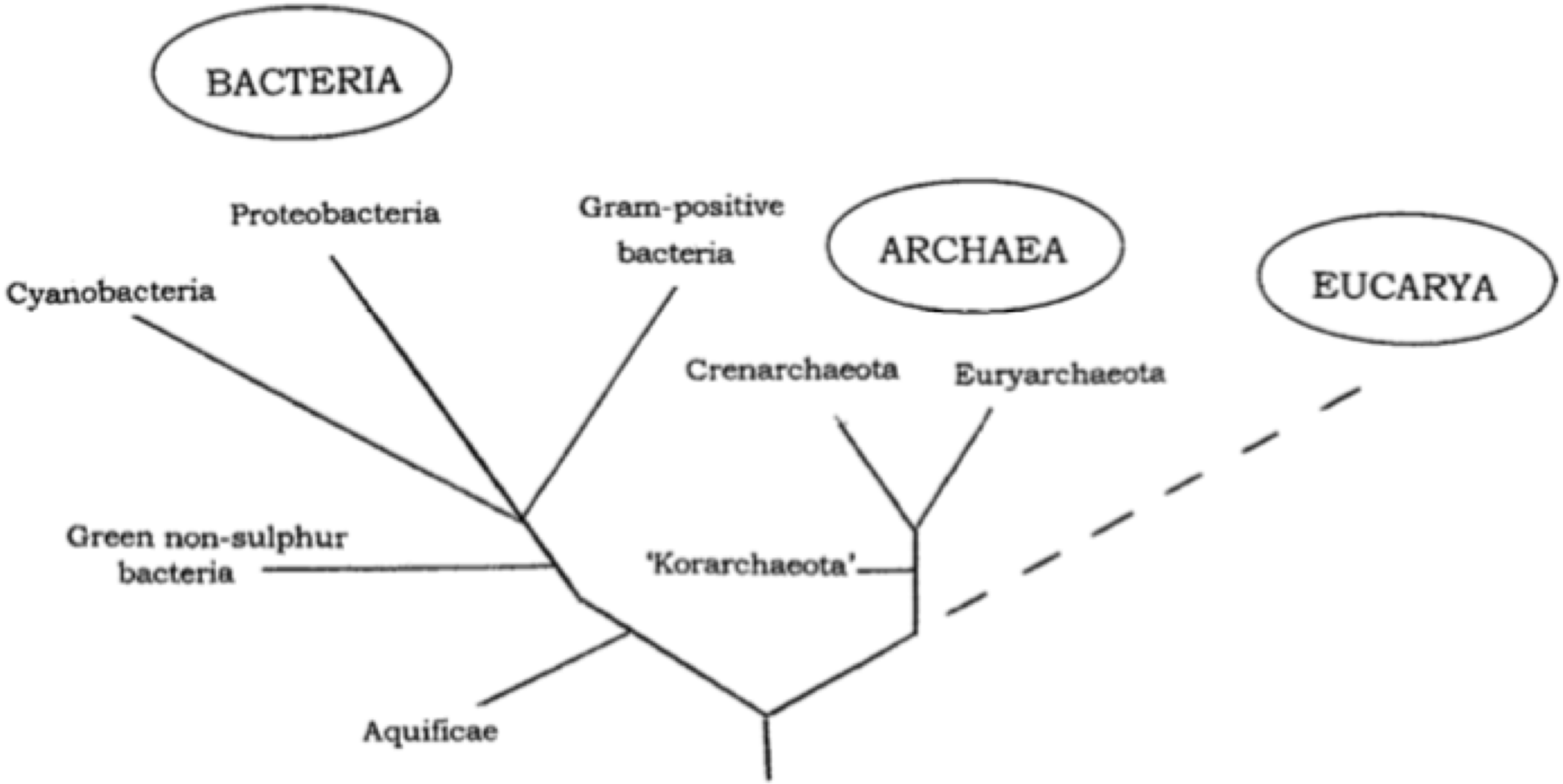
1 ------→ 2 ------→ 4 ------→ 8 ------→ 2^n



WEEK 12 A microbial growth curve



WEEK 13 PROCARYOTE DIVERSITY



EEK 13 Domain: Archaea

- Studies on 16S ribosomal RNA sequences by Carl Woese and colleagues allowed the construction of phylogenetic trees for the procaryotes, showing their evolutionary re-latedness. The major procaryotic
  groups are thought to be related, based on 16S rRNA data.

WEEK 13 The three domains of life: Archaea share some features with true bacteria and others with eucaryotes

	Archaea	Bacteria	Eucarya
Main genetic material	Single closed circle of dsDNA	Single closed circle of dsDNA	True nucleus with multiple linear chromosomes
Histones	Present	Absent	Present
Gene structure	Introns absent	Introns absent	Introns present
Plasmids	Common	Common	Rare
Polycistronic mRNA	Present	Present	Absent
Ribosomes	70S	70S	80S
Protein synthesis	Not sensitive to streptomycin, chloramphenicol	Sensitive to streptomycin, chloramphenicol	Not sensitive to streptomycin, chloramphenicol
Initiator tRNA	Methionine	N-formyl methionine	Methionine
Membrane fatty acids	Ether-linked, branched	Ester-linked, straight chain	Ester-linked, straight chain
Internal organelles	Absent	Absent	Present
Site of energy generation	Cytoplasmic membrane	Cytoplasmic membrane	Mitochondria
Cell wall	Muramic acid absent	Muramic acid present	Muramic acid absent

WEEK 13 FUNGI

- Fungi differ from plants in two quite fundamental respects:
- -plants obtain energy from the sun, fungi do not
- - plants utilise CO2 as a carbon source, fungi do not.
- Fungi range in form and size from unicellular yeasts to large mushrooms and puffballs. *Yeasts* are unicellular, do not have flagella and reproduce asexually by budding or trans- verse fission, or sexually by spore formation. Multicellular forms such as moulds have long, branched, threadlike filaments called *hyphae*, which aggregate together to form a tangled *mycelium*

WEEK 13-FUNGI

- In some fungi the hyphae have crosswalls or septa (sing: septum) separating cells, which may nevertheless be joined by one or more pores, which permit cytoplasmic streaming, a form of internal transport. Such hyphae are said to be *septate*; others have no crosswalls and are therefore *coenocytic*
- Many fungi are *dimorphic*, that is, they exist in two distinct forms. Some fungi that cause human infections can change from the yeast form in the human to a mycelial form in the environment in response to changes in nutrients, and environmental factors such as CO2 concentration and temperature. This change in body form is known as the *YM shift*; in fungi associated with plants, the shift often occurs the other way round, i.e. the mycelial form exists in the plant and the yeast form in the environment.

WEEK 13 -FUNGI

- Most fungi are *saprobic* (although some have other modes of nutrition), that is, they obtain their nu- trients from decaying matter, which they grow over and through, frequently secreting enzymes extracellu- larly to break down complex molecules to simpler forms that can then be absorbed by the hyphae. Most fungi are able to synthesise their own amino acids and proteins from carbohydrates and simple nitroge- nous compounds. Although fungi are unable to move, they can swiftly colonise new territory as a result of the rapid rate at which their hyphae grow. All energy is concentrated on adding length rather than thick- ness; this growth pattern leads to an increase in sur- face area and is an adaptation to an absorptive way of life. Carbohydrates are stored mainly in the form of glycogen (c.f. starch in higher plants, green al- gae). Metabolism is generally aerobic, but some yeasts can function as facultative anaerobes.

WEEK 13THE PROTISTA ALGAE

- The Algae is a collective name traditionally given to several phyla of primitive, and mostly aquatic plants, making up a highly diverse group of over 30 000 species. They display a wide variety of structure, habitat and life-cycle, ranging from single-celled forms to massive seaweeds tens of metres in length. Most algae share a number of common features which caused them to be grouped together. Among these are:
- -possession of the pigment chlorophyll
- -deriving energy from the sun by means of oxygenic photosynthesis
- -fixing carbon from CO_2 or dissolved bicarbonate

WEEK 13Euglenophyta

- This is a group of unicellular flagellated organisms, which probably represent the most ancient group of al-gal protists. Individuals range in size from 10−500 µm. Euglenophytes are commonly found in fresh water, par-ticularly that with a high organic content, and to a lesser extent, in soil, brackish water and salt water. Members of this group have a well-defined nucleus, and chloro-plasts containing chlorophylls *a* and *b*

WEEK 14- VIRUSES

- All viruses are obligate intracellular parasites; they inhabit a no-man’s-land between the living and the non-living worlds, and possess characteristics of both. They are now known to differ radically from the simplest true organisms, bacteria, in a number of respects:
- they cannot be observed using a light microscope
- they have no internal cellular structure
- they contain either DNA or RNA, but not both*
- they are incapable of replication unless occupying an appropriate living host cell
- they are incapable of metabolism
- individuals show no increase in size.
- When inside a host cell, viruses show some of the features of a living organism, such as the ability to replicate themselves, but outside the cell they are just inert chemical structures, thus fuelling the debate as to whether they can be considered to be life forms. A particular virus has a limited host range, that is, it is only able to infect certain cell types.

WEEK 14- VIRAL STRUCTURE