BIOL10002 – Biomolecules and Cells: Detailed Notes

Lecture 1: What is life?

Outcomes

- How do we define life?
- How and when did life begin on Earth?
- The connection between water and life.
- Evidence of early life on Earth.

Big themes of the subject

Evolution

- The origin of life occurred by natural processes; life continues to evolve within a changing environment.
- All organisms are connected by lines of descent from common ancestry; barriers to reproduction foster divergence of lineages.
- Natural selection acts on phenotypic variation, generating adaptations.
- Evolution can occur as a result of processes unrelated to fitness; human interventions can alter the course of evolution.

Cells

- All cells come from pre-existing cells.
- The molecular and structural properties of cells define their function.
- Cells are bounded by a membrane and maintain internal environments that differ from their external environments.
- Cells communicate with other cells.
- Cells are able to form organised units capable of more complex function.

Defining life

Life is composed of a common set of elements, responds to the environment, grows and changes, and is comprised of cells.

Example of response to the environment: "living crystals"

- TPM polymer spheres sit in a solution of hydrogen peroxide.
- When light is applied, the hydrogen peroxide degrades to water and oxygen and creates an energy halo, making the spheres "run around".

Borderline cases: prions and viruses

Prions (non-living)

- Misfolded proteins that can transmit their misfolded shape onto normal variants of the same protein.
- They have no DNA [or RNA] but can replicate [propagate by converting normal protein].
- Must have derived from a living organism.
- Prion disease: damage or disease that affects the brain; usually fatal.

Viruses: alive or not?

Pros (alive)	Cons (not alive)
Contain nucleic acids	Not capable of independent replication
Can replicate	Do not contain the metabolic processes required to be considered "alive"
Evolve and adapt to the environment	

How and when did life begin?

Miller–Urey experiment

- Sought to mimic the conditions thought to exist on Earth about 4 billion years ago (an "atmospheric" compartment and a water compartment).
- It produced organic products: the bases present in DNA and RNA; all 20 amino acids found in proteins; a range of 3- and 6-carbon sugars; fatty acids; vitamin B6, NAD and organic acids.

Protocells can form from fatty acids

- Fatty acids have a hydrophobic and a hydrophilic part, so they form cell-like structures.
- These protocells come together and link, creating a lipid bilayer into which other molecules could pass and be protected.
- Slowly they moved towards more complicated protocells, formed more complex structures, and then were able to replicate through RNA.

Murchison meteorite

- Idea: life or its building blocks may have originated elsewhere and arrived on Earth via meteorites.
- Samples from a meteorite that landed in Australia in 1969 near the Victorian town of Murchison were analysed. The fragments contained amino acids, DNA bases and sugars.
- In 2020, scientists identified a protein whose building blocks differed chemically from those found in Earth proteins. This is evidence that the building blocks of life can be formed basically anywhere.

Lecture 4: The development of early life on Earth: Prokaryotes

Why are cyanobacteria so significant to the evolution of life on Earth?

- The first inhabitants of Earth were prokaryotes.
- Early on, the Earth's atmosphere and oceans had no oxygen, high CO_2, ammonia, methane and intense radiation.
- Cyanobacteria photosynthesised and, significantly, produced oxygen, which changed all of this.
- **Stromatolites** are living fossils that thrive in the hyper-saline water of Hamelin Pool; cyanobacteria make up the built-up skeleton.

Although structurally simple, why are prokaryotes considered highly evolved?

- Resting spores have been brought back to life after 250 million years inside salt crystals.
- They replicate at speed: they divide every 20 minutes, since their DNA is much smaller than that of eukaryotes.

Feature	Prokaryotes	Eukaryotes
Nucleus?	No	Yes
Size	1–10 microns	10–100 microns
Flagellum	Single protein (flagellin) powered by a motor	250–300 different proteins; hugely complicated structure
Ribosomes	55 proteins and 3 rRNA (source says "mRNA"), 2.3 MDa; 50S + 30S subunits = 70S ribosome	80 proteins and 4 rRNA, ~3.3 MDa; 60S + 40S subunits = 80S ribosome
Replication	Binary fission: the genome is replicated before a protein draws the two genomes apart and the 2 cells pinch off	Mitosis
DNA	Circular, double stranded	Double-stranded DNA wrapped around histones
Diversity	Mutations occur at high frequency = huge biochemical diversity	Little [biochemical] diversity

- Prokaryotic cell structure (figure): outer capsule, cell wall, plasma membrane.

Prokaryotic ribosomes are frequent drug targets

- Antibiotics such as chloramphenicol inhibit the 50S subunit's formation of the peptide bond.
- Such antibiotics often truncate the protein or produce a non-functional protein.
- Since prokaryotic ribosomes are so different from eukaryotic ones, they are used as a target.

Prac 1 (Appendices): Microscopy and biological drawing

Appendix 1: Using the compound microscope

Parts: eyepiece, objective lenses, limb, stage, stage clip, coarse focus, fine focus, iris diaphragm, stage adjustment knobs, on/off switch.

1. The limb can be towards or away from you; normally work with it towards you.
2. Plug in the power and turn the light switch on. Turn the light intensity up to maximum; if this is too bright, reduce it using the iris diaphragm.
3. Start with scanning power before zooming in (easier to focus). Move the red (×4) scanning-power objective lens into position.
4. Place the slide on the stage and secure it with a stage clip. The clip can be moved using the stage adjustment knobs.
5. Use the coarse focus knob to move the stage up/down until a sharp image can be seen (normally at the highest point).
6. Then use the fine focus knob to fine-tune the sharpness.
7. If the object is too small, zoom in by switching from scanning power to low power (yellow, ×10). Use the fine focus knob to fine-tune the image again.
8. Do not touch the coarse focus knob anymore.
9. Repeat at high power (blue, ×40) if necessary.
10. Adjust the iris diaphragm to alter contrast.

Appendix 2: Using the dissecting microscope

- Used to observe larger or 3D samples; magnification is lower and there is a larger stage.
- Parts: eyepiece, zoom, coarse focus, light intensity, stage, on/off switch.

1. Place the sample on the stage and switch on the microscope.
2. Use the coarse focus knob to get the sample in focus.
3. Adjust the light intensity knobs (one on top and one on bottom).
4. There is only one objective lens for zoom, unlike the compound microscope.

Estimating size on the compound microscope

- **Magnification** is the product of the magnification of the objective lens (4×, 10× or 40×) and the eyepiece.
- The diameter of the field of view needs to be known.
- Step 1: on high power (400× magnification), count the number of cells that fit across the diameter of the field of view.
- Step 2: divide the diameter of the field of view by your cell count from Step 1.
- A dissecting microscope usually has a sample big enough to measure with a ruler.