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IPGs and pain relief

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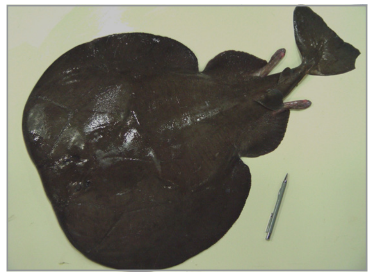
Early attempts to control pain

The first evidence of active measures to control pain date back to the Stone Age where teeth have been discovered with fillings made of bees wax to reduce the pain of dental cavities.

The Ancient Egyptians, Greeks and Romans used electricity to treat pain. How was this possible when the 'invention' of electricity was almost 2000 years in the future? The answer is simple; they used electricity produced by animals (fish) to stun their prey or to deter predators.

The Egyptians used electricity produced by electric eels from the Nile, to treat the pain caused by wounds and also the pains of childbirth, by laying the eels on the site of the pain until it went numb.

In the first century AD the personal physician to Emperor Claudius, Scribounius Largus recommended electrical treatment for the control of the pain of migraine. He placed the electric torpedo ray (right) on the head, in the area of the pain, until the area went numb and the pain disappeared.



Benjamin Franklin, who famously and very dangerously flew a kite in a thunderstorm, was one of the first to investigate electricity in a scientific way. He apparently used static electricity to cure his migraine. However it caused ***retrograde amnesia*** and as a result of this he went so far as to suggest it could be used to treat the insane. This was probably where the idea of was born.

What is pain?

Pain, according to the International Association for the Study of Pain '*is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage"*

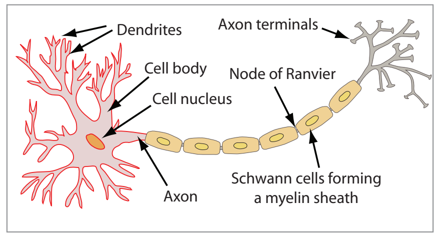
You have probably at some time in your life suffered pain from a toothache or a sports injury, and when playing a computer game the pain has disappeared as you became totally involved in the game. The cause of the pain was still there but the feeling had disappeared. The same is true when you are under an anaesthetic. Pain is not simply a physical sensation but also a state of mind. How can this happen?

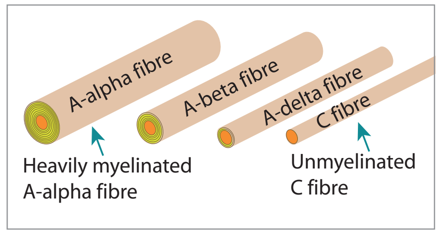
Sensing pain

There are special ***sensory neurons*** called ***nociceptors*** that tell the body "this feels bad!" Nociceptors have free nerve endings and the cell body is in the dorsal root ganglion as shown in the diagram to the right. These form three basic groups of nociceptors. Some detect harmful temperature (such as the burning sensation of a hot plate), some detect harmful chemicals (such as capsicum in chillies) and others detect body damage (such as spraining your wrist or ankle in sports.)

These messages are relayed to the brain in different ways. Some fibres, called ***A-fibres***, are ***myelinated*** and relay the message rapidly and directly. (There are three types of A-fibre: A-alpha, A-beta and A-delta.) A-delta fibres signal sharp pain, such as when your wrist is overextended. Signal speed in these fibres is 5 to 35 m/s.

Another type called ***C-fibres*** are non-myelinated relaying the message much less rapidly (< 2 m/s) and they are also branched, reporting to the brain from many different areas at once. These C-fibres are responsible for the dull ache felt after the initial stab of pain. These messages reach the brain and are then exchanged back and forth between the thalamus and the hypothalamus and it is this exchange that is responsible for the sensation of pain.





It has been known for a very long time that the brain has no nociceptors, and because of this patients having brain surgery are normally fully conscious during the procedure. If the brain has no nociceptors, then how does a headache occur? Brain freeze (that intense pain you get in the centre of your head when you eat too much ice cream too quickly) is a good example to explain this. When the blood vessels in the roof of your mouth are cooled suddenly by the ice-cream they suddenly ***dilate*** and this triggers nociceptors to fire. These nociceptors have lots of branches and are not very precise in describing their location so the brain interprets the signals as coming from the centre of your head rather than the roof of the mouth. This results in a pain in the head. Pain that appears to be coming from a location other than its real source is called ***referred pain***. One classic example of referred pain is the pain in the arm often felt by those experiencing a heart attack.

As well as being able to ignore pain signals when you are engrossed in some activity the brain also has the ability to create feelings of pain when there are no nociceptors active or even present. Amputees sometimes feel pain from limbs that are no longer there; these are called ***phantom pains***.

Chemical pain relief

We are all well aware that taking certain chemicals (such as aspirin) can reduce the severity of pain especially of pains that only last only a relatively short time. However when it comes to chronic pain these are less effective in the long term.

Hippocrates advised that willow bark and leaves be chewed during childbirth, which was reasonably good advice since both contain a form of salicylic acid, the active ingredient in aspirin so it probably took the edge off the pain. Opiates have also been used for thousands of years and are very effective but many of them are addictive and toxic, as well as sleep inducing. Modern versions are less addictive but must still be treated with respect.

Use of electricity for pain relief

Around the start of the 19th century people were able to create and store electricity at will and this opened a new era in electro medicine, first of all using ***direct current***, and then ***alternating current***. Electricity was used for the treatment of a whole variety of ailments including; gynaecological, dental, psychiatric and neurological. However it was not well understood by the general public and so was open to "quackery" by fake doctors. By the start of the 20th century it had fallen from grace, being branded as non-scientific and 'hocus pocus'.

An implantable pulse generator (right), charger (centre) and a remote control (left)

Despite this it began to make a comeback in the 1960's; initially in the form of deep brain stimulation using high frequency alternating current, and a few years later by spinal stimulation in an attempt to treat intractable pain. The publication of the ***gate theory*** of pain in 1965 by Melzak and Wall gave much needed scientific credibility to the whole branch of electro medicine.

In simple terms when the C fibre fires it causes the Projection Neuron fire and we feel pain. However when the A fibres fire they cause the Inhibitory Neurons to fire and this stops the Projection Neurons from firing as frequently thus reducing the pain. The pain is not stopped altogether but is rather replaced by a reportedly pleasant tingling sensation called paraesthesia.

Electrodes implanted into the spinal cord at various locations stimulate both A and C fibres and as a result block the pain signals. This is referred to a ***neuromodulation*** as it alters the cellular or synaptic properties of some neurons so that transmission from one to the other is changed.

Initially the devices required to produce the required the high frequency electric current were large and unwieldy, but with the advent of microelectronics, wireless devices and improved battery technology is has become possible to implant subcutaneous devices with electrodes inserted into various parts of the nervous system. These impulses can be controlled by the wearer in response to pain using an external keypad to obtain maximum relief. These devices are called ***implantable pulse generators (IPGs)***. You will probably have heard of them as pacemakers for people with certain heart problems, but they are becoming more and more important in the relief of pain and in the control of tremors such as those that are afflicted by ***Parkinson's disease***.

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Syllabus References

The main syllabus references for the lesson are:

Leaving Certificate Biology (pp. 37-38)

- The nervous system: two-part division into the central nervous system (CNS) and the peripheral nervous system (PNS). Neuron: its structure and function, with reference only to cell body, dendrites, axon, myelin sheath, Schwann cell, and neurotransmitter vesicles. Movement of nerve impulse.
- Activation and inactivation of neurotransmitter. Role and position of three types of neuron: sensory, motor and interneuron.
- Central nervous system: brain and spinal cord.
- Peripheral nervous system: location of nerve fibres and cell bodies.

Science and Technology in Action is also widely used by **Transition Year** classes.

Learning Outcomes

On completion of this lesson, students should be able to:

- Explain the terms pain, nociceptors, A-fibres and C-fibres
- Outline how pain in the head is caused by imprecise information from C-fibres being misinterpreted by the brain although the brain has no nociceptors
- Understand that the feeling of pain arises from the bouncing of impulses between the thalamus and hypothalamus
- Describe some chemical and electrical treatments for pain
- Understand what IPGs are and give some of their use.

General Learning Points

These are additional relevant points which are used to extend knowledge and facilitate discussion.

- Pain control has been practiced for thousands of years using all sorts of methods; physical, psychological and chemical.
- Nerves are far more complex than at first thought; they interact and are influenced by a variety of chemicals.
- Pain is more than just the transmission of impulses along nociceptors; it also has an emotional aspect as well. Emotions have an influence on our perception of pain.
- The brain responds to some nerve impulses, ignores others and sometimes creates imaginary impulses.
- Modern pain control of intractable pain is multidisciplinary.
- Electric pulses have a whole variety of uses other than simple pain control. IPGs can control heartbeat, tremors, stimulate muscle movement.

Student Activities

1. Find out more about the different classes of chemical pain killers and their possible dangers.
2. Investigate the different types of implantable pulse generators (IPGs) and what conditions they are used use. What problems may be encountered in their use and how are these problems overcome?
3. List two examples of referred pain and in each case state where the pain is felt and the source of the pain.
4. Investigate how hypnotism can be used to control pain.
5. Can you discover why rubbing your leg after getting a kick during a game helps relieve the pain? Do you think physiotherapy can help relieve pain; explain your answer?
6. Find out more medical practices that people tend to think are modern but were in fact carried out in ancient times. (Removing cataracts in the eye will get you started.)
7. Distinguish between the following terms: static electricity, direct current and alternating current.
8. Discover more about retrograde amnesia and electric shock therapy.
9. How many different animals can you discover that use electricity to catch their prey and discourage predators. In what parts of the world are they found?

True/False Questions

a)	Myelinated nerves carry impulses faster than non-myelinated nerves.	T F
b)	Nociceptors respond to potentially harmful situations by sending messages to the brain.	T F
c)	All pain is the same.	T F
d)	The stimuli that cause sharp pains travel through the myelinated A fibres.	T F
e)	Using electrical impulses to control pain is a modern phenomenon.	T F
f)	Nociceptors are receptors that transmit information about things that may cause damage to the body.	T F
g)	John Bonica was the first person to establish a multidisciplinary approach to pain relief.	T F
h)	Pain is felt when impulses bounce between the thalamus and hypothalamus.	T F
i)	IPG stands for internal pulse generator.	T F
j)	IPGs can help control Parkinson's disease.	T F

Check your answers to these questions on **www.sta.ie**.

Examination Questions

Leaving Certificate Biology (HL) 2004, Q.15 (a)

(i) Draw and label sufficient of two neurons to show a synaptic cleft.

(ii) Describe the sequence of events that allows an impulse to be transmitted across a synapse from one neuron to the next.

(iii) Suggest a possible role for a drug in relation to the events that you have outlined in (ii).

Leaving Certificate Biology (HL) 2006, Q.14 (b)

(i) What is a neuron?

(ii) Distinguish between sensory, motor and interneurons (association neurons).

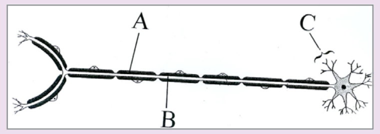
(iii) Briefly explain the role of neurotransmitter substances.

(iv) State a function for 1. Schwann cells, 2. Myelin sheath.

(v) In relation to Parkinson's disease or paralysis give;
1. A possible cause, 2. A method of treatment.

Leaving Certificate Biology (HL) 2008, Q.4

The diagram shows a motor neuron.



(a) Identify parts A, B and C.

(b) Give a function of A

(c) Place an arrow on the diagram to show the direction of the impulse.

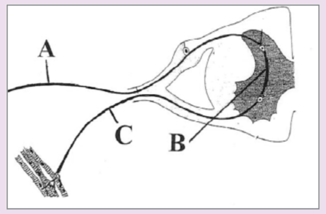
(d) Give a function of C

(e) Place an X on the diagram at a point at which a neurotransmitter substance is secreted.

(f) What is the role of the motor neuron?

Leaving Certificate Biology (OL) 2017 Q.13 (b)

The diagram shows the nerve cells (neurons) in a reflex arc.



(i) Name the neurons labelled A, B, C.

(ii) Is the impulse transmitted from A to B to C or from C to B to A?

(iii) Give one example of a reflex action in humans.

(iv) Why are reflex actions important to humans?

(v) What name is given to the gaps between neurons?

(vi) Neurotransmitters are released into the gaps between the neurons. Why does this occur?

(vii) What happens to neurotransmitters once they have carried out their function.

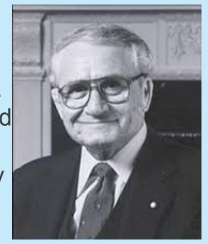
Did You Know?

Facts about neurons

- The number of neurons in the human body is approximately 90 billion.
- That's almost as many as the number of stars in the Milky Way galaxy!
- About 90% of human neurons are in the brain.
- You are born with all the neurons you will ever have.
- The axons of some human neurons are over a metre long. However many are very thin — about 4 microns in diameter.
- The speed of nerve signals depends on the thickness of the myelin sheath that surrounds the axon of the neuron. C -fibres are unmyelinated and signals travel at less than 2 metres per second. Signals travel fastest along A-alpha fibres — 120 metres per second or about 430 km/h.

Biographical Note

John Bonica (1917 – 1994)



John Bonica is known as the father of pain relief study. He was a very unusual character. He was born in Sicily and the family emigrated to America when he was ten. His father died when he was 15 and he took on responsibility for the family selling newspapers to make ends meet. He took up wrestling in an effort to put himself through college and he became very proficient, winning a World Championship in 1941. However, wrestling left him with chronic pain.

His experience as an anaesthesiologist with the army had a profound effect on him. In 1960 he founded the Department of Anesthesiology in Seattle and there he established his Multidisciplinary Pain Center. This was so successful that others copied his approach and by the late 1970's there were almost 200 such centres scattered around the US. He was also a busy author, writing or editing over 40 textbooks and over 240 papers.

Revise The Terms

Can you recall the meaning of the following terms?
Revising terminology is a powerful aid to recall and retention.

A-fibre, alternating current, C-fibre, direct current, electric shock therapy, implantable pulse generator (IPG), myelinated, neuromodulation, nociceptors, pain, Parkinson's disease, phantom pain, referred pain, retrograde amnesia, sensory neuron.

Check the Glossary of terms for this lesson on www.sta.ie