LECTURE 1—INTRODUCTION

1st Foundation of Biology—

EVOLUTION THROUGH NATURAL SELECTION:

- All life evolved from pre-existing life
- Homology ⇒ derived from common ancestral feature
    - limbs are **homologous** among many animal groups ⇒ evolved & diverged (independently) from a common ancestor
    - evolve different functions
- Fossils
    - fossil record is strong evidence for evolution ⇒ increasing complexity of organisms
    - a time in evolutionary history when extinct organisms were alive
- Ontogeny recapitulates phylogeny ⇒ **development is a fast action replay of ancestry**
    - our embryonic development replays structures from ancestral species
    - e.g. webbing between finger degenerates to free digits
- Biogeography also supports evolution

Darwin's three observations:

- Individuals in a population vary ⇒ fitness (variability)
    - population more likely to survive
- Pass on traits (fitness) to offspring ⇒ heredity (genes)
- Never enough resources ⇒ competition for survival and reproduction
- Evolution is a two-step process:
    - variability
    - ordering variability by ***NATURAL SELECTION***

2nd Foundation of Biology—

UNITY OF BIOCHEMICAL REACTIONS:

- Unity of biochemical processes ⇒ all organisms share core biochemical reactions (homology)
    - all organisms have genetic material (DNA) containing the *instructions* for development
    - organisms have proteins to carry out *instructions*

3rd Foundation of Biology—

CELL THEORY (SCHLEIDEN AND SCHWANN):

- All known living things are made up of one or more cells
    - ***i.e. first living thing was a cell***
- All living cells arise from pre-existing cells by division
- The cell is the fundamental unit of structure & function in all living organisms
- Cells contain DNA which is passed from cell to cell during division
- Pauling and Zuckerkandl recognised that DNA contains the history of evolution

Studying the evolution (relatedness of all life)—

- All organisms have genes (DNA)
- DNA contains a history of evolution
- We recognise the main types of cells ⇒ prokaryotes (no nucleus) & eukaryotes (nucleus)
- The further down an evolutionary tree, the lower the percentage of similarity of DNA

Three domains of life—

- DNA data revealed two very different groups of prokaryotes
    - Bacteria, Archaea & Eukarya
- Archaea are our ***nearest*** ancestors in microbial world
    - all living things came from a common ancestor which existed before natural selection

LECTURE 2—PROKARYOTES

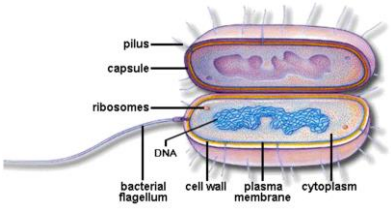
Prokaryotes—

- Although all prokaryotes look morphologically similar it is because *they are so simple*
    - i.e. don't have many distinguishing features
- Prokaryotes have been diverging apart in evolution

Life depends on prokaryotes—

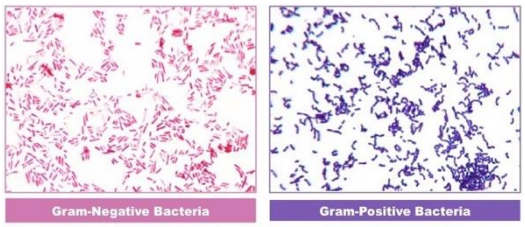
- Archaea allow herbivores to break down the sugars in plants
- Bacteria in our intestines help to make essential vitamins
- Harmless bacteria in our skin protect us from attack by other invaders
- Prokaryotes are used in food production
    - e.g. yoghurt, cheese, wine, beer, vinegar etc.
- Free oxygen & biologically available nitrogen produced/processed by bacteria
- Bacteria also play a role in disease
- ***Archaea are not known to cause any diseases***
- Bacteria can develop antibacterial resistance (natural selection)

Prokaryotic cells—

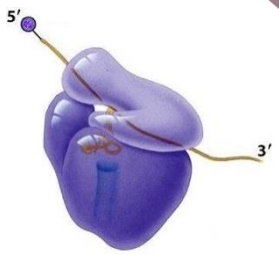


- Usually microscopic (1-10 µm)
- DNA is a single, circular chromosome (nucleoid)
- No proteins are attached to DNA in Bacteria
- Histones are attached to DNA in **Archaea**
    - ***ONLY*** bacterial cell wall is made of peptidoglycan

Bacterial cells—



- Typically have a wall ⇒ peptidoglycan
- **ONE** surrounding membrane ⇒ Gram positive
    - rod-shaped, purple staining & fat peptidoglycan layer
- **TWO** surrounding membranes ⇒ Gram negative
    - pink/faint as double membrane restricts contact between stain and wall material
        - **bacterial cells able to function properly with a thinner wall**



Ribosomes—

- All cells have ribosomes (ancestral character)
- Composed of numerous proteins and several RNAs
- Site of translation (protein synthesis) ⇒ ***sensitive part to any cell***
- Take mRNA sequence & *translate* it to a protein sequence
- Prokaryotic ribosomes are small (70S)
- Eukaryotic ribosomes are larger (80S)
    - differences are *due to divergence*
        - sensitive to drugs (antibiotics)
        - can inhibit ribosomes (& thus protein synthesis) in a bacterium **only**

Prokaryotic flagellum—

- Motility appendage
- Long thin filament with ***corkscrew action***
    - composed of flagellin protein
- Extracellular ⇒ not inside cell membrane

Prokaryotic division—

- Prokaryotes divide by binary fission
- Constricting ring cleaves parent cell into two daughter cells
- Bacterial DNA molecules have an attachment point to the plasma membrane

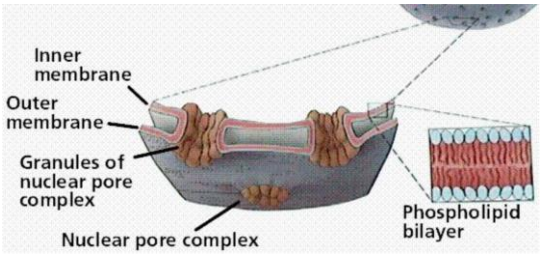
Prokaryotes vs Eukaryotes—

PROKARYOTES	**EUKARYOTES**
• Prokaryotes are microscopic	• Eukaryotes can be large & multicellular
• Prokaryotes lack a nucleus	• Eukaryotic cells have a nucleus

LECTURE 3—EUKARYOTES

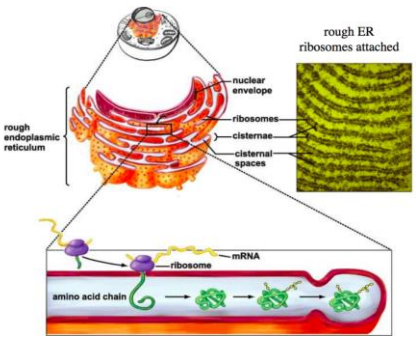
Pores—

- Pores are lined with proteins & attached to lamina (nuclear skeleton)
- Pores are evenly spaced over nuclear envelope and are gateways into/out of the nucleus
- Traffic of *proteins and RNAs* into/out of nucleus
- **Pore is located at site where inner membrane curls around to become outer membrane**



Endoplasmic Reticulum—

- Consists of membrane cisternae that ramify through the cytoplasm
  - *forms channels that link different parts of the cell*
- Nuclear envelope is **CONTINUOUS** with ER
  - outer part of the nuclear envelope that extends to the membranes of the cell
- *ROUGH ER* when ribosomes **attached**
  - ribosome docks on rough ER & newly synthesised protein is received into the lumen to be exported via a vesicle
  - proteins can be **chemically modified** to alter their functions & *tagged* for delivery
- ER is a dynamic structure & consistently disassembles/reassembles
- *SMOOTH ER* when ribosomes **absent**
  - **less ordered**
  - involved in lipid & steroid manufacture, glycogen degradation and detoxification



Major functions of intracellular membranes—

- Provides surface for biochemical reactions
- Establish a number of compartments to prevent mixing ⇒ ***MORE*** efficient
- Transport for materials from cell to exterior/from cell to adjacent cell

Golgi complex—

- Flattened stacks of membrane/cisternae
  - collectively known as the Golgi complex

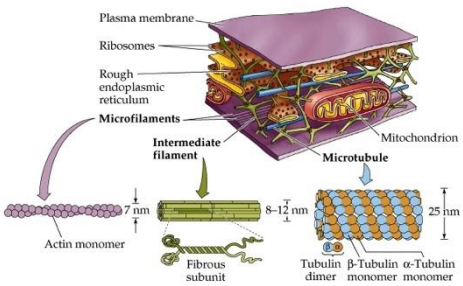
- Golgi bodies are ***functional extensions*** of ER
- Functions in collection, packaging & distribution of molecules synthesised elsewhere
    - most polysaccharides in cells manufactured in Golgi bodies
- Proteins from **ER** ⇒ Golgi apparatus ⇒ plasma membrane fused ⇒ expulsion of protein into extracellular environment
- Polysaccharide may be attached to either protein or lipid molecules in Golgi
    - polysaccharides act as *self* & *non-self markers*
- Golgi composed of three components:
    - cis (closest to nucleus)
    - medial (middle)
    - trans (furthest from nucleus)
- Vesicles bleb off from envelope & carry materials to Golgi (i.e. lipids or proteins)
    - at Golgi may be combined with polysaccharides
- Once *packaged* the trans cistern breaks into vesicles ⇒ travel to different parts of the cell
    - **secretory vesicles** move from Golgi to cell membrane & fuse with membrane/release contents (exocytosis)
- Endomembrane system contributes to size difference in eukaryotes & prokaryotes

The Cytoskeleton—

- ***NOT*** composed of membrane (rigid structures)
    - present in eukaryotic cells as they do not contain cell walls
- Act as *scaffolding or structural elements*
    - maintains shape & induces cell movement

Major elements of the cytoskeleton—

- Actin filaments (7nm diameter)
    - gelsolin controls filament assembly (not hollow)
- Intermediate filaments (10nm diameter)
    - several proteins
- Microtubules (25nm diameter)
    - 13 protofilaments of tubulin protein form **cylinder**



Motor elements of the cytoskeleton—

- Actin filaments interact with myosin motors to cause actin to move
- Intermediate filaments are *predominantly static* ⇒ long-term durable structures

- microtubules interact with kinesin or dynein motors

ACTIN FILAMENTS:

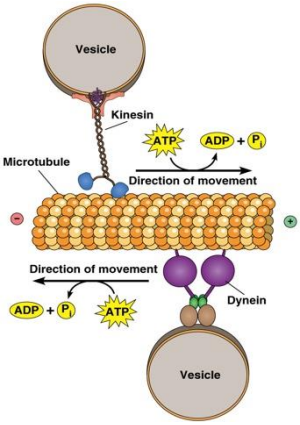
- Interact with myosin motors (in muscle tissue only)
  - ***roles in muscle contraction & cytoplasmic streaming***
- Myosin heads pull themselves along actin
- Forms & deforms to create movement in SINGLE DIRECTION
- Actin monomers form **LONG** chains
  - associates with other proteins (meshwork) in some cell types to help maintain structure

MICROTUBULES:

- Tubulin protein forms protofilament
  - 13 protofilaments form hollow cylinder
- Can assemble & disassemble
- Lengthen from – to + end & act as scaffold for transport (e.g. kinesin transporting vesicles)
  - kinesin carries in +ve direction (towards exterior)
  - cytoplasmic dynein carries in –ve direction (towards interior)
- Dynein can slide one microtubule against one another

Eukaryotic Flagella—

- They *beat* whereas prokaryotic flagella *rotate*
- Consist of microtubules & dynein motors *whereas* prokaryotic contain flagellin protein
  - ***convergent evolution*** ⇒ fundamentally different in motion & structure
- **Axonemal dynein** slides one microtubule against another
  - microtubule doublets anchored together by nexin
    - cannot slide ⇒ force generated by dynein movement causes bending
  - *basal body at base holds flagellum into cell/coordinates movement*
- Dynein attached from one tubule to another (kinesin walks along single microtubule) to carry cargo
- Kinesin responsible for movement of vesicles from Golgi to outer membrane
- Microtubules are fixed at one end and so the *walking motion* of the dynein doesn't make them slide instead it causes them to bend ⇒ curvature



Ciliates—

- Ciliates are unicellular eukaryotes covered in cilia
    - also contain microtubules & dynein ⇒ make bends & waves
- Ciliates swim by waving their cilia (short flagella)

The cytoskeleton—

- *Actin* ⇒ myosin drives muscle contraction, cytoplasmic streaming, microvilli movements
- *Intermediate filaments* ⇒ intra- and intercellular stabilisation
- *Microtubule* ⇒ **kinesin** moves vesicles & **dynein** drives cilia/flagella beating