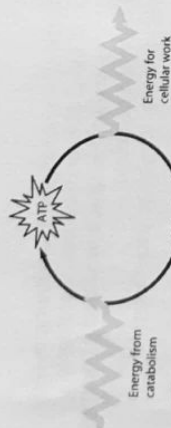


Part A - Multiple Choice (33 questions, 1 mark each = 33 marks)
 Select only the single best answer. Please transfer your answers, in pencil, to the Scantron sheet provided – we will not transfer answers

- 1) Living organisms increase in complexity as they grow, resulting in a decrease in the entropy of an organism. How does this relate to the second law of thermodynamics?
- A. Living organisms do not obey the second law of thermodynamics, which states that entropy must increase with time.
 - B. Life obeys the second law of thermodynamics because the decrease in entropy of the organism grows is exactly balanced by an increase in the entropy of the universe.
 - C. Living organisms do not follow the laws of thermodynamics.
 - D.** As a consequence of growing, organisms cause a greater increase in entropy in their environment than the decrease in entropy associated with their growth.
 - E. Living organisms are able to transform energy into entropy.
- 2) Which of the following is an example of kinetic rather than potential energy?
- A. a steak dinner
 - B. the total lipid mass of an organism
 - C. a molecule of glucose
 - D.** the muscle contractions of a person mowing grass



- 3) How do cells use the ATP cycle shown in the figure above?
- A. Cells use the cycle to recycle ADP and phosphate.
 - B. Cells use the cycle to recycle energy released by ATP hydrolysis.
 - C.** Cells use the cycle to recycle ADP, phosphate, and the energy released by ATP hydrolysis.
 - D. Cells use the cycle to generate or consume water molecules as needed.
 - E. Cells use the cycle primarily to generate heat.
- 4) If the formation of acetyl-CoA from acetate and CoA has a ΔG of +31.4 kJ/mol and the hydrolysis of ATP has a ΔG of -30 kJ/mol, would coupling these two reactions be sufficient to allow the formation of acetyl-CoA to proceed?
- A. Yes
 - B. No
 - C.** The question does not provide sufficient information to decide
- 5) True or False. The metabolic reactions in a health living cell exist in a state of chemical equilibrium.
- A.** True
 - B. False

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6) A number of systems for pumping ions across membranes are powered by ATP hydrolysis and are often called ATPases. Muscle cells keep cytoplasmic calcium concentrations low by transporting calcium from the cytosol into the membranous system called the sarcoplasmic reticulum (SR). If a resting muscle cell's cytosol has a free calcium ion concentration of 10^{-7} while the concentration in the SR is 10^{-2} , then how is the ATPase acting?

Ca^{2+} 10^{-2}
(in cytosol)

- A. ATPase activity must be powering an inflow of calcium from the outside of the cell into the SR.
- B. ATPase activity must be transferring inorganic phosphate to the SR to enable this to occur.
- C. ATPase activity must be pumping calcium from the cytosol to the SR against the concentration gradient.
- D. ATPase activity must be opening a channel for the calcium ions to diffuse back into the SR along the concentration gradient.
- E. ATPase activity must be routing calcium ions from the SR to the cytosol, and then to the cell's environment

7) Zinc, an essential trace element for most organisms, is present in the active site of the enzyme carboxypeptidase. The zinc most likely functions as a(n)

- A. competitive inhibitor of the enzyme.
- B. noncompetitive inhibitor of the enzyme.
- C. allosteric activator of the enzyme.
- D. cofactor necessary for enzyme activity.
- E. coenzyme derived from a vitamin.

8) HIV is the virus that causes AIDS. In the mid-1990s, researchers discovered an enzyme in HIV called protease. Once the enzyme's structure was known, researchers began looking for drugs that would fit into the active site and block it. If this strategy for stopping HIV infections were successful, it would be an example of what phenomenon?

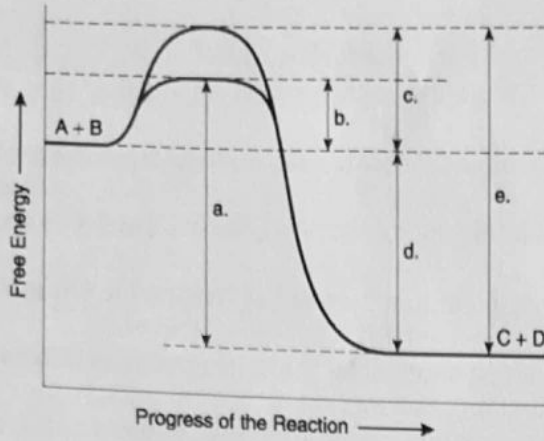
- A. vaccination
- B. denaturation
- C. allosteric regulation
- D. competitive inhibition
- E. feedback inhibition

respiration
exergonic

9) Which of the following metabolic processes can occur without a net influx of energy from some other process?

- A. $ADP + P_i \rightarrow ATP + H_2O$
- B. $C_6H_{12}O_6 + 6 O_2 \rightarrow 6 CO_2 + 6 H_2O$
- C. $6 CO_2 + 6 H_2O \rightarrow C_6H_{12}O_6 + 6 O_2$
- D. amino acids \rightarrow protein
- E. glucose + fructose \rightarrow sucrose

Questions 10 – 14 are based on the reaction $A + B \leftrightarrow C + D$ shown in the free energy diagram below.



- 10) Which of the following terms best describes the forward reaction in the figure above?
- A. endergonic, $\Delta G > 0$
 - B. exergonic, $\Delta G < 0$
 - C. endergonic, $\Delta G < 0$
 - D. exergonic, $\Delta G > 0$
 - E. chemical equilibrium, $\Delta G = 0$
- 11) Which of the following in the figure above would be the same in either an enzyme-catalyzed or a noncatalyzed reaction?
- A. a
 - B. b
 - C. c
 - D. d
 - E. e
- 12) Which of the following represents the difference between the free-energy content of the reaction and the free-energy content of the products in the figure above?
- A. a
 - B. b
 - C. c
 - D. d
 - E. e
- 13) Which of the following represents the activation energy required for a noncatalyzed reaction in the figure above?
- A. a
 - B. b
 - C. c
 - D. d
 - E. e

14) Which of the following represents the activation energy needed for the noncatalyzed reverse reaction, $C + D \rightarrow A + B$, in the figure above?

- A. a
- B. b
- C. c
- D. d
- E. e

15) According to the induced-fit hypothesis of enzyme catalysis, which of the following is correct?

- A. The binding of the substrate depends on the shape of the active site.
- B. Some enzymes change their structure when activators bind to the enzyme.
- C. A competitive inhibitor can outcompete the substrate for the active site.
- D. The binding of the substrate changes the shape of the enzyme's active site.
- E. The active site creates a microenvironment ideal for the reaction.

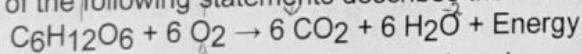
16) Which of the following statements best describes the relationship between photosynthesis and respiration?

- A. Respiration runs the biochemical pathways of photosynthesis in reverse.
- B. Photosynthesis stores energy in complex organic molecules, whereas respiration releases it.
- C. Photosynthesis occurs only in plants and respiration occurs only in animals.
- D. ATP molecules are produced in photosynthesis and used up in respiration.
- E. Respiration is anabolic and photosynthesis is catabolic

17) The primary role of oxygen in cellular respiration is to

- A. yield energy in the form of ATP as it is passed down the respiratory chain.
- B. act as an acceptor for electrons and hydrogen, forming water.
- C. combine with carbon, forming CO_2 .
- D. combine with lactate, forming pyruvate.
- E. catalyze the reactions of glycolysis.

18) Which of the following statements describes the results of this reaction?



- A. $\text{C}_6\text{H}_{12}\text{O}_6$ is oxidized and O_2 is reduced.
- B. O_2 is oxidized and H_2O is reduced.
- C. CO_2 is reduced and O_2 is oxidized.
- D. $\text{C}_6\text{H}_{12}\text{O}_6$ is reduced and CO_2 is oxidized.
- E. O_2 is reduced and CO_2 is oxidized.

$\text{C}_6\text{H}_{12}\text{O}_6$ - oxidized.
 O_2 - reduced
 H_2O - oxidized
 CO_2 - reduced.

19) The ATP made during the citric acid cycle is generated by

- A. substrate-level phosphorylation.
- B. electron transport.
- C. photophosphorylation.
- D. chemiosmosis.
- E. oxidation of NADH to NAD^+ .

- 20) Which kind of metabolic poison would most directly interfere with glycolysis?
- A. an agent that reacts with oxygen and depletes its concentration in the cell
 - B. an agent that binds to pyruvate and inactivates it
 - C. an agent that closely mimics the structure of glucose but cannot be metabolized
 - D. an agent that reacts with NADH and oxidizes it to NAD⁺
 - E. an agent that blocks the passage of electrons along the electron transport chain
- 21) The main purpose for the fermentation pathway is to _____ when oxygen is absent.
- A. maintain a pool of oxidized NAD⁺
 - B. maintain a pool of reduced NADH
 - C. generate ATP
 - D. provide an alternative fuel to glucose, in the form of alcohol,
 - E. drive the citric acid cycle
- 22) Phosphofruktokinase is an enzyme that catalyzes the conversion of fructose 6-phosphate to fructose 1,6-bisphosphate, an early step of glycolysis. In the presence of oxygen, an increase in the amount of ATP in a cell would be expected to
- A. inhibit the enzyme and thus slow the rates of glycolysis and the citric acid cycle.
 - B. activate the enzyme and thus slow the rates of glycolysis and the citric acid cycle.
 - C. inhibit the enzyme and thus increase the rates of glycolysis and the citric acid cycle.
 - D. activate the enzyme and increase the rates of glycolysis and the citric acid cycle.
 - E. inhibit the enzyme and thus increase the rate of glycolysis and the concentration
- 23) Which of the following is characterized by a cell releasing a signal molecule into the environment, followed by it responding to that signal?
- A. hormonal signalling
 - B. autocrine signalling
 - C. paracrine signalling
 - D. endocrine signalling
 - E. synaptic signalling
- 24) Which of the following is *true* for the signalling system in an animal cell that lacks the ability to produce GTP? *no activation of G proteins.*
- A. It would not be able to activate and inactivate the G protein on the cytoplasmic side of the plasma membrane.
 - B. It could activate only the epinephrine system.
 - C. It would be able to carry out reception and transduction but would not be able to respond to a signal.
 - D. It would use ATP instead of GTP to activate and inactivate the G protein on the cytoplasmic side of the plasma membrane.
 - E. It would employ a transduction pathway directly from an external messenger.

- 25) Herceptin is a anti-cancer drug which is recognized by the HER2 cell surface receptor. Herceptin could be appropriate to treat breast cancer in which of the following cases?
- A. If Herceptin is found in the breast lymph nodes of the patient.
 - B. If HER2 is co-administered by injection in sufficient concentration.
 - C. If the patient's cancer cells express the HER2 receptor.
 - D. If the patient's genome codes for the manufacture of Herceptin.

- 26) Which of the following would most likely be an immediate result of a growth factor binding to its receptor?
- A. protein kinase activity
 - B. adenylyl cyclase activity
 - C. GTPase activity
 - D. protein phosphatase activity
 - E. phosphorylase activity

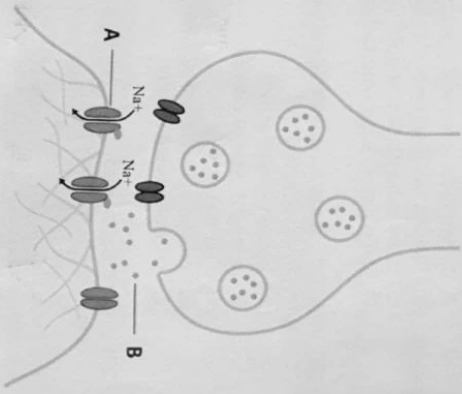


MARCK
RTK
RAS
MAPKKK
CAMP → activate PKA

- 27) An inhibitor of which of the following could be used to block the release of calcium from the endoplasmic reticulum?
- A. tyrosine kinases
 - B. serine/threonine kinases
 - C. phosphodiesterase
 - D. phospholipase C
 - E. adenylyl cyclase

- 28) Which of the following is the best explanation for the fact that most transduction pathways have multiple steps?
- A. Most of the steps were already in place because they are steps in other pathways.
 - B. Multiple steps in a pathway require the least amount of ATP.
 - C. Multiple steps provide for greater possible amplification of a signal.
 - D. Each individual step can remove excess phosphate groups from the cytoplasm.
 - E. Each step can be activated by several G proteins simultaneously.

Use the image below to answer questions 29 -31.



29) The type of communication depicted is ...

- A. juxtacrine signalling.
- B. autocrine signalling.
- C. endocrine signalling.
- D. synaptic signalling.
- E. None of the above

30) The receptor labeled A is a

- A. GPCR
- B. RTK
- C. Ligand gated ion channel
- D. Intracellular receptor
- E. Intracellular ion channel

31) The molecules labeled B are the ...

- A. Neurotransmitters
- B. Second messengers
- C. Relay molecule
- D. Sodium ions

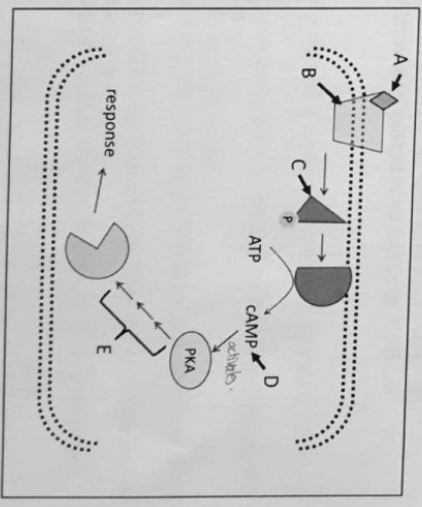
Use the following figure to answer the questions 32-33.

32) The structure labelled A is

- A. very small.
- B. hydrophilic.
- C. hydrophobic.
- D. NO.
- E. aldosterone.

33) In the diagram, the structure labelled D is a(n)

- A. first messenger.
- B. second messenger.
- C. activated relay molecule.
- D. receptor.
- E. phosphorylation cascade.



Part B - Written Answers (9 questions, varying marks = 47 marks)

Please answer only in the space provided below, answers outside of those areas will not be marked. Answers in point form and/or those accompanied by diagrams will be accepted so long as they are complete.

1. Fill in the blanks to complete each of the following. (1 mark each x 7 = 7 marks)

- a) Metabolism is the sum of all the energy transformation reactions in an organism.
- b) A/an catalyst is a chemical agent that speeds up a reaction without being consumed. A/an enzyme plays the same role in the cell.
- c) Chemiosmosis uses the exergonic flow of H⁺ back down its concentration gradient to drive phosphorylation of ADP to form ATP.
- d) During cellular respiration, nicotinamide adenine dinucleotide (NADH) and flavin adenine dinucleotide (FADH₂) act as ~~co-enzymes~~ electron carriers.
- e) Quorum sensing is a type of communication allows bacteria to sense local population density based on the concentration of signalling molecules present in the environment.
- f) Plant and animal cells communicate over long-distances using chemical messengers known as hormones.

2. Name 2 types cellular work that requires energy input and provide one example of each type. (4 marks)

4

Mechanical work - contraction of muscle fibres which brings about contraction of entire muscles.
Transport work - pumping of sodium (Na ⁺) ions out of a neuron (active transport) to maintain resting potential.

3. For mitochondria that are actively carrying out cellular respiration, indicate whether the movement of each of the following molecules IN or OUT of the matrix is thermodynamically favorable. (4 marks)

3

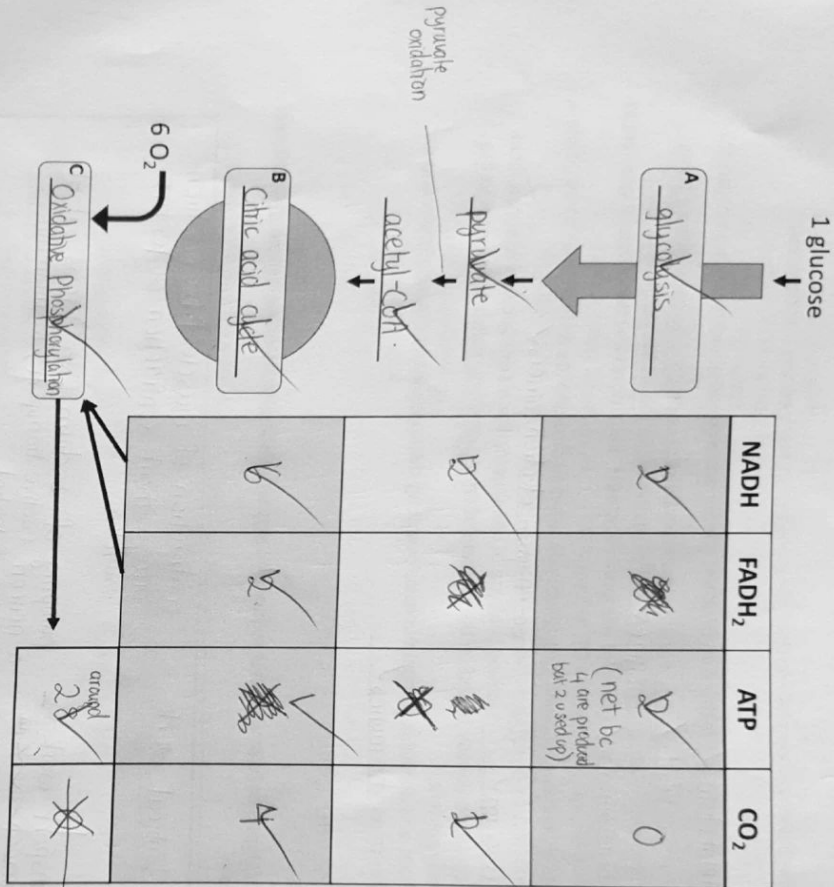
IN O₂ OUT H⁺ IN ADP OUT CO₂

14

Student #: _____

4. Fill in the blanks to complete the following diagram. Complete the adjacent table providing an energy summary, accounting for both input and output in each process. (8 marks)

write the numbers in the processes & intermediate



	NADH	FADH ₂	ATP	CO ₂
A	✓	✓	✓ (net bc 4 are produced but 2 used up)	0
B	✓	✓	✓	✓
C	✓	✓	✓ around 28	✓

5. Which of the following is a correct association? Justify only if False. (5 marks)

	T (True) or F (False)	Justify if False (F)
Adenylyl cyclase activity and conversion of ATP to cAMP	T ✓	
Phosphodiesterase activity and removal of phosphate groups	F ✓	Phosphodiesterase breaks cGMP → GMP and cAMP → ATP. Phosphatase removes phosphate groups. ✓
GTPase activity and hydrolysis of GDP to GTP	F ✓	GTPase hydrolyzes GTP to GDP. ✓
crossphosphorylation activity and addition of tyrosine groups	F ✓	Crossphosphorylation is addition of phosphate groups to the tyrosine residues on opposite Receptor tyrosine kinases (RTKs). ✓

6. Indicate true (T) and false (F) statements below regarding the Ras-MAP-kinase signaling pathway. (5 marks)

- a) F The MAPK cascade produces cellular responses, exclusively in the form of changes in gene expression.
- b) I Ras-GTP binds directly to, and activates, the first kinase (MAPKKK) of the cascade.
- c) F Signal transduction through the MAP-kinase pathway occurs via small second messengers.
- d) F A loss of MAPKK activity will only affect the transduction stage of communication along this pathway. (reception and cellular response will be unaffected.)
- e) I The MAPK cascade can be activated by both GPCRS and RTKs

7. Name 2 classes of chemical messengers used by animal cells to communicate. (2 marks)

- 1. Retinoids ~~Retinoids~~ (Vitamin A)
- 2. Steroids
- 3. Amino acids (glutamate)

8. Describe in detail the molecular mechanism by which binding of a signalling molecule to the receptor depicted in the diagram below, leads to the activation of a signal transduction cascade in that cell. (7 marks)

The receptor shown in this diagram is a hydrophilic dimer.

Detailed molecular mechanism

- 1) Ligand binds to the receptor
- 2) ~~change~~ A change in conformation (shape) of the two ~~subunits~~ of the RTKs (receptor tyrosine kinases)
- 3) This change in conformation allows them to dimerize.
- 4) The kinase activity is then activated. (^{intrinsic enzymatic} activity)
- 5) Tyrosine residues on the ^{intracellular} compartments (domains) of the RTKs are ~~phosphorylated~~ phosphorylated (a phosphate group is added to each residue).
- 6) SH domains on ^{some} intracellular proteins allow the proteins to recognize the phosphorylated tyrosine residues and so the proteins dock onto them
- 7) the proteins are hence activated and can act on other molecules in the signal transduction pathway.

(in case of the MAPK pathway - mitogen-activated protein kinase pathway - # one of the proteins is the RAS protein which can activate # MAP kinase kinase kinase and hence the MAPK pathway).

8b. How is signalling terminated at this type of receptor (2 marks)

Protein phosphatase enzymes remove the phosphate groups that are on the tyrosine residues and so # inactivating the RTKs.

The signalling molecule (^{ligand}) is also removed from the receptor ~~be~~ binding site in one of several ways - eg. extracellular enzymes degrade it and so it is no longer in the correct shape to bind to the two RTKs.

9. Name and briefly describe two different ways cells can regulate, or fine-tune, a cellular response other than terminating the response: (3 marks)

a) Amplification - one activated product can activate many other molecules and so a small signal can result in a major response.

b) Coordination Control - different sets of proteins/enzymes are present in different cells and so not all cells respond to the same signal in the same manner.

1.5

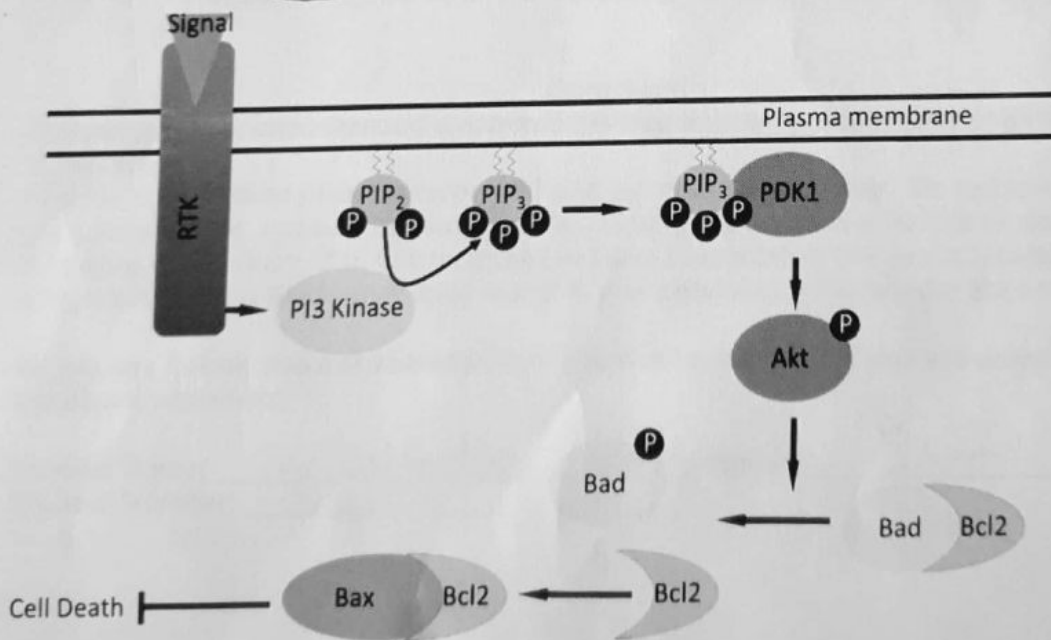
Section C- Bonus

1) Name the type of cell death in which each of the following events occurs. (2 marks)

- a) Necrosis ✓ The cell swells and ruptures.
- b) Apoptosis ✓ Large cells break up into membrane-enclosed fragments which are engulfed by macrophages.
- c) Autophagy ✓ Formation of a membrane bound vesicle which binds to the lysosome to degrade its contents.
- d) Apoptosis ✓ The nuclear DNA breaks into fragments.

2

2. Referring to the diagram below, circle promote or prevent that correctly completes the sentence: loss of PI3K activity will (promote/prevent) cell death, while increased phosphorylation of Bad will (promote/prevent) cell death. (1 mark)



4.5