Cell & Molecular Biology Concept List
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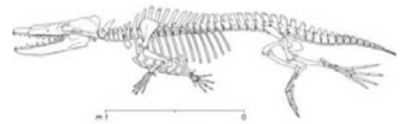

Course title:

Institution:

Semester:
Year:
Instructor:

Are you / where you...

- ❑ **The instructor of the course**
- ❑ **A teaching assistant in the course**
- ❑ **A student taking the course**

While not exhaustive (and we would appreciate it if you would concept statements below if you cover them and they are not listed), the list will enable you to make explicit to yourself, your teaching assistants and your students, which concepts you intend to cover.

It will also enable your teaching assistants (and students) to indicate what concepts they thought you covered.

Concept statements you should add to your list:

We would very much like to get a copy of your list, since this list can be more informative than the typical syllabus. Please mail or email it to us at
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CONCEPT STATEMENT AREA	**emphasized**	**Mentioned**	**Not covered**
Bioenergetics – 26 Questions			
1. Living organisms contain the information necessary to replicate themselves and metabolic machinery that allows them to do so at the expense of energy and raw materials from their environment.	❏	❏	❏
2.The **cell** is the basic unit of living organisms.	❏	❏	❏
3. **Virions,** free form of **viruses,** are not alive, because they lack metabolic machinery. To replicate themselves, they must invade and parasitize cells.	❏	❏	❏
4. Cells are bounded systems of interacting chemical reactions. The rate of each reaction is controlled by a **catalyst** (either an **enzyme** or a **ribozyme**).	❏	❏	❏
5. **Metabolism** is the sum of all of the chemical reactions that occur within a particularly living system.	❏	❏	❏
6.Cells are **non-equilibrium** systems; they depend upon a continual influx of **energy,** and they increase the **entropy** of their environment.	❏	❏	❏
7.Living organisms obey all of the laws of **thermodynamics**.	❏	❏	❏
8. In an **oxidation-reduction reaction**, electrons are transferred from one molecule to another. The molecule that loses electrons is **oxidized**, and the molecule that gains electrons is **reduced.**	❏	❏	❏
9. The addition of electrons to a molecule may increase its **free energy** (energy that can do biochemical work).	❏	❏	❏
10.Under the conditions that normally exist within a cell, energy can be stored by **reducing** molecules and released by **oxidizing** them.	❏	❏	❏
11. The **rate** of a reaction is determined by the rate of the step in the reaction with the highest **activation energy** (the rate-limiting step).	❏	❏	❏
12. Reactions that result in an overall decrease in free energy are **energetically favorable** and will proceed spontaneously. Reactions that result in an increase in free energy are energetically unfavorable and will not proceed spontaneously.	❏	❏	❏
13. An energetically favorable reaction can be **coupled** through **common intermediates** to an energetically unfavorable reactions. If the two reactions result in a net decrease in free energy, then the favorable reaction will drive the unfavorable one to proceed.	❏	❏	❏
14. The **equilibrium constant** of a reaction indicates the relative concentrations of reactants and products when the reaction reaches **equilibrium.**	❏	❏	❏

Bioenergetics – continued			
15. The equilibrium constant does not predict the rate at which the reaction will proceed to equilibrium, which depends on the **activation energy** of the reaction.	❑	❑	❑
16. A **catalyst** reduces the activation energy of a reaction.	❑	❑	❑
17.Biological catalysts are either proteins (**enzymes**), RNAs (**ribozymes**) or macromolecules complexes (e.g. the **ribosome** and the **splicesome**) that contain both polypeptides and RNAs.	❑	❑	❑
18. The **energy** of visible light can be captured by cells using **pigments**, associated with **proteins** that **absorb** these **wavelengths** of light.	❑	❑	❑
19. When light is absorbed by a molecule, an **electron** moves into a higher energy state. The electron is said to be **excited**. When the electron relaxes the energy released can excite an electron in another molecule, be emitted as a photon (**fluorescence**) or transformed into molecular motion (**heat**).	❑	❑	❑
20. An **electron transport chain** (ETC) is a series of membrane proteins.	❑	❑	❑
21. As an excited electron moves through an electron transport chain, the components of the electron transport chain undergo sequential **oxidation** and **reduction**.	❑	❑	❑
22. As electrons move through an electron transport chain, H^+ ions are pumped across a membrane, generating a H+ **gradient**.	❑	❑	❑
23. **Adenosine triphosphate** (ATP) is a major storage form of chemical energy within cells.	❑	❑	❑
24. ATP can be generated from **adenosine diphosphate** (ADP) and **phosphate** as H^+ ions move through the membrane-protein **ATP synthase**, an enzyme.	❑	❑	❑
25. The **hydrolysis** of ATP into ADP and phosphate can be used to generate ion gradients across membranes.	❑	❑	❑
26. A non-equilibrium situation, for example the existence of a high concentration of protons on one side of a membrane and a low concentration on the other, provides an opportunity for cells to capture energy to do metabolic work.	❑	❑	❑
Water and Membranes– 10 statements			
1. Hydrogen-bonding between water molecules is the cause of water's unique physiochemical properties. A water molecule can interact with four neighboring water molecules.	❑	❑	❑

Water and Membranes– continued			
2. Molecules that cannot make H-bonds are insoluble in water. The larger such a molecule, the more insoluble. Such molecules are termed **hydrophobic**.	❑	❑	❑
3. **Lipids** are molecules that contain two domains, one capable of making H-bonds, the other not. The ability to make H-bonds makes a region **hydrophilic**. They are **amphipathic**.	❑	❑	❑
4. When dispersed into **aqueous solvent**, lipids can self-assemble into higher order structures such as **micelles** and **bilayers**. In these states, the lipid's **hydrophilic** domain interacts with water while its **hydrophobic** domain(s) are removed from contact with water.	❑	❑	❑
5. The primary boundary layer of a cell, the **plasma membrane**, is based on the ability lipids to self-assemble.	❑	❑	❑
6. The plasma membrane poses a barrier to the movement of hydrophilic molecules into and out of the cell.	❑	❑	❑
7. **Proteins** within the plasma membrane regulate molecular movements into and out of the cell.	❑	❑	❑
8. Within the plasma membrane is a concentrated solution of proteins and other small and macromolecules, the **cytoplasm**.	❑	❑	❑
9. Energy can be stored in the form of **chemical gradients** across the membranes.	❑	❑	❑
10. The high concentration of cytoplasmic components leads to a lower concentration of water within the cell, compared to outside the cell. This produces **osmotic effects** across the plasma membrane.	❑	❑	❑
Polypeptide Basics – 12 statements			
1. A **polypeptide** is a linear polymer of amino acids, linked together by **peptide bonds**.	❑	❑	❑
2. **Proteins** are functional entities composed primarily of polypeptides and often non-polypeptide cofactors. A protein without its co-factors is known as an **apoprotein**.	❑	❑	❑
3. All terrestrial organisms use the same set of 19 **L-form amino acids** and 1 **imino acid, proline**.	❑	❑	❑

Polypeptide Basics – continued			
4. **Translation** is the process by which polypeptides are synthesized based on information carried in an **mRNA** sequence, a **tRNA** adaptor. This reaction is catalyzed by the **ribosome**.	❑	❑	❑
5. All terrestrial organisms, with a few minor exceptions, use exactly the same the **genetic code** to specify polypeptide sequences synthesized by the process of translation. The exceptions primarily involved the use of stop codons to encode amino acids and the reassignment of a few codons to different amino acids.	❑	❑	❑
6.The ubiquity of the genetic code indicates that it was a trait present in the last common ancestor of all organisms.	❑	❑	❑
7. The presence of minor variations in the genetic code suggests that it is not a predetermined, obligate feature of the translation process, but an inherited trait.	❑	❑	❑
8. **Amino acids** are linked together in a condensation reaction that leads to the formation of a **peptide bond**.	❑	❑	❑
9. During translation, new amino acids are added to the –COOH (C) terminus of the growing polypeptide chain.	❑	❑	❑
10. A functional protein can consist of one or more polypeptides.	❑	❑	❑
11. A specific polypeptide can be part of more than one protein.	❑	❑	❑
12. Amino acids are distinguished by the "R" groups, which attach to the alpha C. These R groups of different sizes: some are hydrophobic, hydrophilic, positive or negatively charged at physiological pH.	❑	❑	❑
Protein Activities – 8 Questions			
1. Protein function or activity can be regulated by the binding of other polypeptides or small molecules; this binding leads to a change in protein structure.	❑	❑	❑
2. Protein function or activity can be regulated by **post-translational modifications** that lead to changes in protein structure.	❑	❑	❑
3. Protein function or activity can be regulated by interactions between proteins.	❑	❑	❑

Protein Activities – continued			
4.Most post-translational modifications are reversible and regulated.	❑	❑	❑
5. Some proteins are post-translationally modified by coupling to a lipid molecule -- such modifications regulate a protein's localization within the cell.	❑	❑	❑
6. Post-translational addition of the small polypeptide **ubiquitin** is often used to target proteins for proteolytic degradation by the proteosome.	❑	❑	❑
7. The concentration and net activity of the protein can be regulated by both the rate of its synthesis, assembly and degradation.	❑	❑	❑
8. **Allostery** involves the regulation of protein function by molecules that bind to sites other than the protein's active site.	❑	❑	❑
Protein Folding & Targeting - 12 statements			
1. In aqueous solution, **polypeptides** will fold to minimize the interactions between their hydrophobic R-groups with water.	❑	❑	❑
2. Generally this leads to a compact globular, rather than an extended, structure.	❑	❑	❑
3. Generally, the **native** (functional) state of a protein is the state of lowest free energy.	❑	❑	❑
4. **Chaperones** facilitate the process by which a polypeptide folds into its native state, primarily by unfolding incorrectly folded polypeptides.	❑	❑	❑
5. **Chaperones** recognize incorrectly folded polypeptides by the fact that they have display hydrophobic R-groups on their surface.	❑	❑	❑
6. Some chaperones catalyze **proline-peptide bond isomerization** or break cysteine disulphide bonds, thereby facilitating correct polypeptide folding.	❑	❑	❑
7. Some chaperones can mediate the assembly of multipolypeptide proteins by binding and stabilizing polypeptides prior to their assembly with the 'final' partners.	❑	❑	❑
8. The process of protein folding begins as the newly synthesized polypeptide emerges from the **ribosomal tunnel**; before that folding is sterically suppressed.	❑	❑	❑

Protein Folding & Targeting - continued			
9. H-bonds that form between the -C=O and -NH groups of the peptide bond are responsible for the common secondary structural motifs of proteins, **α helices** and **β-sheets**.	❑	❑	❑
10. In an α helix, the R-groups of the amino acid residues point outward, perpendicular to the helix axis. In a β-sheet, the R-groups alternate in pointing above and below the plane of the sheet.	❑	❑	❑
11. The synthesis of all polypeptide begins in the cytoplasm. For many proteins that are inserted into the plasma (or internal cellular membranes), translation is regulated by specific signals.	❑	❑	❑
12. Polypeptides and proteins are targeted to specific cellular compartments but signals encoded in their structure. In some cases these signals are cleaved away once the polypeptide reaches its target.	❑	❑	❑
Nucleic Acids & Genes– 16 statements			
1. All organism store genetic information in molecules of double-stranded **deoxyribonucleic acid** (DNA).	❑	❑	❑
2.Some viruses use single stranded DNA, single- or double-stranded **ribonucleic acid** (RNA) rather than double-stranded DNA to store genetic information.	❑	❑	❑
3. DNA differs from RNA in that the hydroxyl group on the C2 carbon of ribose is replaced by a -H. Instead of **uracil** (in RNA), DNA contain **thymine**.	❑	❑	❑
4. In both DNA and RNA, information is stored in the sequence of the nucleotides along the length of the molecule.	❑	❑	❑
5. Each strand of a DNA double helix is a **polynucleotide molecule**, composed of deoxynucleotide subunits.	❑	❑	❑
6. A **deoxyribonucleotide** consists of a phosphate group, attached to the 5’ carbon of the sugar deoxyribose. One of four nitrogenous ‘bases’, either a purine (cytosine or thymine) or a pyrimidine (guanine or adenine), is attached to the 1’ carbon of the sugar. In a **ribonucleotide**, the sugar ribose and the purine uracil is used instead of thymine are used)	❑	❑	❑
7. The chains in a double stranded DNA molecule are **anti-parallel** and **complementary**. If there is an adenine residue on one chain, there is a thymine residue on the other. Similarly, if there is a cytosine on one chain, the other chain contains a guanine residue.	❑	❑	❑

Nucleic Acids & Genes– continued			
8.These **base pairs** interact through **hydrogen bonds**, three between C and G, two between A and T.	❑	❑	❑
9. Both DNA and RNA are synthesized using **nucleotide triphosphates**. These are added the 3' OH group of the sugar (deoxyribose or ribose), creating a phosphodiester bond and releasing pyrophosphate	❑	❑	❑
10. The enzymes that mediate DNA synthesis require a pre-existing nucleic acid **primer** to add on to.	❑	❑	❑
11. Both DNA and most RNA polymerases use a nucleic acid template to determine the sequence of nucleotides in the newly synthesized molecule. An exception, **polyA polymerase**, mediates the addition of AAA(n) to mRNAs.	❑	❑	❑
12. During **DNA replication** and **RNA transcription**, the two strands of a double-stranded DNA molecule must separated so that they can be used as the **templates** for the synthesis of a new nucleic acid strand. Replication uses both strands, transcription one.	❑	❑	❑
13. DNA is used only to store information, RNA can both store information and perform structural/catalytic functions.	❑	❑	❑
14. The information stored in DNA is used in two distinct ways. First, sequences along the DNA are recognized by **regulatory factors**, mostly proteins, that bind to specific nucleotide sequences and determine which regions of the DNA are **transcribed** into RNA. Second, sequences of DNA are **transcribed** into RNA.	❑	❑	❑
15.A gene can be defined as the region of DNA that contains the sequences transcribed to produce the gene product and regulatory sequences that control transcription.	❑	❑	❑
16. Changes in the nucleotide sequence of a gene can change when, where, how much and the type of gene product produced.	❑	❑	❑
RNA - 8 Statements			
1. To be used by the cell, DNA is transcribed into **ribonucleic acid** (RNA).	❑	❑	❑
2. RNA is synthesized by a **DNA-dependent RNA polymerase** using ribonucleotides.	❑	❑	❑
3. A ribonucleotide consists of a phosphate group, attached to the 5′ carbon of the sugar ribose. One of four nitrogenous 'bases', either a **pyrimidine**(cytosine or uracil) or a **purine** (guanine or adenine), is attached to the 1′ carbon of the sugar.	❑	❑	❑

RNA - continued			
4. RNAs can perform many functions: structural, catalytic, informational and regulative. Translation involves **mRNA**, **tRNA** and the RNAs of the ribosome.	❑	❑	❑
5. The enzymes that mediate RNA synthesis can synthesize RNA *de novo* that is without a primer.	❑	❑	❑
6. After their synthesis (**transcription**), RNA can be modified in various ways, for example by **splicing**, 5' inverted G **cap addition**, RNA **editing** and **post-transcriptional modification** of the nucleotide bases.	❑	❑	❑
7. Given their ability to both template their own replication and to act as catalysts, RNAs are often assumed to have played a key roll in the origins of life. This is so-called **RNA world** hypothesis.	❑	❑	❑
8. A ribosomal RNA catalyses peptide bond formation during mRNA/tRNA-based translation on ribosomes.	❑	❑	❑
Cellular Basics – 13 Statements			
1. Cells are bounded by a plasma membrane, composed of lipids and proteins.	❑	❑	❑
2.Within the boundary defined by the plasma membrane there is a concentrated solution of macromolecules (RNAs, proteins), macromolecular complexes (ribosomes, proteosomes) and organelles (in eukaryotes - mitochondria, endoplasmic reticulum, Golgi apparatus, peroxisomes, lysosomes | in plants - chloroplasts).	❑	❑	❑
3.The cytoplasm is the site of protein synthesis (via ribosomes, tRNAs and mRNAs) and a wide array of basic metabolic reactions.	❑	❑	❑
4.As polypeptides are synthesized, they often interact with cytoplasmic factors (chaperones) that facilitated their correct folding.	❑	❑	❑
5.Chaperones can also facilitated the correct folding of proteins that become unfolded.	❑	❑	❑
6. Without further information, a newly synthesized polypeptide will end up in the cytoplasm. In most cases, specific 'targeting' sequences are used to direct a polypeptide other cellular targets (for example the nucleus, mitochondria, endoplasmic reticulum).	❑	❑	❑

Cellular Basics – continued			
7. Without further information, a newly synthesized polypeptide will end up in the cytoplasm. In most cases, specific 'targeting' sequences are used to direct a polypeptide other cellular targets (for example the nucleus, mitochondria, endoplasmic reticulum).	❑	❑	❑
8. Aberrantly folded polypeptides are degraded by specific proteolytic complexes, for example proteosomes.	❑	❑	❑
9. Controlling the lifetime of an RNA or polypeptide is an important regulatory mechanism. polypeptides. Specific signaling within RNAs and polypeptides are used to target these macromolecules for degradation.	❑	❑	❑
10. Whether a macromolecule is stable or degraded can be regulated, as can its location within a cell.	❑	❑	❑
11. Proteins that are secreted by the cell are first targeted to the endoplasmic reticulum.	❑	❑	❑
12. Cells internalize extracellular macromolecules through the process of endocytosis.	❑	❑	❑
13. Lysosomes are intracellular organelles that contain hydrolases, which function in the degradation of extracellular macromolecules that have been endocytosed.	❑	❑	❑
Cell Division, Differentiation & Death – 12 statements			
1.All cells are derived from preexisting cells by the process of cell division. Cells die either because they are damaged (**necrosis**) or by the active process of programmed cells death (**apoptosis**).	❑	❑	❑
2.During typical cell division, the two daughter cells can receive the same number of chromosomes as were present in the mother cells (**mitosis**) or half the number of chromosomes (**meiosis**).	❑	❑	❑
3.In eukaryotic cells, the processes of **chromosome segregation** (mitosis and meiosis) are mediated by a macromolecular machine, the **spindle**. The spindle is composed of **microtubules**, microtubule-associated and chromosome-associated proteins.	❑	❑	❑
4.In eukaryotic cells, the process of cell division (**cytokinesis**) is mediated by a macromolecular machine, the **cleavage furrow** in animal cells and the **phragmoplast** in plants. In prokaryotes, the formation of a **septum** divides cells.	❑	❑	❑

Cell Division, Differentiation & Death – continued			
5. In multicellular eukaryotes, cells can be part of the body (**somatic cells**) or the **germ line**. Most somatic cell can divide only a limited number of times before they senesce. The exception of **stem cells**, which can divide in an unlimited manner.	❑	❑	❑
6. Stem cells divide asymmetrically, one daughter remains a stem cell and the other goes on to **differentiate**.	❑	❑	❑
7. Cellular differentiation is associated with changes in gene expression, that is which genes are transcribed and which gene products (RNAs and polypeptides) accumulate and are active.	❑	❑	❑
8. Cellular differentiation is often associated with changes in the organization of the **chromatin**, so that these changes may be effectively irreversible.	❑	❑	❑
9. To survive and differentiate correctly, cells depend upon external signals. Generally these include secrete factors made by neighboring cells.	❑	❑	❑
10. In the absence of the appropriate external signals, a normal cell will undergo **programmed cell death** (apoptosis).	❑	❑	❑
11. While the death of a damaged (necrotic) cell leads to **inflammation**, apoptotic cell death does not, and the cell corpse is rapidly engulfed by neighboring cells.	❑	❑	❑
12. S phase (DNA replication) and M phase (mitosis) are temporally distinct stages of the cell cycle.	❑	❑	❑
Gene regulation basics – 15 statement			
1. A **gene** consists of DNA sequences that are **transcribed** and those that are not. Both transcribed and non-transcribed sequences are used to regulate gene expression. The sequences of DNA that make up a gene need not occupy a single continuous stretch of DNA.	❑	❑	❑
2. The final products of genes can be RNAs or polypeptides. For genes that encode polypeptides a transitional (mRNA) RNA is produced through the processing of the primary transcript RNA.	❑	❑	❑
3. Gene expression refers to the level of the final gene product that a gene produces.	❑	❑	❑

Gene regulation basics – continued			
4. The first step in the regulation of gene expression is the control of the number of copies of the gene's transcribed region that are synthesized. This synthesis is catalyzed by RNA polymerases.	❑	❑	❑
5. A gene has at least one, and may have more than one, distinct **transcription start site**. Each transcription start site is defined by a distinct **promoter**.	❑	❑	❑
6. A gene's **promoter** is the region of DNA that, through interactions with regulatory proteins (transaction or transcription factors), determines the binding site, binding affinity and enzymatic activity of RNA polymerase.	❑	❑	❑
7. Promoters can be (semi-arbitrarily) divided into **proximal** and **distal** elements. The proximal promoter is located near the transcription start site. Distal elements are located further away from the transcription start site. In humans, promoter elements can occupy many hundreds of kilobases of DNA both 'upstream' and 'downstream' of the transcription start site.	❑	❑	❑
8. It is possible that more than one gene can be present within a specific region of a DNA molecule; in fact more than one gene can use a specific DNA sequence.	❑	❑	❑
9. The ability of transcription factors to recognize and bind to DNA is regulated by the binding of other transcription factors and the packing of the DNA into **chromatin**	❑	❑	❑
10. Once transcription begins, the amount of the final transcript that accumulates is a function of transcription, processing and degradation rates. Particularly in eukaryotes, transcript processing can be quite complex and include 5' cap addition, 3' polyadenylation, RNA splicing, RNA editing, RNA modification and RNA transport/localization within the cell.	❑	❑	❑
11. Differential splicing can generate different final RNA transcripts from a single gene. If the RNA is used to direct polypeptide synthesis, different transcripts can produce related by distinct polypeptides. The pattern of splicing can itself be regulated.	❑	❑	❑
12. Some transcripts are rapidly degraded, others are relatively stable. Transcript stability directly impacts gene expression.	❑	❑	❑

Gene regulation basics – continued			
13. mRNAs can differ in the efficiency with which they engage the translational machinery. The efficiency of an mRNA's translation can be regulated	❑	❑	❑
14. Once a polypeptide is synthesized, the efficiency with which it folds or assembles into a functional protein through interactions with other polypeptides and co-factors can be regulated. Misfolded proteins are often rapidly degraded.	❑	❑	❑
15.The activity of a protein can be regulated directly, through interactions with allosteric effectors, competitive inhibitors and cooperative interactions. It can be regulated indirectly by controlling the cellular localization and stability.	❑	❑	❑