

This handbook belongs to:

Smooth Muscle Cells: Excitation and Communication

The **Brilliant** Club

KS5 Biology

Tutor: Rachel Sheldon

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Introduction

Welcome to BI409 – Smooth Muscle Cells: Excitation and Communication.

The purpose of this course is to introduce you to university-style tutorial teaching through a subject area that builds on your existing knowledge.

This course will introduce you to the idea of cell-to-cell communication and excitation of cells. In particular, we will focus on the smooth muscle cells involved in generating contractions in a pregnant woman. This topic is still a relative mystery! Whilst the key parts have been established, how these contractions regulate themselves is still being researched – by me!

The module will be assessed through weekly assignments designed to be of university style. For instance, you will be reading papers, making scientific posters and writing articles. Being able to complete these tasks will be very good practice for university and will help you learn to formulate and organise your ideas into a clear argument. Therefore, how much you get out of this course depends on the effort you put in!

I hope you enjoy it!

Rachel Sheldon

PhD Student, University of Warwick

Brilliant Club Tutor

Class Rules

1. Always come to tutorials ready to work hard and learn
2. Respect other students' ideas
3. Come to tutorials prepared by doing your homework. This means we can make more progress in our sessions!
4. Stay focused and pay attention at all times
5. Enjoy learning!
- 6.
- 7.
- 8.
- 9.
- 10.

I _____ agree to follow these rules to make the most of my time in Brilliant Club tutorials

Signed: _____

Date: ____/____/____

Course Expectations

Module Objectives:

- To learn how cells communicate with each other and become electrically excited
- To be able to formulate your ideas into a clear argument
- To learn to question everything you read – not everything on the internet/in books is correct!
- To gain experience of university style tutorials and assessments

Weekly assignments will consolidate work done in tutorials, and prepare you for the work we will be doing in the next tutorial. Therefore it is very important you complete work on time. Your final assignment will be a piece of extended writing and should take longer than previous assignments.

If you are struggling with any aspects of the course outside of tutorials, you can contact me on R.E.Sheldon@warwick.ac.uk.

| | Tutorial Date | Tutorial Time | Tutorial Homework Deadline |
|-----------------|----------------|---------------|----------------------------|
| Launch Trip | 12/06/2013 | 10:00 – 16:00 | 20/06/2013 |
| Tutorial 1 | 20/06/2013 | 15:10 – 16:25 | 27/06/2013 |
| Tutorial 2 | 27/06/2013 | 15:10 – 16:25 | 05/07/2013 |
| Tutorial 3 | 05/07/2013 | 15:10 – 16:25 | 11/07/2013 |
| Tutorial 4 | 11/07/2013 | 15:10 – 16:25 | 05/08/2013 |
| Graduation Trip | w/c 23/09/2013 | 10:00 – 16:00 | |

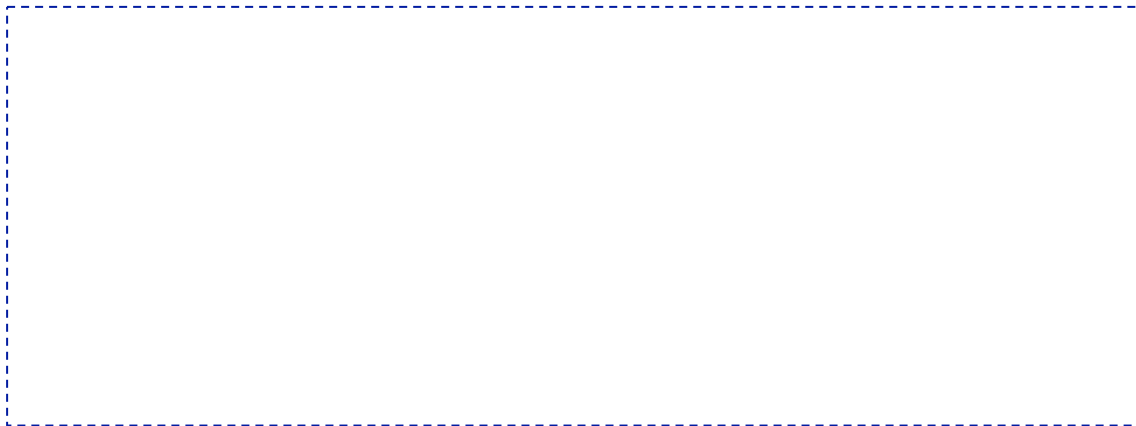
About this handbook

This handbook is organised into tutorials and corresponding assignments. Feel free to read ahead, but don't worry if you don't understand everything you read just yet – we will go through it!

All assignments should be done on separate pieces of paper, not in this handbook!

Please take notes during the tutorial, and while I'm talking! At university, we are not told when we should be making notes!

If you see a box like the one below, it is your cue to write something down!



Words underlined (such as uterus) can be found with a definition in the glossary at the back of the booklet.

Tutorial 1: The Problem of Preterm Labour

Preterm labour is still a huge problem throughout the world – it is not just a problem in developing countries! Managing preterm labour costs the NHS £2.9 billion a year.

Amazingly, we still don't know enough about why preterm labour occurs! Scientists cannot predict when preterm labour will occur, or who will be affected.

The cause of preterm labour is thought to be to do with inappropriate muscle function in the uterus. Without understanding how this muscle layer works, we cannot start to effectively treat preterm labour!

Is it ethical to be doing research to prevent preterm labour? Write your opinions in the box below.

We must make sure to think about other people's viewpoints too before we make an informed decision. Make a note here of other people's viewpoints in the class.

True or False?

The internet is a great resource to have when doing science research – we no longer need to spend hours in the library to find the information we need! However, websites are very easily created and changed. This is particularly true of Wikipedia, where *anyone* can change it! We need to make sure that the information we use is true. This isn't always easy, but sometimes we just need to use some common sense.

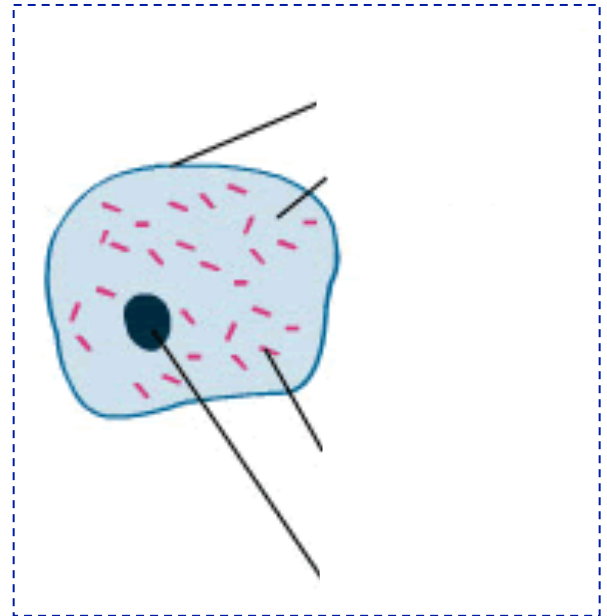
Have a look at the following “facts”. Do you think they make sense or not? What questions do you need to ask yourself to decide if they're true?

| | True | False |
|--|------|-------|
| 15 million babies are born too early each year | | |
| The UK has the highest number of pre-term births in the world | | |
| Prematurity is the leading cause of newborn deaths | | |
| Babies born before 32 weeks gestation have no chance of survival | | |
| The USA is in the top 10 countries with the greatest number of pre-term births | | |
| Three-quarters of premature babies could be saved with current, cost-effective interventions | | |
| Premature birth has been decreasing in the past 20 years | | |

Revision: Cells and their Functions

Label the _____ (animal/plant/fungus) cell from the following list of cell parts.
Beware, there may be some trick answers!

- Cell Wall
- Cell Membrane
- Nucleus
- Cytoplasm
- Chloroplasts
- Mitochondria
- DNA



Fill in the function that matches the type of cell based on the matching activity from the tutorial.

| Type of Cell | Function of Cell |
|------------------|------------------|
| Muscle Cell | |
| Nerve Cell | |
| Red Blood Cell | |
| White Blood Cell | |
| Skin Cell | |
| Fat Cell | |
| Gamete | |

There are three types of muscle cell. Describe each in a few words

Cardiac muscle cell

Skeletal muscle cell

Smooth muscle cell

ADAM.



Contracted/relaxed smooth muscle cell
(delete as appropriate)



Contracted/relaxed smooth muscle cell
(delete as appropriate)

In this course, we're going to look at smooth muscle in more detail, and investigate its relationship with preterm labour.

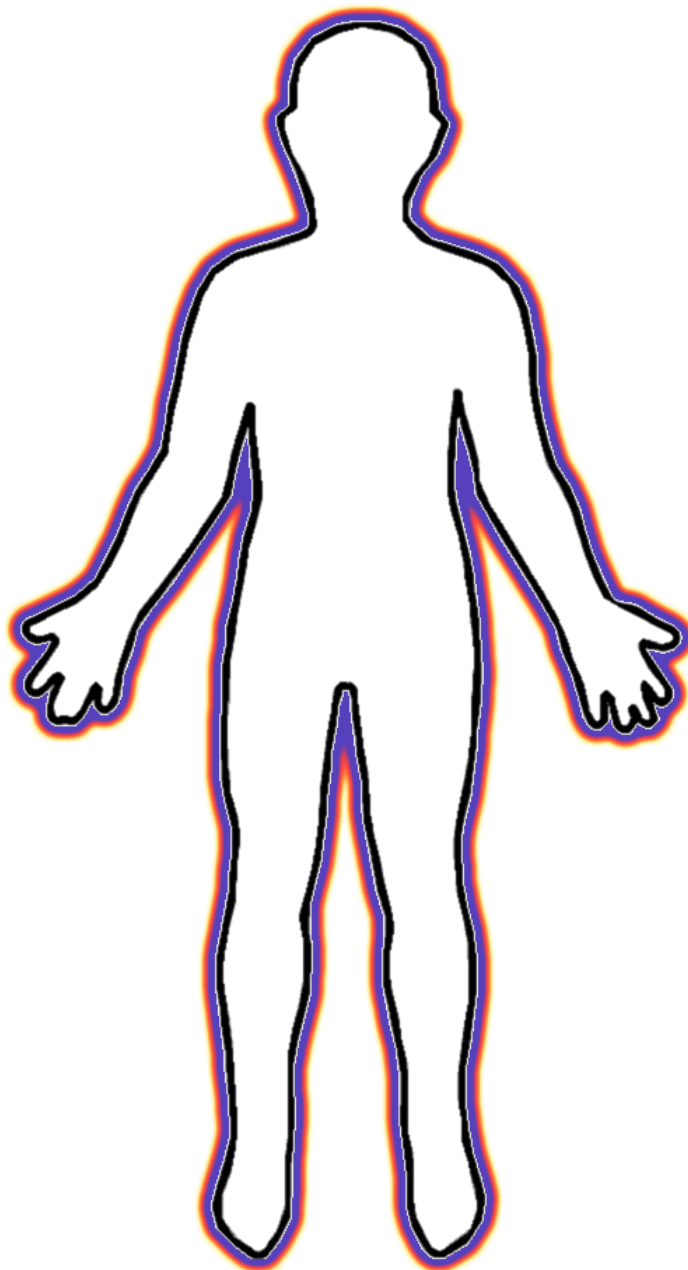
Due date:

Assignment 1

Identify 10 regions of smooth muscle in the human body, and describe their function. Indicate these regions on the following diagram, and in the accompanying table.

Then, write a 300 word essay entitled “The Role of Smooth Muscle in the Human Body”. Your essay should include a description of the structure of smooth muscle cells, and how the structure is adapted to its function in the body. Make sure to include how smooth muscle is different from other muscle cells in the body.

Label the figure with at least 10 places where smooth muscle can be found in the human body.



| | Area of Smooth Muscle | Function of Smooth Muscle in this Area |
|----|-----------------------|--|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

Tutorial 2: Smooth Muscle in the Myometrium

We are going to focus on the smooth muscle that is found in the myometrium. The myometrium is one of the layers of tissue found in the uterus.

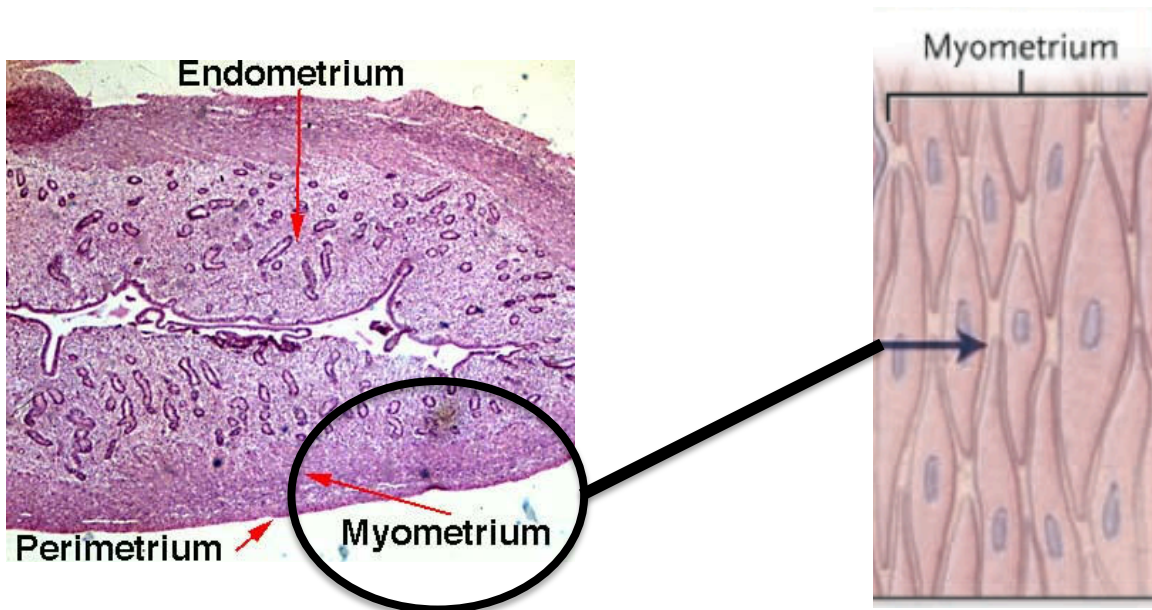


Image of a human uterus

These muscle cells work together to produce contractions when a pregnant woman is in labour. In the rest of this course, we will learn more about how these cells are connected and how they produce contractions.

The main purpose of investigating the myometrium is to help manage pre-term labour. What do you understand by the term **pre-term labour**?

Abstracts of Scientific Papers

An abstract is a summary of the ideas presented in a paper. It is the first part of the paper the reader will see, and may be used to help the reader decided whether they want to pay to see the rest!

Abstracts should cover:

- The background to the research
- Methods
- Results
- Conclusions

and may be written as a free-flowing paragraph or under these sub-headings.

The background should be the shortest section, and outline what was known previously and where gaps in knowledge are.

Methods should provide enough information for the reader to understand how experiments were carried out.

Results should contain as much information about the findings of the paper as possible!

The conclusion should give the “take home message” of the study and perhaps address the importance of the findings to the research field.

All this has to come under a word count! For most journals the word count is only 200-250 words.

Andrade, C. How to write a good abstract for a scientific paper or conference presentation. Indian J Psychiatry. 2011, 53, pp. 172-175

The Different Types of Scientific Publication

- **Scientific articles** published in scientific journals
- **Patents** – stops others from making, using or selling an invention for a set period of time
- **Books** – might be written by a number of authors
- **Presentations** at scientific conferences (usually topic specific)
- **Government reports** – e.g. the government release information to the public on key science matters such as climate change
- **Internet publications**
- **Blogs and forums**

There are also different types of scientific articles:

| Type of Article | Purpose of Article |
|-----------------|---|
| Letter | Short descriptions of important current findings – considered urgent |
| Research Notes | Short descriptions of current research – less urgent |
| Articles | Extended description of current original research findings |
| Review Articles | Put together results from lots of different papers to give a complete picture of the research field. They provide information about the topic and references to original research |

Most scientific journals require an article to be **peer reviewed** before it can be published. This means that experts in the research field must read and approve the article (and so agree with everything it says!) before it can be made public. This can be a very long and tedious process.

Due date:

Assignment 2

In the tutorial we had a look at the different types of scientific papers and what goes into an abstract.

For this assignment, re-write the abstract for the paper “Structure and Function of the Myometrium” by Garfield et al. The paper will be provided in the tutorial.

Your abstract should be no more than 200 words.

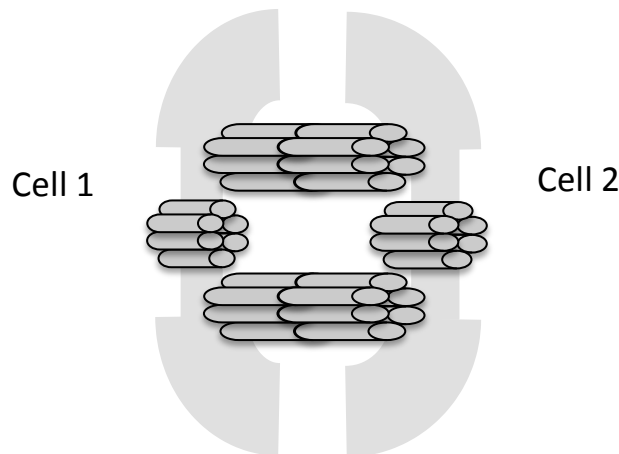
Bring your abstract to the next tutorial, where we will “peer-review” each other’s work.

I realise that the actual abstract is available online. It is very important that you do this in your own words, and don’t just copy the real abstract.

Tutorial 3: SMC Connections and Excitation

Gap Junctions

Smooth muscle cells are connected through gap junctions. Six connexin proteins join together to form a hemichannel. Hemichannels from each cell join together to form a connexon. Hundreds of connexions form a gap junction plaque.



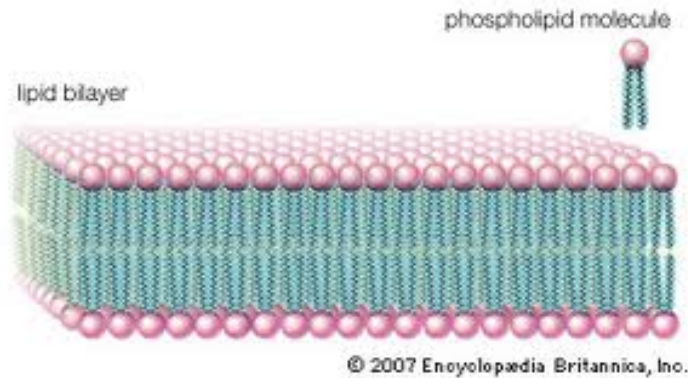
Gap junctions allow the passage of ions and small metabolites from one cell to another. This means excited cells can make their neighbours excited also. If a gap junction is removed, cells can still be connected and can still become excited.

Can you remember the laws for resistors in series and parallel?

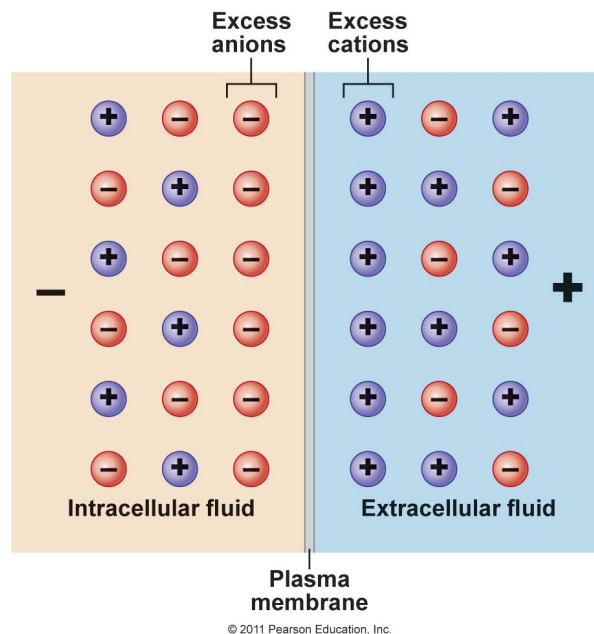
Each connexin protein carries its own resistance r . So the total resistance of a gap junction is:

Cell Membrane

All animal cells are surrounded by a membrane, which is made up of a lipid bilayer with proteins embedded in it.



Each cell has a **membrane potential**. This is the different in voltage between the inside and the outside of a cell. For example, a cell may have more positive charges (cations) outside the cell than inside, and more negative charges (anions) inside the cell which gives the cell a **negative** charge.



A myometrial smooth muscle cell has a **resting** membrane potential of -60mV. The changes in this membrane potential can cause a cell to become excited.

Excitable Cells

All cells have ion channels, which allow ions into and out of the cell. Most ion channels are specific to certain ions. Some ion channels are voltage dependent. This means they are only open to allow ions in and out at certain membrane potentials.

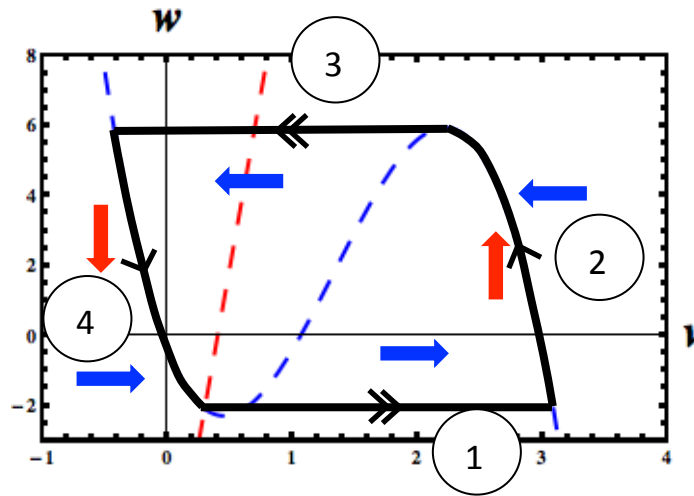
In smooth muscle cells the important ions for excitability are calcium and potassium.



In an action potential calcium enters the cell which increases the membrane potential. This opens voltage-gated calcium channels, which allows more calcium to rush into the cell. This causes the cell to become excited.

The potassium channels then open. These allow potassium ions **into** the cell, so repolarising it.

The calcium and potassium channels work together to excite and repolarise the individual myometrial cell.



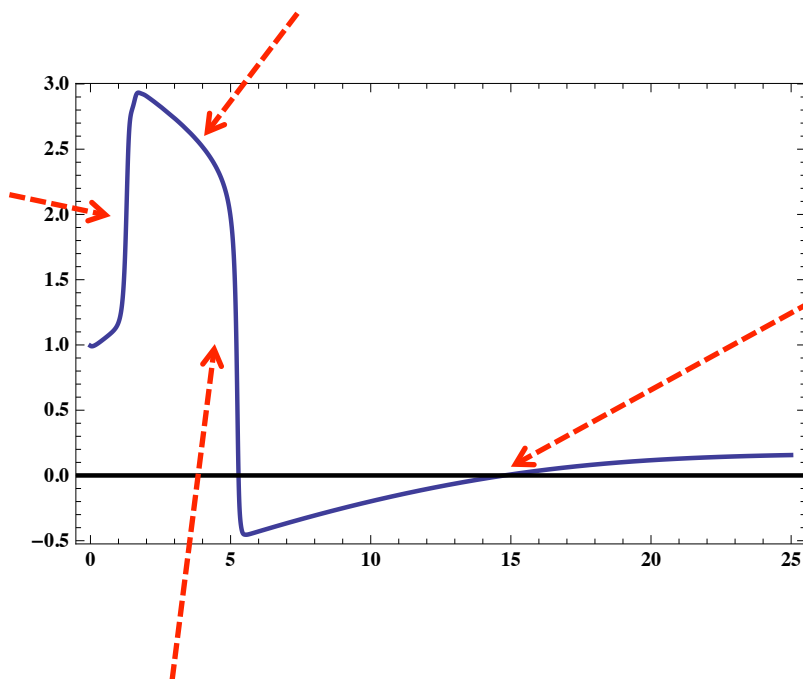
The picture above shows the points where **the rate of change of our two variables is 0**. The trace shown in black demonstrates what we mean by an excited cell.

2

Excited state

1

Rapid excitation



4

Slow repolarisation to rest

3

Rapid repolarisation, overshooting the rest state

In the models I work on, each cell is modelled using FitzHugh-Nagumo dynamics. The calcium channel is modelled through an excitation variable v ; the potassium channel is modelled through a recovery variable w .

Recall,

$$\text{Velocity} = \frac{\text{Change in Distance}}{\text{Change in Time}}$$

Let's call distance s and time t . Then we could write this as

$$\text{Velocity} = \frac{ds}{dt}$$

or velocity is the rate of change of distance.

Here, we use equations for rate of change of excitation (dv/dt) and rate of change of recovery (dw/dt).

HINT: Don't worry about the actual equations. They're not important here and we're not going to use them or solve them. The important thing is that you understand what dv/dt and dw/dt represent.

$$\frac{d}{dt}v = \frac{1}{\varepsilon}(Av(1-v)(v-\alpha) - w - w_0)$$

$$\frac{d}{dt}w = v - \gamma w - v_0$$

Writing a Review Article

A review article is intended to summarise what is currently known about a topic. They do not report new results; instead they discuss research done by other people and combine it into one reference article.

Writing a review article requires the author to have read a lot around the subject! The author should have a good knowledge of the subject and current developments.

The review article should focus on a specific aspect of the research field.

HINT: Highlight the key points from each article and use this as the starting point for your review.

Don't worry if this doesn't make sense yet - you will be given some examples to look at in the tutorial.

Due date:

Assignment 3: Scientific Posters

Create a poster entitled “The Structure and Function of the Myometrium in Pregnancy and Labour”.

Your poster should be made in PowerPoint, be A1 in size and follow the guidelines given below. Remember to make it eye-catching, colourful and not to use too much text.

Refer to the examples shown in the tutorial for more advice!

Similar to a paper, a poster should have:

- An abstract/short summary
- An introduction
- Methods
- Results
- Conclusions
- References

It should be eye-catching visually attractive – it is a prompt for someone to come and talk to you about your work. Therefore, it shouldn't have too much text. No one wants to stand and read an essay! However, not everyone will talk to you about your work, so it should make sense on its own too.

Handy hints:

- Don't spend too much time on the colour scheme
- Your poster should be able to be read from 1 metre away when printed
- Make it stand out from the crowd – use images and show graphs
- Don't overdo the text!!

The role of gap junctions in determining the connectivity and synchronicity of the myometrial smooth muscle network

Rachel E. Sheldon, Andrew M. Blanks, Anatoly Shmygol, Hugo A. van den Berg



The aim of this project is to understand how intracellular communications via gap junctions shape the dynamics of the myometrial smooth muscle cell network in its transition from quiescence to increased activity associated with labour.

1. Introduction

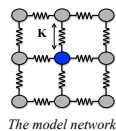
- The myometrium is the muscular layer that makes up most of the uterine wall
- It forms a network of interconnected smooth muscle cells and acts as an excitable system which can propagate signals across long distances [1]
- Throughout most of pregnancy the myometrium is poorly connected [2]
- In the final days before labour, the number of gap junctions connecting smooth muscle cells increases dramatically [2]

2. Modelling

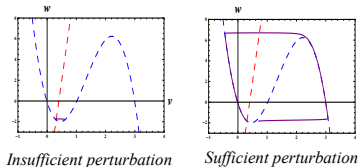
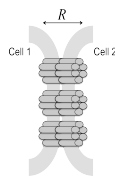
- Each cell in the model obeys FitzHugh-Nagumo dynamics:

$$\frac{d}{dt}v = \frac{1}{\epsilon}(Av(1-v)(v-\alpha) - w - w_0)$$

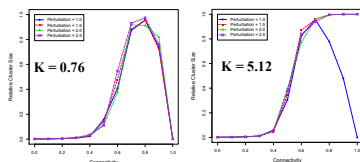
$$\frac{d}{dt}w = v - \gamma w - v_0$$



- Cells are coupled via gap junctions
- One gap junction hemichannel comprises 6 connexin proteins
- A current is applied to a single cell to examine the spread of excitation through the system



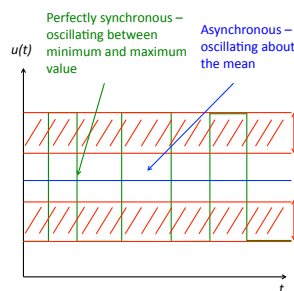
Spatial heterogeneity increases the excitability of the network



This work was submitted for publication in the Royal Society Journal Interface in May 2013

3. Synchronicity Analysis

- Experimental data is analysed by looking at relative intensity values – a bright cell is excited, whereas a dark cell is not
- We consider two extremes: perfectly synchronous and asynchronous. We expect most systems to be between these two extremes.



- We score the amount of time each cell spends near the minimum and maximum intensity

$$I_z(t) = \begin{cases} 1 & \text{if } \sum_{i=1}^n u_i(t) < u^{(0)} - z(\bar{u} - u^{(0)}) \\ & \text{or } \sum_{i=1}^n u_i(t) > u^{(1)} - z(u^{(1)} - \bar{u}) \\ 0 & \text{otherwise} \end{cases}$$

- From this we can calculate a mean value and so express the strength of synchronisation

$$S = \int_0^{\Delta} \frac{1}{T} \int_0^T I_z(\tau) d\tau dz$$

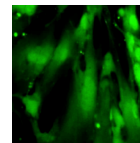
$S \approx 0$ For asynchronous systems

$S \approx 1$ For strongly synchronised systems

4. Experimental Work

- Freshly isolated strips of myometrium are enzyme treated to isolate the smooth muscle cells, which are cultured into a monolayer or cell clusters

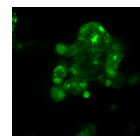
- Cells are stained with green fluorescent calcium indicator (Fluo-4) for confocal microscopy



Isolated smooth muscle cells imaged after 2 days in culture.

- Movement of calcium throughout the system can be visualised – indicating spontaneous activity in the smooth muscle cells

- Cell density can be adjusted, and connections between cells pharmacologically removed to investigate the spread of activation



- Cell clusters can be manipulated pharmacologically, or by passing electric current via microelectrode

Visit my website to see videos of cell activation



5. References

- [1] Garfield, R.E. et al. 1977 Gap junctions: their presence and necessity in myometrium during pregnancy. *Science*
- [2] Challis, J.R.G et al. 2000 Endocrine and paracrine regulation of birth at term and preterm. *Endocrine Reviews*

Tutorial 4: Developing Science Skills

In this tutorial, we will be working on computers and learning how to use information we find on the Internet effectively. We will also be developing the sort of skills you need to be able to study or work in science, and to get high marks in your final assignment!

Worksheets will be provided to develop your skills in referencing, plagiarism (learning not to do it!) and the different methods of presenting your work to an expert, or non-expert audience. All the work done here will support your work for your final assignment – in particular, make a note of all the papers and articles we find today!

The next few pages give you some examples, and guidance to support the work in the tutorial.

Guide to Referencing

There are many different styles of referencing. Each journal has its own preferred style. If you are interested in learning about the different styles, a simple Google search will tell you more.

In this course, we will use the Vancouver style of referencing. Southampton University has produced a good guide to this style of referencing:

<http://www.southampton.ac.uk/library/resources/documents/vancouverreferencing.pdf>

To reference a journal article, you need to know:

- Author
- Title of journal article
- Title of journal (this should be in italics)
- Year of publication
- Volume number
- Page numbers of the article

The reference should look like the following:

1. Sheldon, R. How to reference an article. *The Journal of Referencing* 2013; 42 (1): 209-238.

When you refer to an article in your text, it should be followed by a superscript number which links to the reference list at the end of the text. e.g. “Everything you refer to in a piece of work should be properly referenced.¹”

Remember: never reference Wikipedia! It can be changed by anyone!

Guide to Plagiarism

Plagiarism is the copying of someone else's work and passing it off as your own (for instance, not changing the wording, and not referencing it).

While plagiarism is not illegal, it is considered ethically immoral. It is taken **very** seriously in academia. In a university setting, plagiarised work can result in you being removed from your module or course, and failing!

Each university has its own definition of plagiarism. The University of Warwick's definition of cheating is:

“an attempt to benefit oneself or another, by deceit or fraud. This shall include deliberately reproducing the work of another person or persons without proper acknowledgement. Plagiarism examples include:

- reproducing ideas from another published work without citing the source;
- reproducing words from another published work without quotation marks and a citation of the source;
- copying another student's work and pretending it is yours, with or without their permission, and whether they are a present or past student at this or any other university;
- downloading part or all of a document or ready-made essay from an internet website and pretending it is your own work.”

Plagiarism is punished by a mark of 0.

How to Present Your Work

One of the most important things for a scientist to consider is how they are going to present their work. Scientists need to make sure that both experts and non-experts will be able to understand what they have done, and why their work is so important.

Have a look at the table below and decide who the audience would be for each method of presentation, and what level of detail you would have to go into.

| Presentation Method | Expert/non-expert | Content |
|--|-------------------|---------|
| Department Seminar | | |
| Conference presentation | | |
| Poster presentation | | |
| Article in specialist journal | | |
| Article in general interest journal (e.g. New Scientist) | | |

Due date:

Assignment 4

This assignment will be the first draft of your final piece of work. In the next tutorial, we will talk through your drafts and discuss ways of improving them.

Your final piece of work will be to write a 2500 word review discussing what we currently know about the myometrium, linking it to the management of pre-term labour. Your review should include:

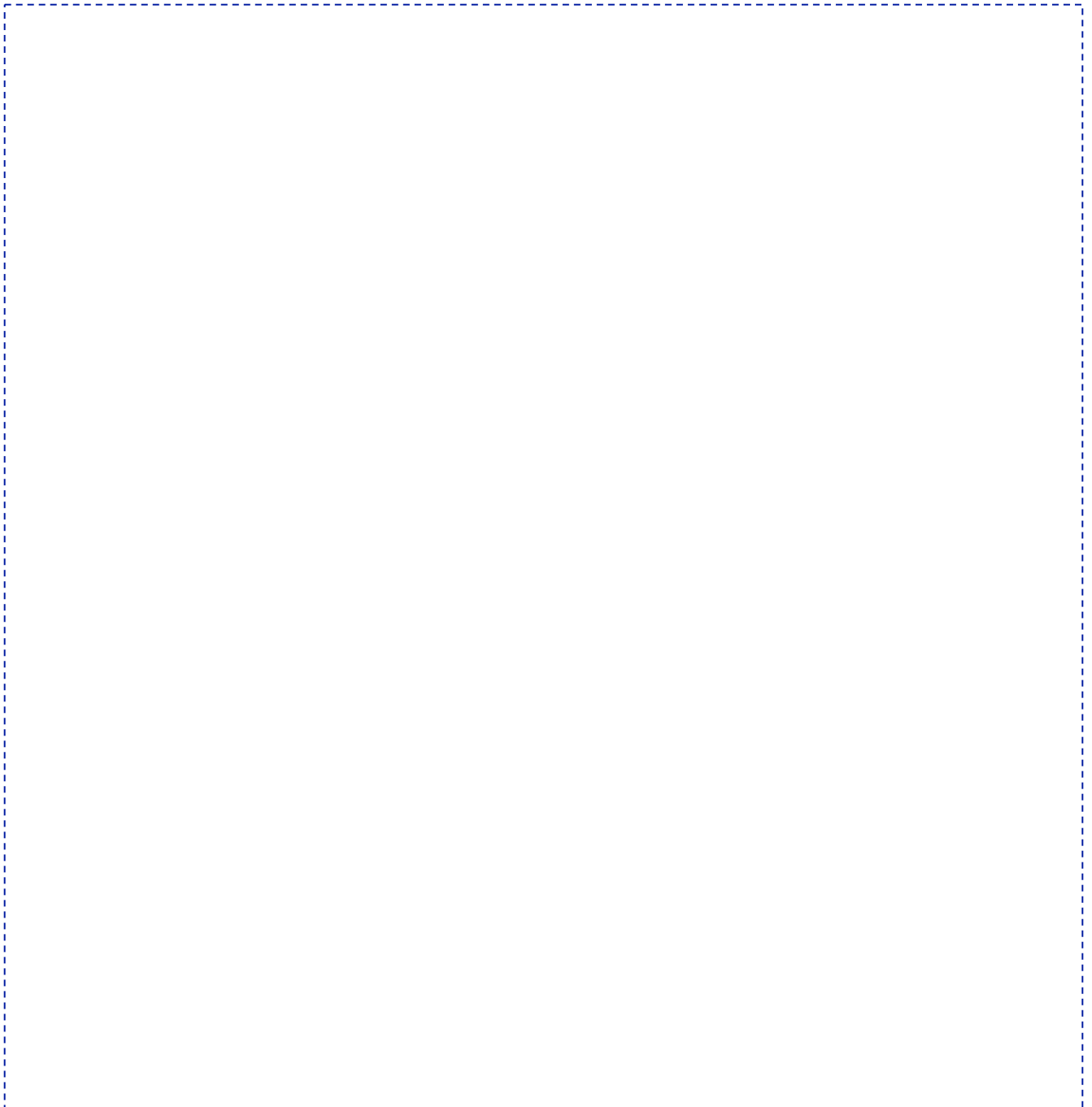
- An abstract
- An introduction – *this can include some of the facts and figures about pre-term labour and why this research is important*
- The structure of the myometrium
- Connections between myometrial cells – *including gap junctions, how they form and how ions pass between cells*
- How myometrial cells become excited – *including action potentials, and maybe some of the equations if you're feeling brave!*
- Summary/conclusions
- References – *every paper you use must be referenced in the text*

More detailed marking criteria will be issued in the tutorial (including grade boundaries), along with some suggested articles to get you started.

Tutorial 5: Feedback

In this tutorial we will focus on the first drafts of your essays, and improving them before the final submission deadline.

We will also be quizzing each other on what we've learnt in the course!
Write down some questions for others in the group below.

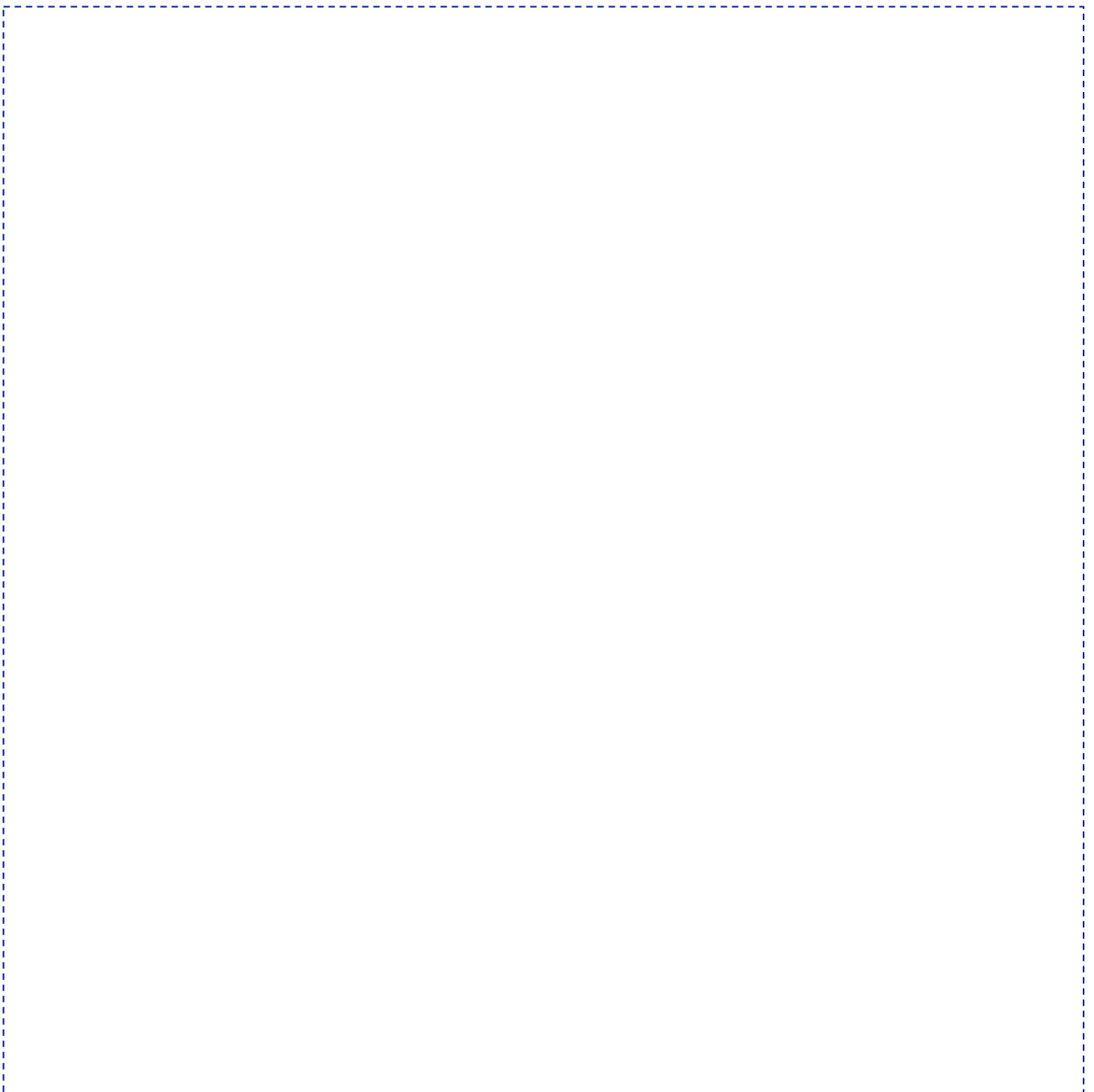


Due date:

Assignment 5

Taking note of the feedback given in today's tutorial, finish your final review article.

You can make a note of any of the general feedback I have given below.



Marking Criteria

Write a 2500 word review article covering the structure of the myometrium, gap junctions and ion channels.

In addition to the table below, marks will be awarded for:

- Spelling and grammar
- Quality of writing
- Use of diagrams
- Structure of essay
- Scientific reasoning
- Research in addition to papers given in tutorials

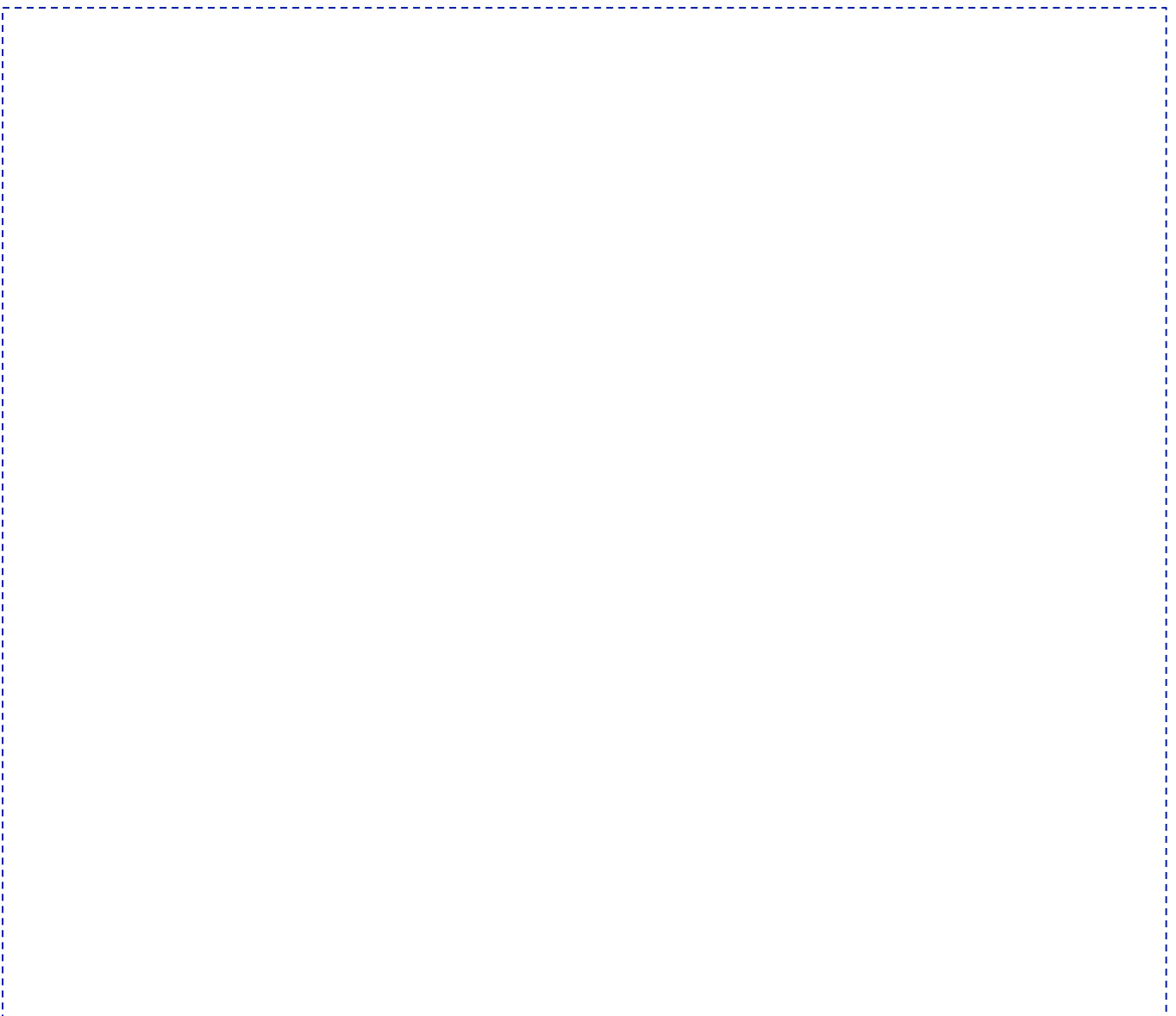
| Section | Description | 1 st Class Essay Marking Criteria | 2 nd Class Essay Marking Criteria | 3 rd Class Essay Marking Criteria |
|---|---|--|---|--|
| Abstract (150 words) | Give a brief overview of your essay. Present the main points you have discussed. | Clear, relevant, comprehensive and concise abstract, outlining the points discussed in the essay. | Generally good abstract, but failing to mention some of the key essay points, but with no irrelevant details. | Abstract omitting most of the essay's key points, containing some irrelevant details. |
| Introduction (250 words) | Introduce your readers to the main points that you will be considering in your essay. Set out the structure your essay will follow. Why is it important that we do this research? Is pre-term labour really that much of a problem? | All of the main points of the essay are introduced here, highlighting the structure that the essay will follow. There is a clear discussion of the ethics of research into pre-term labour, including key statistics about the importance of the research. | Most of the main points of the essay are introduced, following a structure that is largely clear. There is a brief discussion of ethical arguments, lacking evidence or a clear focus. | The main points of the essay are introduced without any clear structure. There is no background to the research given, and no discussion of any ethical arguments. |
| Structure of the Myometrium (300 words) | Describe the structure of the myometrium including what it is made up of, where it is found and how it differs in different species. | A detailed structure of the myometrium is given, including its location within the body. There is a description of its purpose and function. Clear, annotated diagrams are included. Research has been done into how myometrium compares in different species. | There is a description of the structure of the myometrium with a reference to purpose and function. Some extra research has been carried out, but links between species have not been made. | There is a brief description of the structure of the myometrium with no reference to purpose and function. No extra research has been carried out. |

| Section | Description | 1 st Class Essay Marking Criteria | 2 nd Class Essay Marking Criteria | 3 rd Class Essay Marking Criteria |
|-------------------------------------|---|--|---|---|
| Gap Junctions (300 words) | Describe the way in which smooth muscles are connected. Which parts of the cell do they connect? What are the connections made up of? What can travel between the cells? | There is a detailed description of the way in which smooth muscles are connected. The section includes relevant, annotated diagrams. Information is taken from scientific papers and clearly referenced. | There is a description of the way in which smooth muscle cells are connected, but not much detail is given. Some information is taken from scientific papers, which are mostly well referenced. | There is a brief description of gap junctions that does not go into any detail. Information is poorly referenced. |
| Ion Channels (300 words) | What does it mean for a cell to become excited? How does a cell become excited? Which ion channels are relevant to smooth muscle contractions in the uterus? How do they generate contractions? | There is a detailed description of how ion channels function in cell membranes. The ions of interest in the uterus have been identified, and have been used to give a clear description of the method of exciting cells. | There is a description of ion channels, which is linked to smooth muscle contraction. The ions of interest in the uterus have been identified. | There is a brief description of ion channels but no link to smooth muscle contraction in the uterus. |
| Conclusion (200 words) | Summarise the findings of your essay, and link the three sections together to give a clear picture of the way in which a contraction is produced. | Conclusion re-states the points of the essay and incorporates new information to give a detailed description of the method of producing a contraction. | Conclusion re-states the points of the essay. There is an attempt to link the sections together to give a clear description of a contraction. | Conclusion re-states the points of the essay. There is no attempt to link together the sections of the essay |
| References | Everything that features in the essay should be correctly referenced. | Everything included in the essay is clearly referenced (including figures). References are complete and detailed. | Most facts are clearly referenced. References are complete and detailed. | Some facts are referenced, but not all. References are incomplete and not detailed enough. |

Graduation Trip

If you've made it this far, congratulations! You have passed this Brilliant Club module.

In the final tutorial, we will go through the essays and then discuss access to university and university applications. If you have any questions you would like to ask me, make a note of them below:



Glossary

Feel free to add your own definitions to the table.

| Word | Definition |
|---------------------------------|--|
| Action Potential | The potential difference between inside and outside the cell changes direction. Action potentials play a central role in cell-to-cell communication. |
| Anion | A positive charge |
| Cation | A negative charge |
| Connexins | Transmembrane proteins that assemble to form gap junctions. |
| Connexons | An assembly of 6 connexin proteins that form a gap junction channel. |
| Depolarisation | The membrane potential of a cell becomes more neutral. |
| Ethics | Moral philosophy. Is the action “right” or “wrong”? |
| Excitation | The membrane potential of a cell depolarises causing an action potential. |
| FitzHugh-Nagumo Dynamics | The equations I use for modelling smooth muscle cells. They are a simplified version of Hodgkin-Huxley equations for nerve cells. |

| | |
|---------------------------|--|
| Gap Junctions | The pores that link two smooth muscle cells together. |
| Hemichannels | Half of a gap junction channel. Connect the membrane of a cell to extra-cellular space. |
| Ion Channels | Pore-forming membrane proteins that gate the flow of ions across the cell membrane. |
| Lipid Bilayer | Thin membrane made of two layers of lipid molecules (e.g. fat molecules) |
| Membrane Potential | The difference between the voltage inside the cell and outside the cell. |
| Metabolites | Small molecules involved in fuel, structure, signalling and other cellular functions. |
| Repolarisation | The membrane potential of the cell becomes more negative, typically after an action potential. |
| Uterus | Scientific name for the womb. Holds the baby during pregnancy. |
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The **Brilliant** Club

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