Q1 (1 point). Name three amino acids that are typically found at the surface of integrated membrane proteins.

Answer: Hydrophobic amino acids - Alanine, Isoleucine, Leucine, Methionine, Phenylalanine, Tryptophane, Valine.

Q2 (1 point). How many carbon atoms does a glucose molecule contain?

Answer: 6.

Q3 (1 point). What do you call the type of chemical reaction that leads to the generation of macromolecules, e.g., carbohydrates and polypeptides (proteins)?

Answer: Condensation.

Q4 (1 point). Provide three examples of how active transport of ions differs from simple diffusion.

Answer: Examples of correct answers:
- For active transport, the rate of transport is independent of the molecule size
- Active transport requires chemical energy
- Active transport can occur against a concentration gradient
- Active transport can occur over a lipid membrane
- Active transport is selective
- Active transport requires a transmembrane transport protein

Q5 (1 point). What would be the consequence for the Sodium-Potassium pump, if a mutation were to occur, so that the protein could no longer hydrolyze bound ATP?
Answer: ATP will be constantly bound to the transporter along with sodium, so that a conformational change will not be possible. As a consequence, the transporter will be inactive at step 1 (figure 6.16, p. 121)

Q6 (1 point). Explain the concept of activation energy on the molecular level for an enzymatically catalysed reaction. Include an explanation of why the free energy is briefly increased.

Answer: The activation energy is the energy required to initiate the catalyzed reaction. As the substrate binds to the active site, the order of the system increases, which requires energy. This energy is used to change the bindings of the substrate and potentially induce conformational changes in the enzyme sidechains around the substrate. The increased energy makes the catalysis possible, and more energy is released.

Q7 (1 point). How will a gradual increase in temperature affect enzyme activity?

Answer: The increase in temperature will increase the kinetic energy and hence the catalytic ability of the enzyme. However, at some point, the increased temperature will lead to the enzyme denaturating.

Q8 (1 point). How will a gradual decrease in pH typically affect enzyme activity?

Answer: The gradual decrease in pH will protonate carboxyl groups potentially interrupting the active site. Further decrease will destroy salt bridges, the tertiary protein structure, and ultimately the enzyme activity.

Q9 (1 point). Describe what is understood by oxidation and reduction?
Answer: Oxidation = The loss of electron(s) by an atom, ion or molecule. Reduction = The gain of electron(s) by an atom, ion or molecule.

Q10 (1 point). How much energy (mol ATP) per mol glucose can be harvested by:
1) glycolysis followed by fermentation?
2) glycolysis followed by cellular respiration?

Answer: Glycolysis + fermentation = 2 ATP, Glycolysis + cellular respiration = 32 ATP

Q11 (1 point). Choose one of the answers a-e to make the sentence below correct:
Phosphofructokinase, the major flux-controlling enzyme of glycolysis, is allosterically inhibited by ___A___ and activated by ___B___.

a) A = AMP, B = P_i
b) A = ADP, B = AMP
c) A = citrat, B = ATP
d) A = ATP, B = PEP
e) A = ATP, B = ADP

Answer: e) A = ATP, B = ADP; ATP is the inhibitor of phosphofructokinase and ADP and AMP are activators.
Q12 (1 point). Choose one of the answers a-e to make the sentence below correct:
In the metaphase chromosomes, DNA is combined with _____A____, called _____B____, to form structures known as ___C____.

f)  A = proteins, B = nucleoproteines, C = centrosomes  
g)  A = nucleic acids, B = nucleosomes, C = histones  
h)  A = proteins, B = histones, C = nucleosomes  
i)  A = small molecules, B = histones, C = centrioles  
j)  A = proteins, B = nucleosomes, C = histones

Answer: c) proteins; histones; nucleosomes

Q13 (1 point). Look at the DNA sequence below. Fill out the blanks with either a-d. NOTE: One of the answers should not be used.

5’ G T C A A A G G G___C A ___
3’ C A G T T T C C C A G T ___

e) 5’  
f) U  
g) 3’  
h) T

Answer:
5’ G T C A A A G G G_TC A 3’
3’ C A G T T T C C C A G T _5’

Q14 (1 point). What do you call the mitotic phase during which the sister chromatids are separated and move towards the poles of the cell?

Answer: Anaphase.
Q15 (1 point). Mark the sentences below as either true or false.

Linked genes…..

<table>
<thead>
<tr>
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Q16 (1 point). What do you call the phenomenon where the effect of one gene influences the effects of other genes?

Answer: Epistasis
Q17 (1 point). In humans, spotted teeth are caused by a dominant sex-linked gene. A man with spotted teeth marries a woman with normal teeth and they have children. The man’s father had normal teeth. Statistically speaking, what is the proportion of sons and daughters that will have spotted teeth?

Answer: Since we are told that the disease-causing allele is dominant and that the man’s father did not have spotted teeth, the man must have inherited the allele from his mother. Accordingly, it must be placed on the X chromosome (the mother of the man must have had spotted teeth). None of the sons of the couple will have spotted teeth, since they only inherit the father’s Y chromosome. All the daughters will have spotted teeth, since they all inherit the father’s X chromosome carrying the disease-causing allele, which is dominant.

Q18 (1 point). How many origins does a bacterial chromosome contain?

Answer: 1.

Q19 (1 point). DNA from a newly discovered organism contains 17% C (cytosine) and 33% A (adenine). How many percent G (guanine) does the DNA contain?

Answer: 17% (identical to C, since C is complementary to G).

Q20 (1.5 point). If one were to isolate DNA from a eukaryotic cell in the process of replicating, and subsequently heated this DNA in order to separate the two DNA strands, one would be able to observe very long, single-stranded DNA. Additionally, one would be able to observe some short, single-stranded DNA fragments of approximately 100-200 nucleotides. What do you call the short DNA fragments and why are they present during replication?
Answer: The short DNA fragments are called Okazaki fragments. They are present during replication, since the lagging strand is synthesised in fragments following inserted RNA primers. And they are only ligated to continuant strands of DNA at a later time point.

Q21 (1 point). Mark the sentences below as either true or false. The topic is translation.

<table>
<thead>
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Q22 (1 point). Mark the sentences below as either true or false. The topic is the lac operon.

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When lactose binds to the operator, transcription is stimulated.  
When the repressor binds to the operator, transcription is inhibited.  
The repressor can be bound to DNA and lactose at the same time.  
When lactose binds to the repressor, the shape of the repressor is changed.

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Q23 (1 point). What would the consequence be, if one were to add only labelled di-deoxynucleotides, and no unlabelled deoxynucleotides, to a Sanger sequencing reaction? (Explain your reasoning).

Answer: Only the first base would be incorporated, since there would not be any free 3’-OH groups to add additional bases.
Q24 (1 point). Which of the options a-c apply for a eukaryotic organism? Explain your reasoning.

- d) The number of different proteins exceeds the number of different protein coding genes.
- e) The number of different protein coding genes exceeds the number of different proteins.
- f) There is an equal number of proteins and protein coding genes.

**Answer:** a) The number of different proteins exceeds the number of different protein coding genes due to alternative splicing and posttranslational modifications.

Q25 (2 points)
A couple have seven children and decides to voluntarily to participate in a survey were parents, their siblings and their children get their RFLP pattern mapped. The brother to the father only reveals a single band, which might be due to an equal fragment length on both his chromosomes. The father get surprised and rather unsatisfied with the below outcome. Why?

**Answer:** Girl number 6 do not share RFLP fragment with the father, but with the fathers brother.
Q26 (1.5 point).
When recombinant plasmids, exemplified below, are constructed in the laboratory, most often two restriction enzymes are used to digest the plasmid before introducing the new DNA (digested with the same two restriction enzymes) into the mcs (see figure), rather than using only a single restriction enzyme. Why does a plasmid constructed with two restriction enzymes (e.g., EcoR1 and BamH1) result in a higher number of correctly modified clones after transformation of the host cell than a plasmid constructed with only EcoR1, although both plasmids are positively selected by ampicillin and the reporter gene?

Answer: The use of two restriction enzymes ensures that the linear (empty) plasmid cannot self-ligate - it will only ligate to the foreign DNA resulting in a higher rate of positive clones.
Q27 (3 points). Glycolysis initiates the cellular respiratory metabolic pathway in which a hexose, such as glucose, is catabolized. The figure below outlines key stages of the glycolysis.

![Glycolysis Diagram]

i) Where in the cell does glycolysis take place?

*Answer: In the cytosol or cytoplasm.*

ii) Name substance A?

*Answer: Fructose 1,6-bisphosphate.*

iii) Briefly describe what happens to pyruvate in a yeast cell deprived of oxygen.
**Answer:** Under anaerobic conditions in yeast cells, pyruvate from the glycolysis is converted into acetaldehyde and CO₂ is released. NADH(+H⁺) from the glycolysis is used to reduce acetaldehyde to ethanol, thus regenerating NAD⁺ to keep the glycolysis operating.

Q28 (3 point). A new bacterial strain is isolated in Nature. Growth experiments demonstrate that the strain can sustain growth in a simple medium containing either glucose or cellulose. Cellulose is normally difficult to break down and is a main part of the plant material used for bio-ethanol production. The genome of the bacterium is sequenced in the search of genes involved in cellulose breakdown, but no genes have homology (resemble) already known genes encoding proteins for cellulose breakdown.

i) Describe how you would use DNA microarray analysis to identify the genes being differentially upregulated when the bacterium is grown on cellulose.

*Answer: The bacterium is grown in media containing either glucose or cellulose and mRNA is isolated from each culture. The mRNA is formed to cDNA and labelled with two different fluorophors (one for cellulose and one for glucose) before hybridization to the chip surface. Genes upregulated by cellulose will have a strong color from the cellulose-induced mRNA.*

The above DNA microarray experiment identified five genes being more highly expressed when the bacterium is growing on cellulose. The genes are shown to be essential for cellulose supported growth of the bacterium. One of the four genes is found to encode a cellulase (an enzyme hydrolyzing cellulose to short oligosaccharide fragments). Enzyme kinetic investigation of the enzyme shows that the monosaccharide fructose is a competitive inhibitor of the enzyme.

ii) Where does the fructose bind to the enzyme?

*Answer: Fructose binds in the active site, being a competitive inhibitor (p. 162).*
iii) How does the presence of fructose alter the theoretical maximal catalytic rate of the enzyme (Vmax)?

Answer: It doesn’t. The Vmax is unaltered for a competitive inhibitor. The normal substrate will at high concentrations be the only molecule bound in the active site.
Q29 (6 point): A hypothetical disease results in the arms of the patient falling off around the age of 40. The disease, which is autosomal, recessive, is caused by a deletion in the NOARM gene. The figure below shows 480 internal nucleotides in the NOARM gene. In the disease-causing allele, 81 nucleotides, corresponding to allele no. 234-314, is deleted (marked in bold).

You want to design a PCR test to be used for examining if different individuals carry the disease-causing allele.
i) Mark the below sentences as either true or false:

To run PCR you need...

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ii) One of the steps in PCR includes heating of the PCR mixture to app. 95°C. What is the purpose of this?

Answer: The two DNA strands in the DNA molecule will denaturate.
Two primers are designed for the PCR. Their sequence is shown below and their bindingsites in the gene are underlined. (NOTE: primer A binds to the complementary DNA stand that is not shown in the figure).

Primer A: 5’ AGTGAATTGAGCTCGGTACC 3’

Primer B: 3’ AGGAGATCTCAGCTGGACGT 5’

iii) What is the size of the PCR product, if the NOARM gene is as shown in the above figure and does not contain the deletion?

Answer: 127 bp (each primer is 20 bp + number of nucleotides between the two primers (87 bp): 2 * 20 + 87 = 127).

iv) What is the size of the PCR product, if the NOARM gene contains the deletion?

Answer: 46 bp (127 bp – 81 bp).
PCR is performed using DNA from three people (let us call them B, C, and D) as template along with the above primers. The PCR product is afterwards run on a gel. The results are shown in the figure below. In lane A, a ladder with DNA fragments of known size has been run. The size of the fragments are 500 bp, 400 bp, 300 bp, 200 bp, 100 bp, and 50 bp. Lane B-D contains the PCR product produced by PCR with person B, C, and D’s DNA. NOTE: The widths of the different bands are not relevant.

v) Which of the individuals, B, C, or D are likely to loose their arms?

*Answer: C – this person is homozygous for the short, disease-causing allele. Person D is heterozygous and carrying both the normal and the disease-causing allele, but since we are told that the disease-causing allele is recessive, his arms will not fall of.*
The area that is deleted in the disease-causing allele corresponds to the start of the protein-coding region. The three first nucleotides, ATG (position 234-236) are the start codon. The 18 first nucleotides (of the coding strand) are shown below.

5’- ATGATCAATGCAAGGATG - 3’

vi) Translate the above 18 nucleotides to amino acids.

*Answer: M I N A R M (Methionine, Isoleucine, Asparagine, Alanine, Arginine, Methionine)*