**What do I know about Cell Biology?**

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| **Key area 1: Division and differentiation in human cells.** | I know this. | I need to go over this. | I don’t know this. |
| Somatic cells divide by mitosis to form more somatic cells. |  |  |  |
| Cellular differentiation is the process by which a cell develops more specialised functions by expressing the genes characteristic for that type of cell. |  |  |  |
| Once a cell becomes differentiated it only expresses the genes that produce the proteins characteristic for that type of cell. |  |  |  |
| Stem cells are unspecialised somatic cells that can divide to make copies of themselves (self-renew) and/or differentiate into specialised cells. |  |  |  |
| Tissue (adult) stem cells are involved in the growth, repair and renewal of the cells found in that tissue. They are multipotent. |  |  |  |
| Tissue stem cells are multipotent as they can make all of the cell types found in a particular tissue type. For example, blood (haematopoietic) stem cells can make all of the cell types in the blood. |  |  |  |
| The main body tissue types are epithelial, connective, muscle and nerve tissue. The body organs are formed from a variety of these tissues. |  |  |  |
| Development of tissue (adult) stem cells in bone marrow into red blood cells, platelets and the various forms of phagocytes and lymphocytes. |  |  |  |
| Epithelial cells cover the body surface and line body cavities, connective tissue includes blood, bone and cartilage cells, muscle cells form muscle tissue and nerve cells form nervous tissue. |  |  |  |
| The cells of the early embryo can make all of the differentiated cell types of the body. They are pluripotent. |  |  |  |
| The inner cell mass cells of an early embryo (blastocyst stage) are pluripotent as they can make nearly all of the cell types in the body. |  |  |  |
| When grown in the lab scientists call these embryonic stem cells. |  |  |  |
| These cells can self-renew, under the right conditions, in the lab. It is then they are termed embryonic stem cells. |  |  |  |
| Germline cells divide by mitosis to produce more germline cells or by meiosis to produce haploid gametes. |  |  |  |
| Mutations in germline cells are passed to offspring. |  |  |  |
| During cell division the nucleus of a somatic cell divides by mitosis to maintain the diploid chromosome number. |  |  |  |
| Diploid cells have 23 pairs of homologous chromosomes. |  |  |  |
| Research and therapeutic uses of stem cells by reference to the repair of damaged or diseased organs or tissues |  |  |  |
| Stem cells can also be used as model cells to study how diseases develop or for drug testing. |  |  |  |
| The ethical issues of stem cell use and the regulation of their use. |  |  |  |
| Stem cell research provides information on how cell processes such as cell growth, differentiation and gene regulation work |  |  |  |
| The therapeutic uses of stem cells should be exemplified by reference to the repair of diseased or damaged organs, eg corneal transplants and skin grafts for burns. |  |  |  |
| Cancer cells divide excessively to produce a mass of abnormal cells (called a tumour). |  |  |  |
| These cells do not respond to regulatory signals and may fail to attach to each other. If the cancer cells fail to attach to each other they can spread through the body to form secondary tumours. |  |  |  |
| **Key area 2: Structure and replication of DNA** | I know this. | I need to go over this. | I don’t know this. |
| Structure of DNA — nucleotides contain deoxyribose sugar, phosphate and base. |  |  |  |
| DNA has a sugar–phosphate backbone, complementary base pairing — adenine with thymine and guanine with cytosine. |  |  |  |
| The two DNA strands are held together by hydrogen bonds and have an antiparallel structure, with deoxyribose and phosphate at 3' and 5' ends of each strand. |  |  |  |
| All cells store their genetic information in the base sequence of DNA. |  |  |  |
| The genotype is determined by the sequence of DNA bases. DNA is the molecule of inheritance and can direct its own replication. |  |  |  |
| Chromosomes consist of tightly coiled DNA and are packaged with associated proteins. |  |  |  |
| Prior to cell division, DNA is replicated by a DNA polymerase. This process occurs at several locations on a DNA molecule. |  |  |  |
| Replication of DNA by DNA polymerase and primer. DNA is unwound and unzipped to form two template strands. DNA polymerase needs a primer to start replication and can only add complementary DNA nucleotides to the deoxyribose (3') end of a DNA strand. This results in one strand being replicated continuously and the other strand replicated in fragments which are joined together by ligase. |  |  |  |
| **Key area 3: Gene expression** | I know this. | I need to go over this. | I don’t know this. |
| Phenotype is determined by the proteins produced as the result of gene expression. |  |  |  |
| Only a fraction of the genes in a cell are expressed. |  |  |  |
| Gene expression is influenced by intra- and extra-cellular environmental factors |  |  |  |
| Gene expression is controlled by the regulation of both transcription and translation. |  |  |  |
| Structure and functions of RNA. RNA is single stranded, contains uracil instead of thymine and ribose instead of deoxyribose sugar. |  |  |  |
| Messenger RNA (mRNA) carries a copy of the DNA code from the nucleus to the ribosome. |  |  |  |
| Ribosomal RNA (rRNA) and proteins form the ribosome. |  |  |  |
| Each transfer RNA (tRNA) carries a specific amino acid. |  |  |  |
| Transcription of DNA into primary and mature RNA transcripts in the nucleus. This should include the role of RNA polymerase and complementary base pairing. |  |  |  |
| mRNA is transcribed from DNA in the nucleus and translated into proteins by ribosomes in the cytoplasm. RNA polymerase moves along DNA unwinding and unzipping the double helix and synthesising a primary transcript of RNA by complementary base pairing. Genes have introns (non -coding regions of genes) and exons (coding regions of genes). |  |  |  |
| The introns of the primary transcript of mRNA are non -coding and are removed in RNA splicing. The exons are coding regions and are joined together to form mature transcript. This process is called RNA splicing. |  |  |  |
| Translation of mRNA into a polypeptide by tRNA at the ribosome. tRNA folds due to base pairing to form a triplet anticodon site and an attachment site for a specific amino acid |  |  |  |
| Triplet codons on mRNA and anticodons translate the genetic code into a sequence of amino acids. |  |  |  |
| Start and stop codons exist. |  |  |  |
| Codon recognition of incoming tRNA, peptide bond formation and exit of tRNA from the ribosome as polypeptide is formed. |  |  |  |
| Different proteins can be expressed from one gene as a result of alternative RNA splicing and post -translational modification. |  |  |  |
| Different mRNA molecules are produced from the same primary transcript depending on which RNA segments are treated as exons and introns. |  |  |  |
| Post -translation protein structure modification by cutting and combining polypeptide chains or by adding phosphate or carbohydrate groups to the protein. |  |  |  |
| **Key area 4: Genes and proteins in health and disease** | I know this. | I need to go over this. | I don’t know this. |
| Proteins are held in a three dimensional shape by peptide bonds, hydrogen bonds, interactions between individual amino acids. |  |  |  |
| Proteins have a large variety of structures and shapes resulting in a wide range of functions. |  |  |  |
| Polypeptide chains fold to form the three dimensional shape of the protein. |  |  |  |
| Amino acids are linked by peptide bonds to form polypeptides. |  |  |  |
| Mutations result in no protein or a faulty protein being expressed. |  |  |  |
| Genetic disorders are caused by changes to genes or chromosomes that result in the proteins not being expressed or the proteins expressed not functioning correctly |  |  |  |
| Single gene mutations involve the alteration of a DNA nucleotide sequence as a result of the substitution, insertion or deletion of nucleotides. |  |  |  |
| Nature of single-nucleotide substitutions including: missense, nonsense and splice-site mutations. Missense (replacing one amino acid codon with another), nonsense (replacing an amino acid codon with a premature stop codon — no amino acid is made and the process stops) and splice-site mutations (creating or destroying the codons for exon/intron splicing). |  |  |  |
| Nucleotide insertions or deletions result in frame-shift mutations or an expansion of a nucleotide sequence repeat. |  |  |  |
| The effect of these mutations on the structure and function of the protein synthesised and the resulting effects on health. |  |  |  |
| Chromosome structure mutations. The structure of a chromosome can be altered. These mutations can take the form of a deletion (loss of a segment of a chromosome), duplication (repeat of as egment of a chromosome) or translocation (the rearrangement of chromosomal material involving two or more chromosomes). |  |  |  |
| **Key area 5: Human genomics** | I know this. | I need to go over this. | I don’t know this. |
| Bioinformatics is the use of computer technology to identify DNA sequences. |  |  |  |
| The sequence of bases can be determined for individual genes and entire genomes. |  |  |  |
| The enormous amount of data produced by DNA and protein sequencing can be managed and analysed using computer technology and shared over the internet. |  |  |  |
| Computer programs can be used to identify gene sequences by looking for coding sequences similar to known genes, start sequences or sequences lacking stop codons. |  |  |  |
| Computer programs can be used to identify base sequences that correspond to the amino acid sequence of a protein. |  |  |  |
| Systematics compares human genome sequence data and genomes of other species to provide information on evolutionary relationships and origins. |  |  |  |
| Personalised medicine is based on an individual’s genome. Analysis of an individual’s genome may lead to personalised medicine through understanding the genetic component of risk of disease. |  |  |  |
| The importance of distinguishing between neutral and harmful mutations and the complex nature of many diseases. |  |  |  |
| Pharmacogenetics and the use of genome information in the choice of effective drugs |  |  |  |
| The polymerase chain reaction (PCR) is a technique for the amplification of DNA in vitro. |  |  |  |
| Amplification and detection of DNA sequences. Polymerase Chain Reaction (PCR) amplification of DNA using complementary primers for specific target sequences. DNA heated to separate strands then cooled for primer binding. Heat-tolerant DNA polymerase then replicates the region of DNA. Repeated cycles of heating and cooling amplify this region of DNA. |  |  |  |
| In PCR, primers are complementary to specific target sequences at the two ends of the region to be amplified. Cooling allows primers to bind to target sequences. |  |  |  |
| Arrays of DNA probes are used to detect the presence of specific sequences in samples of DNA. The probes are short single stranded fragments of DNA that are complementary to a specific sequence. Fluorescent labelling allows detection. |  |  |  |
| Applications of DNA profiling allow the identification of individuals through comparison of regions of the genome with highly variable numbers of repetitive sequences of DNA. |  |  |  |
| By screening a cell sample from a patient for the presence or absence of a particular sequence, a diagnosis of disease status or risk of disease onset can be made. |  |  |  |
| **Key are 6: Metabolic pathways** | I know this. | I need to go over this. | I don’t know this. |
| Metabolism encompasses the integrated and controlled pathways of enzyme catalysed reactions within a cell. |  |  |  |
| Anabolic pathways require energy and involve biosynthetic processes. |  |  |  |
| Catabolic pathways release energy and involve the breakdown of molecules. |  |  |  |
| These pathways can have reversible and irreversible steps and alternative routes. |  |  |  |
| Metabolic pathways may exist that can bypass steps in a pathway |  |  |  |
| Control of metabolic pathways — presence or absence of particular enzymes and the regulation of the rate of reaction of key enzymes within the pathway. Regulation can be controlled by intra and extracellular signal molecules. |  |  |  |
| Metabolic pathways are controlled by the presence or absence of particular enzymes in the metabolic pathway and through the regulation of the rate of reaction of key enzymes within the pathway. |  |  |  |
| Genes for some enzymes are continuously expressed. These enzymes are always present in the cell and their control involves regulation of their rate of reaction. |  |  |  |
| Most metabolic reactions are reversible and the presence of a substrate or the removal of a product will drive a sequence of reactions in a particular direction. |  |  |  |
| Induced fit and the role of the active site of enzymes including shape and substrate affinity. Activation energy. |  |  |  |
| The role of the active site in orientating reactants, lowering the activation energy of the transition state and the release of products with low affinity for the active site. |  |  |  |
| The effects of substrate and end product concentration on the direction and rate of enzyme reactions. |  |  |  |
| Enzymes often act in groups or as multi-enzyme complexes. |  |  |  |
| Control of metabolic pathways through competitive (binds to active site), noncompetitive (changes shape of active site) and feedback inhibition (end product binds to an enzyme that catalyses a reaction early in the pathway) |  |  |  |
| Competitive inhibition can be reversed by increasing substrate concentration. |  |  |  |
| **Key area 7: Cellular respiration** | I know this. | I need to go over this. | I don’t know this. |
| Glucose broken down, removal of hydrogen ions and electrons by dehydrogenase enzymes releasing ATP. |  |  |  |
| The metabolic pathways of cellular respiration are central to metabolism. They yield energy and are connected to many other pathways. |  |  |  |
| The role of ATP in the transfer of energy and the phosphorylation of molecules by ATP. |  |  |  |
| ATP is used to transfer energy to synthetic pathways and other cellular processes where energy is required. |  |  |  |
| Metabolic pathways of cellular respiration. The breakdown of glucose to pyruvate in the cytoplasm in glycolysis, and the progression pathways in the presence or absence of oxygen (fermentation). |  |  |  |
| The phosphorylation of intermediates in glycolysis in an energy investment phase and the direct generation of ATP in an energy pay-off stage. The role of the enzyme phosphofructokinase in this pathway. |  |  |  |
| The first phosphorylation leads to a product that can continue to a number of pathways and the second phosphorylation, catalysed by phosphofructokinase, is an irreversible reaction leading only to the glycolytic pathway. Pyruvate progresses to the citric acid cycle if oxygen is available. |  |  |  |
| The formation of citrate. Pyruvate is broken down to an acetyl group that combines with coenzyme A to be transferred to the citric acid cycle as acetyl coenzyme A. Acetyl (coenzyme A) combines with oxaloacetate to form citrate followed by the enzyme mediated steps of the cycle. This cycle results in the generation of ATP, the release of carbon dioxide and the regeneration of oxaloacetate in the matrix of the mitochondria. |  |  |  |
| Dehydrogenase enzymes remove hydrogen ions and electrons which are passed to the coenzymes NAD or FAD to form NADH or FADH2 in glycolysis and citric acid pathways. NADH and FADH2 release the high-energy electrons to the electron transport chain on the mitochondrial membrane and this results in the synthesis of the bulk of the ATP. |  |  |  |
| The electron transport chain as a collection of proteins attached to a membrane. NADH and FADH2 release the high-energy electrons to the electron transport chain where they pass along the chain, releasing energy. The energy is used to pump H ions across the inner mitochondrial membrane. The return flow of H ions drives ATP synthase and produces the bulk of the ATP generated by cellular respiration. |  |  |  |
| ATP synthesis — high energy electrons are used to pump hydrogen ions across a membrane and flow of these ions back through the membrane synthesises ATP using the membrane protein ATP synthase. |  |  |  |
| The return flow of these ions rotates part of the membrane protein ATP synthase, catalysing the synthesis of ATP. |  |  |  |
| The final electron acceptor is oxygen, which combines with hydrogen ions and electrons to form water. |  |  |  |
| Substrates for respiration. The role of starch, glycogen, other sugar molecules, amino acids and fats in the respiratory pathway. |  |  |  |
| Starch and glycogen are broken down to glucose for use as a respiratory substrate. Other sugar molecules can be converted to glucose or glycolysis intermediates for use as respiratory substrates. |  |  |  |
| Proteins can be broken down to amino acids and converted to intermediates of glycolysis and the citric acid cycle for use as respiratory substrates. |  |  |  |
| Fats can also be broken down to intermediates of glycolysis and the citric acid cycle |  |  |  |
| Regulation of the pathways of cellular respiration by feedback inhibition — regulation of ATP production, by inhibition of phosphofructokinase by ATP and citrate, synchronisation of rates of glycolysis and citric acid cycle. |  |  |  |
| The cell conserves its resources by only producing ATP when required. |  |  |  |
| The cell conserves its resources by only producing ATP when required. ATP supply increases with increasing rates of glycolysis and the citric acid cycle, and decreases when these pathways slow down. If the cell produces more ATP than it needs, the ATP inhibits the action of phosphofructokinase slowing the rate of glycolysis. The rates of glycolysis and the citric acid cycle are synchronised by the inhibition of phosphofructokinase by citrate. If citrate accumulates, glycolysis slows down and when citrate consumption increases glycolysis increases the supply of acetyl groups to the citric acid cycle. |  |  |  |
| **Key area 8: Energy systems in muscle cells** | I know this. | I need to go over this. | I don’t know this. |
| Creatine phosphate breaks down to release energy and phosphate that is used to convert ADP to ATP at a fast rate. This system can only support strenuous muscle activity for around 10 seconds, when the creatine phosphate supply runs out. It is restored when energy demands are low |  |  |  |
| During strenuous muscle activity the cell rapidly breaks down its reserves of ATP to release energy. |  |  |  |
| Muscle cells have an additional source of energy in creatine phosphate that can be used to replenish ATP pools during rigorous bouts of exercise. This system can only support strenuous muscle activity for around 10 seconds, when the creatine phosphate supply runs out. |  |  |  |
| When muscle energy demand is low, ATP from cellular respiration is used to restore the levels creatine phosphate. |  |  |  |
| Lactic acid metabolism. Oxygen deficiency, conversion of pyruvate to lactic acid, muscle fatigue, oxygen debt. |  |  |  |
| During vigorous exercise, the muscle cells do not get sufficient oxygen to support the electron transport chain. Under these conditions, pyruvate is converted to lactic acid. This conversion involves the transfer of hydrogen from the NADH produced during glycolysis to pyruvic acid to produce lactic acid. This regenerates the NAD needed to maintain ATP production through glycolysis. |  |  |  |
| Lactic acid accumulates in muscle causing fatigue. Oxygen debt repaid when exercise is complete allows respiration to provide the energy to convert lactic acid back to pyruvic acid and glucose in the liver. |  |  |  |
| Slow twitch (Type 1) muscle fibres contract more slowly, but can sustain contractions for longer and so are good for endurance activities. |  |  |  |
| Slow twitch muscle fibres are good for endurance activities like long distance running, cycling or cross-country skiing. Slow twitch muscle fibres rely on aerobic respiration to generate ATP and have many mitochondria, a large blood supply and a high concentration of the oxygen storing protein myoglobin. The major storage fuel of slow twitch muscles fibres is fats. |  |  |  |
| Fast twitch (Type 2) muscle fibres contract more quickly, over short periods, so are good for bursts of activity. |  |  |  |
| Fast twitch muscle fibres are good for activities like sprinting or weightlifting. Fast twitch muscle fibres can generate ATP through glycolysis only and have few mitochondria and a lower blood supply than slow twitch muscle fibres. The major storage fuels of fast twitch muscles fibres are glycogen and creatine phosphate. Most human muscle tissue contains a mixture of both slow and fast twitch muscle fibres. Athletes show distinct patterns of muscle fibres that reflect their sporting activities. |  |  |  |