recommended background capabilities
general aptitude: recognising patterns, and interpolation and extrapolation

I0. Life

As a philosophical matter, introductions to biology frequently involve a discussion about just what constitutes "life", or what makes something "alive". A few of the commonly proposed features, conditions or requirements for life are listed below. For each one, give an example of something that we might not consider genuinely to be "life" or "alive", even though it possesses that feature or meets that condition or requirement. Alternatively, give an example of something that does not have the feature or meet the condition, yet is still considered "life" or "alive". Try to explain how they are counterexamples.

1. Growth.

Confidence: 0 | 1 | 2 | 3 | 4

2. Reproduction.

Confidence: 0 | 1 | 2 | 3 | 4

3. Response to stimuli.

Confidence: 0 | 1 | 2 | 3 | 4

4. Locomotion.

Confidence: 0 | 1 | 2 | 3 | 4

I1. Metabolism

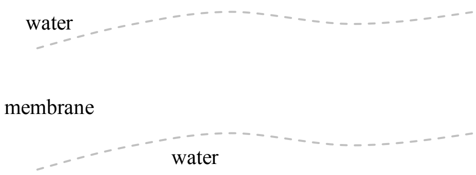
1. Molecules and parts of molecules with the same type of solubility will tend to dissolve in each other: things that are water-soluble will usually mix freely with other things that are water-soluble; things that are fat-soluble will usually mix freely with other things that are fat-soluble. Phospholipids are biological molecules with a water-soluble phosphate region, attached to two long water-insoluble (fat-soluble or "lipid"-soluble) hydrocarbon chains. We can draw a representation of them like this.

water-soluble "head"  lipid-soluble "tails"

1. A small clump of phospholipid molecules suspended in water is called a "micelle". Using the style above, draw what we might expect the structure of a micelle to look like.

Confidence: 0 | 1 | 2 | 3 | 4

2. Phospholipids also form membranes that separate compartments of water. These membranes have a structure described as a "phospholipid bilayer". What might this structure look like?



Confidence: 0 | 1 | 2 | 3 | 4

2. Many organisms use the oxidation of carbohydrates and fatty acids as a source of energy for other chemical processes. The "respiratory quotient" is the ratio between the number of carbon dioxide molecules (CO_2) produced, and the number of oxygen molecules (O_2) used.

1. "Cellular respiration" has the balanced overall chemical equation below.

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

The number prefixes are the number of each molecule, while the number subscripts are the number of each atom in each molecule. The equation is balanced because there are the same numbers of each type of atom on each side.

What is the respiratory quotient for cellular respiration?

Confidence: 0 | 1 | 2 | 3 | 4

2. The oxidation of a particular fatty acid has the balanced overall chemical equation below.

$$C_{17}H_{35}COOH + 26\ O_2 \rightarrow 18\ CO_2 + 18\ H_2O$$

What is the respiratory quotient when using this fatty acid for energy?

Confidence: 0 | 1 | 2 | 3 | 4

3. Occasionally, an organism may use ethanol for energy. Balance the following equation for the oxidation of ethanol, and hence (or otherwise) determine the respiratory quotient for this case.

$$C_2H_5OH + \_\_\_\_\ O_2 \rightarrow \_\_\_\_\ CO_2 + \_\_\_\_\ H_2O$$

Confidence: 0 | 1 | 2 | 3 | 4

I2. Cells

1. Number the following phases of mitosis (replicative nuclear division) in order.

order	phase	description
	telophase	chromosomes revert to normal nuclear chromatin nuclear envelopes form
	metaphase	mitotic spindle becomes fully formed chromosomes are aligned halfway between centrosomes
	prophase	nuclear chromatin condenses to chromosomes nuclear envelope becomes fragmented
	anaphase	chromosomes split into two arms and move along spindle tubules towards poles
	prometaphase	centrosomes align away from each other mitotic spindle forms between poles where centrosomes are

Confidence: 0 | 1 | 2 | 3 | 4

2. In meiosis (gametogenic nuclear division), there are 2 stages, with similar phases to above. In the first stage (meiosis I), pairs of X-shaped chromosomes link together, align in metaphase while still as pairs, and then separate as individual X-shaped chromosomes. In the second stage (meiosis II), individual X-shaped chromosomes align in metaphase, and then their arms separate as individual linear chromosomes.

1. How many chromosomes are there, in a normal human cell with 23 pairs of chromosomes?

Confidence: 0 | 1 | 2 | 3 | 4

\# 2. After meiosis I of a human germ cell, how many chromosomes are there in each resulting cell?

Confidence: 0 | 1 | 2 | 3 | 4

\# 3. After meiosis II, how many chromosomes are there in each resulting human gamete?

Confidence: 0 | 1 | 2 | 3 | 4

I3. Gene Expression

The "transcription" phase of gene expression involves a letter-by-letter matching from nucleotides of DNA to a new, complementary, mRNA nucleotide sequence. Complementary pairings are shown below.

DNA	T	C	A	G
RNA	A	G	U	C

After transcription of a genetic DNA sequence to mRNA, the mRNA leaves the cell nucleus. Ribosomes outside the nucleus (in the cytoplasm or on rough endoplasmic reticulum) "translate" the mRNA sequence into an amino acid sequence. The genetic code matches 3-base-pair "codons" in the sequence, to amino acids, with the mapping represented in the following table. (Codons are in uppercase; amino acid abbreviations are in lowercase.)

UUU	phe	UCU	ser	UAU	tyr	UGU	cys
UUC	phe	UCC	ser	UAC	tyr	UGC	cys
UUA	leu	UCA	ser	UAA	stop	UGA	stop
UUG	leu	UCG	ser	UAG	stop	UGG	trp
CUU	leu	CCU	pro	CAU	his	CGU	arg
CUC	leu	CCC	pro	CAC	his	CGC	arg
CUA	leu	CCA	pro	CAA	gln	CGA	arg
CUG	leu	CCG	pro	CAG	gln	CGG	arg
AUU	ile	ACU	thr	AAU	asn	AGU	ser
AUC	ile	ACC	thr	AAC	asn	AGC	ser
AUA	ile	ACA	thr	AAA	lys	AGA	arg
AUG	met	ACG	thr	AAG	lys	AGG	arg
GUU	val	GCU	ala	GAU	asp	GGU	gly
GUC	val	GCC	ala	GAC	asp	GGC	gly
GUA	val	GCA	ala	GAA	glu	GGA	gly
GUG	val	GCG	ala	GAG	glu	GGG	gly

Translation begins at the "start" codon, AUG, which also encodes methionine. Translation ends at any one of three "stop" codons, which do not encode any amino acid.

\# 1. Transcribe the following sequence from DNA to RNA.

C T A C C G C T G A G A C T A G C G T T C T A G A T C G T G A A

Confidence: 0 | 1 | 2 | 3 | 4

\# 2. If the above resulting RNA sequence were the starting sequence of some mRNA, what first few amino acids of a protein would it translate to?

Confidence: 0 | 1 | 2 | 3 | 4

3. Consider a mutation resulting in the change of a single mRNA letter from A to G. Which of the following effects could result?

- ☐ The translated amino acid sequence is unchanged.
- ☐ Only one amino acid in the translated sequence will change ("missense").
- ☐ Many amino acids "downstream" of the mutation will change (extensive missense).
- ☐ The mutation causes translation to terminate at its codon ("nonsense").
- ☐ The mutation causes translation to terminate at a downstream codon.
- ☐ The mutation leads to an infinitely long protein.

Confidence: 0 | 1 | 2 | 3 | 4

I4. Genetics

The simplest pattern of inheritance has organisms with paired genetic factors for a variety of traits. When two of these organisms breed together, each of them passes one of each paired factor to each of their offspring. The example below shows how we can represent the different possible combinations of factors for a single trait.

Parent 1 (Ff)

Parent 2 (Ff)		F	f
	F	FF	Ff
	f	Ff	ff

In this example, both parents have "genotype" Ff. Shaded boxes show the possible genotypes for their offspring.

'F' and 'f' are different factors ("alleles") that affect the trait in different ways. If the effect of 'F' overrides the effect of 'f' (for example, 'F' produces a dark pigment and 'f' does not, so any organism with one or two 'F' alleles will be dark), then we say 'F' is "dominant" and 'f' is "recessive". The resulting final effect of the alleles is called the "phenotype".

1. What is the overall expected ratio of offspring with the dominant phenotype, to offspring with the recessive phenotype, for the example where both parents have genotype Ff?

Confidence: 0 | 1 | 2 | 3 | 4

2. If, instead, one parent is heterozygous (has a genotype with different alleles, like Ff) and the other parent is homozygous recessive (ff), what are the possible phenotypes of the offspring, and in what ratio?

Confidence: 0 | 1 | 2 | 3 | 4

3. Consider two separate traits, with alleles A (dominant) and a (recessive) for one and B (dominant) and b (recessive) for the other. What possible phenotypes could the offspring have, when parents heterozygous for both traits breed? In what ratio are these phenotypes? (Hint: fill in the table.)

Parent 1 (   )

Parent 2 ( )		AB	Ab	aB	ab
			AABb		
					Aabb
					aaBb
					aabb

Confidence: 0 | 1 | 2 | 3 | 4

END