Name: _____ANSWER KEY_____ Student #: _____ ANSWER KEY _____

BIO114- Introduction to Cell Biology - Midterm 1

Professor: Dr. Alexandra Pettit **Due - Feb 9th noon**

General Instructions:

1. **This exam is worth 14% of your final mark.**
2. **This exam is open book**. I encourage you to use any of the materials I have given you for the class (videos, articles, molecular animations, etc…) and the notes you have created while working with this material. All answers eligible for full marks can be developed from an understanding of these materials.
3. **This is an individual exam,** you are not to complete it in groups. Should there be evidence of collaboration or plagiarism on your submitted exam, you will face allegations of academic fraud.
4. **You should expect to complete the exam in ~ 90 minutes**; you should NOT spend copious amounts of time reading and researching to complete the exam. Should you choose to consult any outside sources, they must be referenced as part of your answer.
5. **You can answer this exam in any way you choose/are able.** This includes but is not limited to:
   - Printing the exam, filling it in by hand, then scanning/photographing it.
   - Answering each question by hand on a blank paper, then scanning/photographing it.
     **You do not need to recopy the questions to your sheet of paper but be sure to clearly indicate which question you are answering and if you must copy sequences/images/etc… to your sheet, do so very carefully to avoid making errors.*
   - Handwriting your answers digitally. (e.g. with a stylus capable of writing in e-ink)
   - Typing your responses directly into the file.
6. **You may ask questions via email.** They will be answered only during regular business hours. Only questions of a technical nature (i.e. – submission issues) will be answered in the final 30 minutes of the exam.
7. Name the digital file (use .pdf format ONLY) containing your completed exam **student#_1140_midterm1_surname.pdf**
   (e.x - I would name my completed exam – 12345678_1140_midterm1_Pettit.pdf).
8. You must submit your completed exam by **noon on Feb 9th** .
   - Upload **a single pdf file** with the entire completed exam to the "BIO1140_Midterm 1 Exam" on Brightspace by **noon on Feb 9th**.
   - You will receive an email confirmation of the receipt of your submission.

   I do, recognize that last minute issues are at times unavoidable and I will navigate these with you on a case by case basis.

   If you find yourself unable to submit your file due to technical issues (e.g. – computer crash, poor internet connectivity, etc…) you should do the following if at all possible:
   - avoid re-opening your exam file after the deadline
   - contact me as soon as you are aware an issue has arisen
   - if possible (i.e – using your data plan or an alternative internet connection), send me your exam file via email

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Helpful Hints and Tips:

- If completing the exam digitally, it is recommended that before beginning to write, that you name and save the document and also activate any automatic save function that your software may have.
- If scanning/photographing your exam to digitize a handwritten file, you may find it helpful to use a free app/program such as clear scanner (for android or iPhone) or pdf merge (web based) to compile multiple pages into a single file.

Academic Integrity Statement

Please complete the section below and submit it with your exam. If completing the exam by hand on blank paper, you do not need to re-copy the academic integrity statement, but you must sign your document.

- I have completed this assignment independently. _____ (initial here)
- I will keep the contents of this examination confidential. _____ (initial here)

By signing this statement, I am attesting to the fact that I have reviewed the entirety of my submitted work and that this assessment meets all of the rules in uOttawa's Academic Regulations about Academic Integrity. I confirm that I did not act in any way that would constitute cheating, misrepresentation, or unfairness, including but not limited to, using unauthorized aids and assistance, impersonating another person, or providing unauthorized assistance to someone else.

Signature: _____ Date: _____
Name (print/type):_____ Student # : _____

Exam Questions (7 questions = 28 marks)

The questions on the following pages ask you to consider a novel cell biology scenario. Throughout the exam, you will find pertinent background information about this specific scenario. **You are expected to use the provided information AND apply the knowledge you have acquired thus far in BIO1140 to answer the questions posed.**

You must answer all of the questions below. Answer each question as concisely as possible, unless otherwise specified, limit yourself to no more than 2-3 sentences per response. Do not simply put all related information about a topic down to answer a question. If a question, ask you to provide a specified number of answers (e.g. – 2 reasons why something occurs) only the first X entries you include in your answer will be graded. Answers in point form and/or those accompanied by drawings will be accepted so long as they are complete.

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For your summer research internship, you have found a placement working in a laboratory at a fertility clinic. Since you are interested in practicing medicine after your undergrad and have just recently completed your fundamental cell biology course at university, you are excited to put your knowledge to the test and see how it might relate to your future career.

You spend the weekend before beginning your placement reviewing your cell biology notes and looking over some resources your placement supervisor shared with you. One of these resources is a molecular animation that depicts the process of fertilization clearly and you end up watching it several times. https://youtu.be/Vv9Kj3XIAbU

**Please note that I have chosen this video for its high-quality scientific animation and strong presentation of the fundamentals of fertilization upon which many of the following questions are based. This video is however several years old, and I acknowledge that the language used surround sex and gender is not inclusive.*

1. Considering what you have learned about the cytoskeleton and the process of fertilization, briefly describe how each of the various types of cytoskeletal fibers is involved in fertility (either directly or indirectly). Your answer must include at least 1 role for each type of cytoskeletal fiber and list a total of 5 roles to be eligible for full marks. (**5 marks**)

Reminder, do not list more than 5 functions total in your table, only the first 5 entries will be graded.

Fiber Type	Role in Fertility **1 mark per point made (must have 1 per category + 2 others)** **TAs – please be careful to place a check mark on each role for which you assign a mark so that student can easily match with the grading rubric)** **Need to relate to fertilisation to receive marks.**
Microtubules	- Cilia lining fallopian tubes move egg and/or embryo into uterus - flagella propels sperm toward egg - Axoneme is related to the cilia and flagellum and related to the movement (must be related to the function) - microtubules are essential for chromosome separation during meiosis and mitosis, and thus required for formation of egg and sperm and/or for development of the embryo following fertilization - Pulls male/female pronuclei together
Microfilaments	- Muscular contractions of uterus help sperm move toward fallopian tube - microfilaments are essential for cytokinesis/contractile ring following meiosis and mitosis, and thus required for formation of egg and sperm and for development of the embryo following fertilization
Intermediate Filaments	- Anchor nucleus in place in gametes and developing embryo cells or maintain shape of the zygote

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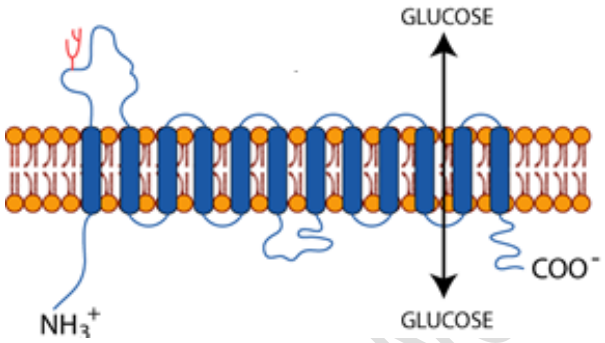
Sperm need significant amounts of ATP to fuel their travel through the reproductive tract. This ATP is generated via oxidative metabolism of the glucose and fructose contained in the seminal fluid.

These sugars are large polar molecules that enter sperm cells via glucose transporters or GLUTS. One such GLUT protein is depicted in the image below. When GLUTS recognize and bind glucose, they undergo a conformational change releasing glucose on the other side of the membrane. Due to the persistent high energy demands of the sperm cell, these sugars are continually being catabolized (broken down).



2.

a. On the image above: i) label the intracellular and extracellular surfaces, and ii) depict the typical concentration gradient for glucose and fructose present across the membrane of a sperm cell found in seminal fluid. Using no more than 1 sentence, explain how you determined the orientation of this membrane? (**3 marks**)
1 mark - labeling intracellular (bottom) and extracellular (top)
1 mark - Higher conc at the extracellular side, lower conc inside
1 mark for the explanation – glycosylation/glycoproteins/carbohydrates is found on the outer membrane

b. GLUTs mediate what type of transport of glucose and fructose across the membrane? _____ Facilitated diffusion_____ (**1 mark**) Is this an active or passive process? ____ passive _____ (**1 mark**)

c. What type of transport protein are the GLUTs described in this question? _____ Carrier _____ (**1 mark**)

d. How many transmembrane domains does this GLUT have? (**1 mark**) ___ 12 _____

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3.

a. Protein synthesis is carried out by what cellular component? ____ribosome_____ (**0.5 marks)**

b. Where are each of the following proteins synthesized in the sperm? (**4.5 marks**)

Protein	**Role**	**Where is this protein synthesized? Be as specific as possible and briefly explain your choice (1.5 marks each)**
glucose transporter	Sugar transport across the plasma membrane	Ribosomes of the rough endoplasmic reticulum (0.5 marks) Must be synthesized here to be embedded in the membrane (0.5 marks) and trafficked to the plasma membrane by the endomembrane system (0.5 marks)
hexokinase	The enzyme that carries out the first step of glycolysis (the first cytoplasmic phase of cellular respiration).	free cytoplasmic ribosomes (0.5 marks) proteins synthesized on free cytoplasmic ribosomes are released into the cytoplasm where this protein carries out its function (1 mark)
complex I	Complex I is the first enzyme complex involved in oxidizing NADH as part of the electron transport chain (ETC). The ETC is the penultimate step in cellular respiration occurring across the inner mitochondrial membrane.	Mitochondrial ribosomes (0.5 mark) Enzymes of the aerobic respiration process are coded for by the mt genome, transcribed and translated with the mt itself by its own dedicated machinery (1 mark).

* students may have done more research about sperm cell biology when answering this question and may therefore go into more depth

- if a student clearly articulate that mature sperm cells lose most organelles during the process of maturation and retain only mitochondrial ribosomes and that therefore, they are the only ribosomes available for transcribing these proteins in a mature sperm cell that should be accepted and awarded marks

4. Sperm cells that do not reach the egg, either flow back out of the vagina or are eliminated by macrophages found in the reproductive tract. This process is depicted in the background information video between 1:37-1:44.

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a. By what process are macrophages able to take up sperm cells? (**1 mark**) _____phagocytosis (1 mark) ____ (endocytosis 0.5)

b. Based on your understanding of cellular organelles and their roles, what happens to a sperm cell once it is inside of the macrophage? Name 2 cellular functions that this will in turn support and briefly describe why/how? (**4 mark**)

The food vacuole that they are a part of fuses with a lysosome which contains digestive enzymes that break it down **(1 mark**)

0.5 marks for name and 1 mark for why – mark first two answers

Energy production – breakdown products may in turn be used to fuel the cell

Production of macromolecules – make new carbs/lipid/nucleic acids/proteins for the resulting building blocks

Remove waste – unnecessary components will be eliminated from the cell

Homeostasis – Maintain levels of BE FLEXIBLE within the cell

I'm confident that there will be many more answers put forward – all reasonable functions/explanations should be accepted.

When investigating fertility concerns, a common course of action is to rule out sperm cell-related causes of infertility first since obtaining the relevant specimens is generally less invasive. Sperm number and motility are typically the first parameters assessed in a semen sample. Vitality is another commonly assessed parameter, particularly when motility is deemed poor since it allows physicians to differentiate between live non-motile sperm and dead sperm cells.

5. The procedure for determining vitality is to place sperm in a hypotonic solution and observe the specimen under the microscope after a 5-minute incubation. This short incubation time allows for observable cellular changes without causing cell death.

a. What type of microscope would you recommend using to observe sperm cells for this laboratory test and why? (**1 mark**)

Light microscope (compound microscope is also acceptable) (**0.5 mark**) – low resolution required (40-400X) (not looking at fluorescent dyes or subcellular organelles) (**0.5 mark**)

b. Describe what you would expect to observe in the case of a live sperm cell and why? How can you distinguish it from a dead sperm cell in the same sample? (**2 marks**)

Live sperm = swollen, this is due to diffusion of water into the cell (**1 mark**)

Membrane integrity is lost in dead sperm cells, so there is no differential in salt conc across their membrane and they will not/cannot swell making it easy to distinguish them from live sperm under the microscope (**1 mark**)

Elements that we have ruled out – clumping of dead sperm, motility, staining

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As discussed in the introductory video, upon entry into the vagina, chemicals in the reproductive tract initially cause the membranes covering the sperm to change becoming more fluid and the sperm to become hyperactive.

6. The increased membrane fluidity has been attributed to the efflux (removal) of a single membrane lipid component. Removal of which component from the sperm's membrane could increase fluidity without significantly altering the size and or shape of the sperm cell? (**1 mark**)
_____cholesterol_____

As a sperm cell finally approaches its final target, its acrosome becomes activated. The acrosome is a specialized organelle found in the cell's head region and activation results in the exocytosis of several types of proteolytic enzymes.

7. Name 2 specific proteins you might expect the enzymes released by the acrosome to breakdown. What purpose does this play in the fertilization of the egg? Explain your reasoning. (**2 marks**)

0.5 marks each – mark first two answers:
Specific Proteins: Collagen, fibronectin, proteoglycans, zona pellucida (ZP1, ZP2, ZP3, ZP4)
Glycoprotein, integrins/transmembrane/anchored proteins alone should not be awarded any marks

Explanation: Digesting the ECM components surrounding the egg cell (will also accept zona pellucida) allows the sperm to access the egg's PM for fertilization. (**1 mark)**