Neurones and their interactions

Introduction

In this activity students review the structure and function of nerve cells (neurones) and synapses using simple practical models. They will need to refer to their textbook or other source of information for Part C, see weblinks for suggestions. Part B might be omitted if time is short or if students are already familiar with the experiments.

Note on spelling: both neuron and neurone are widely used and either are acceptable in this subject.

A Domino model of nerve impulse

Equipment

Dominoes
Ruler, preferably one with a groove running down the middle
Marble, golf ball or other small sphere.

The activity

Dominos arranged on their ends in a line can be used to illustrate some aspects of a nerve impulse.

A simple model of a synapse can be included, using a ball which rolls down a ruler (Fig. 1).

Figure 1

Science explanations

Ja Nerve cells (neurones) are specialised cells, the basic unit of the nervous system. They consist of three parts; branched extensions (dendrites) that receive signals from other cells, a cell body that integrates the signals received from dendrites and a fibre of varying length (axon) that transmits signals to other cells including other neurones.

Jb There are about 10^{11} neurones in a brain. Each neurone is connected to many others giving over 10^{14}. Interconnections.

Jc Waves of electrical activity (impulses) travel very quickly along the length of the neurones carrying the signals.

Jd A chemical transmits the signal across the junction between two neurones (synapse).

Jh Most drugs that influence brain function work by changing levels of neurotransmitters. Two of the ways they may do this are by mimicking neurotransmitters or by affecting their reuptake at synapses. For example; nicotine mimics acetylcholine, anti-depressants inhibit serotonin uptake. All drugs (medical and recreational) that affect the brain have some undesirable side-effects.

Question

1. The information above explains two ways in which this simple model is similar to a real nerve impulse. Describe two ways in it is significantly different. Use your textbook p.3 to learn more about real neurones.
   the model is much slower
   real impulses are electrical not mechanical
   synapses use chemical transmitters, not mechanical

B Estimating the speed of a nerve impulse.

(i) Communicating by hand

Equipment: stop watch (or watch with second hand)

Ask the class to hold hands in a ring. Give the instruction that as soon as each person feels their hand being squeezed, they should squeeze the hand of the next person in the ring as quickly as possible. One person holds a stop watch, and presses the start button, simultaneously squeezing the hand of the person on their left. He/she waits until the sequence comes back round the ring, to their right hand, then presses the stop button. The assumption is made that the distance from finger-tip to finger-tip is 2m. The total distance travelled by nerve impulses is therefore 2m multiplied by the number of people in the ring.

Question

2. Explain whether this method is likely to give an over-estimate or under-estimate of the speed of a nerve impulse.

   It is likely to give an under-estimate because it takes time for each person to react to the stimulus of their hand being squeezed: there is a short delay while the signals cross synapses in the brain during the decision-making process.

(ii) Dropping a ruler to measure reaction time

Equipment
30cm ruler
Calculator

Sample calculation
From Newton's laws of motion: $t = \sqrt{(2 \times s/a)}$
s = distance dropped in cm,
t = time taken to drop that distance in seconds,
a = acceleration due to gravity = 1000cm/sec^2

Assume average distance dropped, s, = 12.5cm

Time, t, taken to drop 12.5cm = $\sqrt{(2 \times 12.5 / 1000)}$ = 0.16 seconds

Reaction time = 0.16 seconds or 160 milliseconds

You may wish to suggest that students read a value from the graph Figure 3 on the student sheet rather than calculating reaction time themselves.

[Some websites also offer a means of calculating reaction time].

Answers to Questions

3a) Explain what reaction time tells you about the speed of a nerve impulse.
b) Suggest some causes of differences in reaction time between individuals.

3a) Reaction time includes the time for light to travel from the ruler to the eye (negligible), the time for the brain to decide what to do (relatively slow) and the time taken for nerve impulses to travel from the motor cortex in the brain to the muscles in the hand, to move the fingers.
b) Some people have quicker responses than others. This could be due either to nature (genes) or nurture (environment). Individual differences can occur in both brain reaction times and speed of muscle contraction. Reaction time is also affected by how well a person is concentrating. Older people may have slower reactions.

4. Use the mean, median and range of your ten measurements to compare the results of the boys and girls in your class, or compare the class results with the teacher's results. Can you explain any differences?

Reaction times of older people tend to be slower. There may be differences between boys and girls in either direction, and students should consider whether any differences are likely to be real ones or simply due to chance. For example if all the boys in a class are slower than all the girls, this is likely to be statistically significant. (Six boys being slower than all six girls – or vice versa - in a class is significant at the 0.05%level). If the results overlap, the difference between the two groups is less likely to be significant.

(iii) Mental task and reaction time

Include a mental task whilst measuring your reaction time. The person dropping the ruler gives a word as s/he releases the ruler. The responder has to give a word association as s/he catches the ruler (eg the dropper says pen and the catcher says paper). Catches without an appropriately associated word do not count.

Answers to questions

5a) Compare your results with the word association task with those without.
b) Explain any differences.
c) Suggest some real situations in which you need to respond physically and verbally at the same time.

5a) Results for the more difficult task involving word association are likely to be much slower.

b) This is multi-tasking and is much more difficult than focusing on one activity as the attention of the brain is divided between two tasks.

c) Such activities include talking while preparing food or using a mobile phone while driving. It is commonly believed that women are better than men at multi-tasking!

C Synapses

Equipment

Enlarged copies of Figure 4 one per group
Scissors or coloured pens

Matching shapes of molecules in a synapse.

Fig. 4 overleaf shows the simplified structure of a synapse.

Figure 4

Answers to questions

6a) Explain, with reasons, which molecule, A, B or C, has each of the effects (agonist, antagonist or reuptake inhibitor). In each case explain how the molecule either increases or decreases the activity of the second neurone.

b) Explain how each of molecules A, B and C could be used as a drug to treat mental illness. Some mental illnesses are believed to be caused by either too much neurotransmitter (schizophrenia) or too little neurotransmitter (Parkinson's or depression).

A is a reuptake inhibitor: it fits into and blocks a (blue) reuptake molecule and prevents the reuptake of the neurotransmitter. This leaves more neurotransmitter in the synaptic gap, increasing the activity of the second neurone. It could be used to treat a mental illness which is caused by a lack of a neurotransmitter, for example Parkinson's disease (lack of dopamine), or depression (lack of serotonin).

B is an agonist: it fits into the (yellow) receptor on the second neurone, mimicking the effects of the natural neurotransmitter, increasing the activity of the second neurone. An agonist can be used to stimulate the brain when a neurotransmitter is lacking (as for A), but they can have a powerful effect even in small amounts.

C is an antagonist: it fits into the (yellow) receptor on the second neurone, but the shape of the 'key' is not quite right. It does not stimulate the second neurone but prevents the natural neurotransmitter from attaching to the receptor, decreasing the activity of the second neurone. An antagonist can be used as drug when a neurotransmitter is present in too great amounts. They are used in anti psychotics used to treat schizophrenia.

December 2010

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Introduction

In this activity you will review the structure and function of nerve cells (neurones) and synapses using simple practical models.

(a) Domino model of nerve impulse

Equipment:

- Dominoes
- Ruler, preferably one with a groove running down the middle
- Marble, golf ball or other small sphere.

Use dominoes arranged on their ends in a line to illustrate some aspects of a nerve impulse. When the first domino is toppled, it sets off a chain reaction, toppling each domino in turn. The 'impulse' travels as a wave down the line. Energy is used to set the dominoes up again, allowing the next 'impulse' to happen. This is analogous to a real nerve impulse since it requires energy to pump ions out of an axon before each nerve impulse can occur. (An axon can carry 50-100 nerve impulses per second).

A simple model of a synapse can be included, using a ball which rolls down a ruler (Fig 1). A small ball represents a neurotransmitter molecule. (The ball needs to be finely balance so that it begins to roll only when the domino hits it). The ball rolls down the ruler and sets off an 'impulse' in the next 'neurone'. The model illustrates the delay to the signal caused by the synapse.

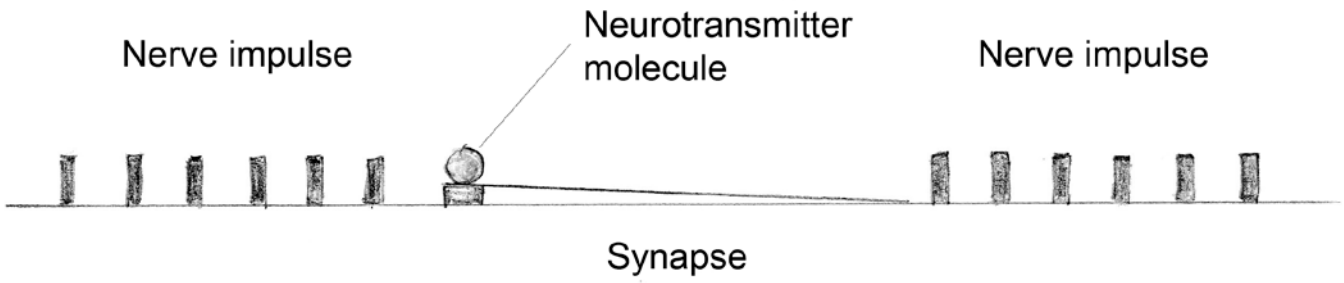

Figure 1

Question

1 The information above explains two ways in which this simple model is similar to a real nerve impulse. Describe two ways in it is significantly different. Use your textbook p.3 to learn more about real neurones.

(b) Estimating the speed of a nerve impulse.

(i) Communicating by hand

Form a ring and measure the time taken for the impulse to get round, as instructed by your teacher. Estimate the speed of the nerve impulse around the ring using a calculation as in the example below, but substituting your own figures. Assume the distance from fingertip to fingertip is 2 metres.

Sample calculation of speed of nerve impulse in metres per second.

Number of people in ring = *10*
Distance travelled by nerve impulses = *10* x 2m = 20m
Time taken = *2.5* seconds.

Nerve impulses travelled 20m in 2.5 seconds = 8 metres per second.

Question

2 Explain whether this method is likely to give an over-estimate or under-estimate of the speed of a nerve impulse.

(ii) Dropping a ruler to measure reaction time

Equipment

- 30 cm ruler
- Calculator

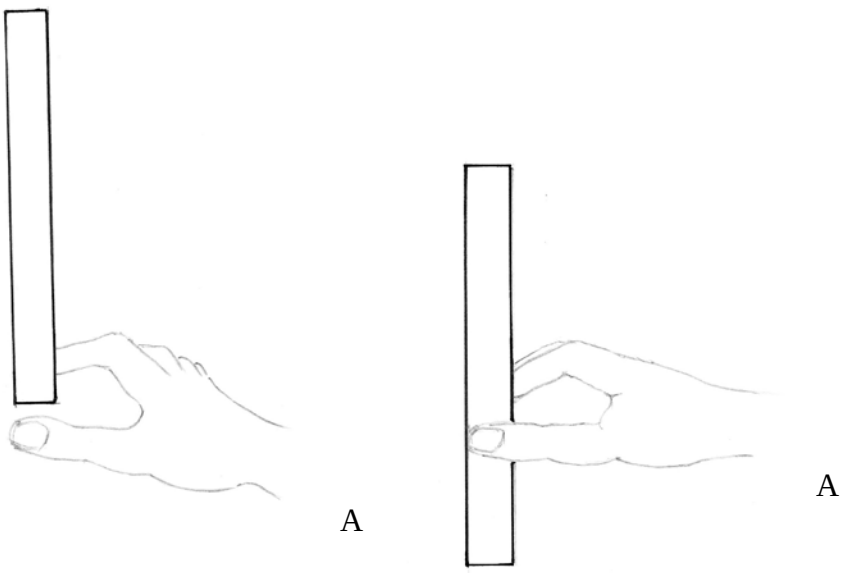

Figure 2

Work with a partner.
Person B holds a ruler vertically near the 30 cm mark
Person A holds finger and thumb apart with the 0 reading between their finger and thumb (Fig 2).
Person B drops the ruler and A catches it as quickly as possible.
The position of A's finger and thumb on the ruler is noted.
The procedure is repeated ten times and an average taken.
The time taken for the ruler to drop the measured distance is calculated using the method below or read from the graph, Figure 3.
Your teacher will tell you which method to use.

Sample calculation
From Newton's laws of motion: $t = \sqrt{2 \times s/a}$)
s = distance dropped in cm,
t = time taken to drop that distance in seconds,
a = acceleration due to gravity = 1000cm/sec^2
Assume average distance dropped, s = 12.5cm

Time, t, taken to drop 12.5cm = $\sqrt{(2 \times 12.5 / 1000)} = 0.16$ seconds

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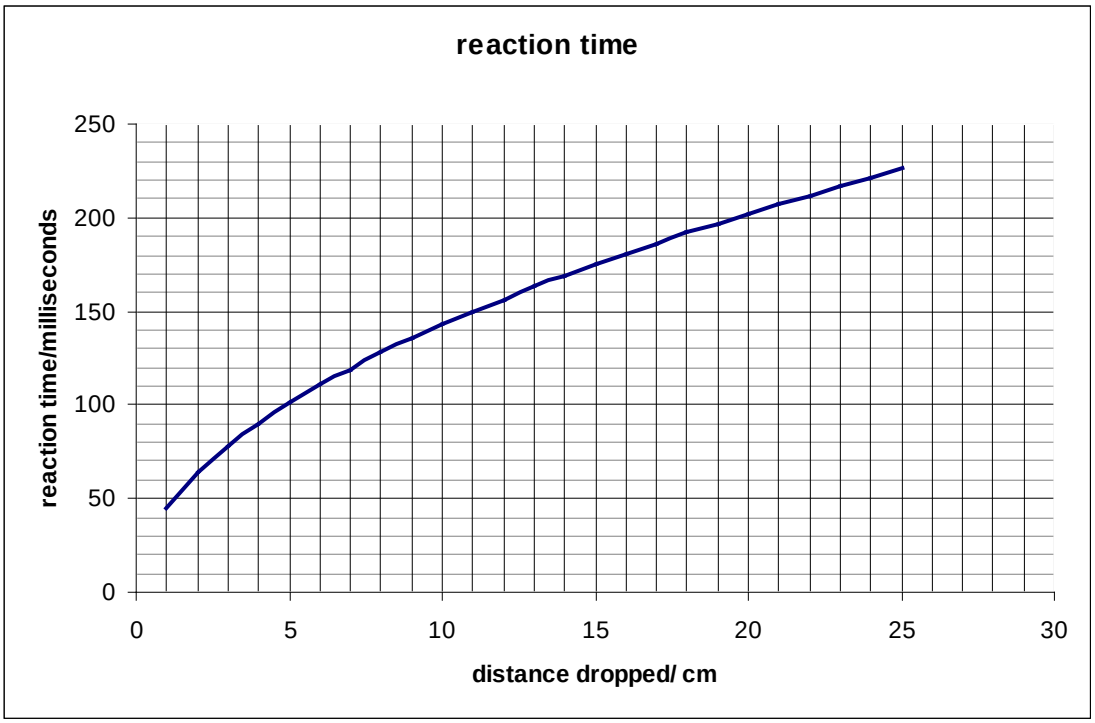

Figure 3

Questions

3a) Explain what reaction time tells you about the speed of a nerve impulse.
b) Suggest some causes of differences in reaction time between individuals.

4 Using the mean, median and range of your ten measurements compare the results of the boys and girls in your class, or compare the class results with the teacher's results. Can you explain any differences?

(iii) Mental task and reaction time

Include a mental task whilst measuring your reaction time. The person dropping the ruler gives a word as s/he releases the ruler. The responder has to give a word association as s/he catches the ruler (eg the dropper says pen and the catcher says paper). Catches without an appropriately associated word do not count.

Question

5a) Compare your results with the word association task with those without.
b) Explain any differences.
c) Suggest some real situations in which you need to respond physically and verbally at the same time.

Synapses

Matching shapes of molecules in a synapse.

Fig. 4 overleaf shows the simplified structure of a synapse. Neurotransmitter molecules (red) are released from the first neurone, diffuse across the synaptic gap and attach to receptor molecules (yellow) on the second neurone. The docking of neurotransmitter onto the receptors, like a key in a lock, initiates nerve impulses in the second neurone. The neurotransmitter is then reabsorbed into the first neurone via reuptake molecules (blue).

Molecules A, B and C (green, mauve and orange) represent, but not in that order:

- an agonist (a drug that binds to a receptor of a cell and triggers a response by the cell)
- an antagonist (a drug that acts against and blocks an action) and
- a reuptake inhibitor

Figure 4

Using a larger version of Figure 4, cut out one or more molecules A, B and C and insert them in their site of action on the diagram. Alternatively draw A, B and C in the appropriate places.
Read the appropriate sections of Chapter 1, then answer the questions:

Questions

6a) Explain, with reasons, which molecule, A, B or C, has each of the effects (agonist, antagonist or reuptake inhibitor). In each case explain how the molecule either increases or decreases the activity of the second neurone.

b) Explain how each of the molecules A, B and C could be used as a drug to treat mental illness. Some mental illnesses are believed to be caused by either too much neurotransmitter (schizophrenia) or too little neurotransmitter (Parkinson's or depression).