## Mark Pollock

During Mark's final year in University, age 22, he lost his sight due to a ***detached retina***. However Mark learned how to get around with a guide dog and how to use a computer that speaks to him. He completed a master's degree and returned to his sport, rowing, and went on to win medals at the Commonwealth Games. He became an ultra endurance athlete and raced across deserts, mountains, and the polar ice caps. Ten years after losing his sight he became the first blind person to race to the South Pole and he used what he learned on his adventures and rebuilding his life after blindness to create a career as a motivational speaker.

*Mark Pollock at the South Pole*

However in 2010, Mark had a terrible fall, 25 feet (8 m) from an open window. He broke his back and the burst fractures of his T9 and L1 ***vertebrae*** damaged his ***spinal cord***; he cannot move or feel anything below his bellybutton. Mark writes: *"Spinal cord injury turns us from our standing upright, running forms into seated compromises of our former selves. It results in a loss of sexual function, normal bladder function and we die before our time. But, I don't think I, or anyone else paralysed, should have to live without hope anymore. I think we can create the cure."*

## The human spinal cord

The human ***nervous system*** includes the brain, spinal cord and nerves. The spinal cord is contained in the bones that make up the vertebral column. Your spinal cord is about 45 cm long. At the top and the bottom, it's as thick as the tip of your baby finger, and maybe half that wide in the middle and is shaped like a slightly flattened circle.

The main spinal cord functions are: -

- **Motor Function** tells muscles to do their work - to make fine movements such as moving our toes or gross movements such as running, walking and kicking.
- **Sensory Function** is the part of the nervous system responsible for processing what we feel or otherwise detect – such as vision, hearing and touch or feeling.
- **Autonomic Function** is the part of your nervous system that controls ***involuntary*** actions, such as the beating of your heart and the widening or narrowing of your blood vessels.

## The human nervous system

There are two main parts: the ***central nervous system (CNS)*** and the ***peripheral nervous system (PNS)***. The system contains cells called neurons that communicate via rapid transmission of either electrical or chemical signals and it coordinates voluntary and involuntary bodily actions.

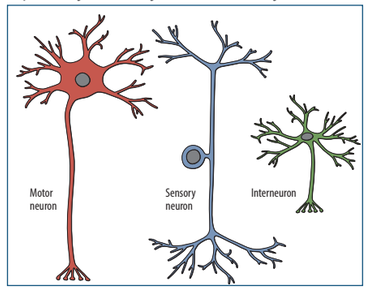
The brain and spinal cord are in the CNS. The PNS connects the CNS to other parts of the body. It does this via neurons that have extensions called ***axons*** (nerve fibres). The function of the axon is to transmit signals to different neurons located in other parts of the body. Some of these signals travel at over 100 m/s.

There are 3 different types of ***neuron*** that work together:

**Motor Neurons**
Using their axons, ***motor neurons*** can speak to other neurons. But some of them can also speak directly to muscles and that neuron is called a motor neuron.

**Sensory neurons**
***Sensory neurons*** have two axons, one of which heads out into your body, where it's attached to a particular part of you — say, the bottom of your toe. At the end of that axon are receptors that can feel the difference between an itch, a sharp poke, or a caress. The receptor shoots that information directly back to your spinal cord, where one of a number of things can happen.

**Interneurons**
***Interneurons*** are like very fast translators, ensuring that the sensory neurons can talk to motor neurons.




*The three types of neuron*

## Working together

Interneurons take the information from sensory neurons and zap it right to the dendrites of nearby motor neurons — the ones that control the muscles you need, for example, to jerk your foot back if you step on something sharp. The brain isn't involved until a tiny fraction of a second later, which is the time it takes for the other split of that sensory neuron's axon to shoot all the way up the cord and get connected with receptors inside the brain.

## How does information travel along the neuron?

There's a tiny gap (or ***synapse***) between one axon and another and the tip of the axon sends tiny molecules called ***neurotransmitters*** into that gap. Neurotransmitters can be electrical or chemical and when they cross the tiny gap and slot into the waiting receptor of another neuron, the chemistry of both of the nerve cells changes. That's how all information moves through your system – hunger, pain, standing - everything comes from tiny neurotransmitters docking into tiny receptors.

## Human spinal cord injury

A common cause of the loss of these functions is a spinal cord injury (SCI). It can occur in many ways including car accidents and falls, or because of a virus that attacks the spinal cord. Generally, human cells are always dividing, dying, and being born for your entire life. But your neurons almost never replace themselves.

## Can science create the cure?

There is not cure for spinal cord injury. But there are brilliant scientists around the world trying to create a cure. Some scientists work in the molecular biology field and are trying to discover whether it might be possible for some other kind of cell to help out, like stem cells for example.

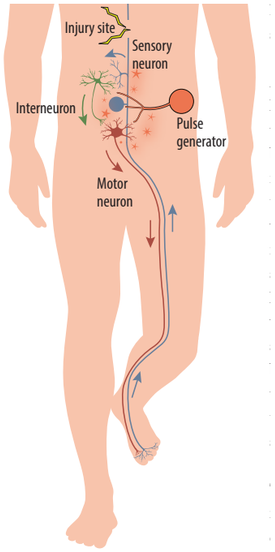
Mark Pollock decided to travel the world to meet these scientists. On his travels he met a scientist called Reggie Edgerton, an Exercise Physiologist who spent his life researching how the human body functions. Reggie has been part of years of research that proved that the spinal cord itself is intelligent and capable of learning new things under the right circumstances with the right kinds of training. Without brain input it coordinates and automates many complex movement functions. For example, when we walk, we don't think about how to take a step, which muscles to use, and when.

## What is neuroplasticity?

For many years people with paralysis were not encouraged to move but this neglected the possibility that new neurological connections might be developed or dormant connections, asleep since the damage to the cord, might reawaken because of it.

The reason for this was a forcefully held and incorrect belief that the brain and the central nervous system stopped developing after the first few years of life. Research like Reggie's has overturned this view: today we recognise that the brain and spinal cord continue to reorganise by forming new neural connections throughout life. This phenomenon, called ***neuroplasticity***, allows the neurons to adjust their activity in response to new situations or changes in their environment.

The processes described in this lesson are still experimental. However, progress is being made and the research team is confident that many more people will have the opportunity to improve the status of their paralysis.




## The robotic exoskeleton

Mark and Reggie decided to bring a number of interventions together in order to discover more about how to fix these complex systems when they are injured. Mark brought his Ekso Bionics robotic ***exoskeleton*** to Reggie's lab in UCLA where Reggie is trialling different types of spinal electrical stimulation and a drug to chemically excite the nervous system.

Mark's robotic legs are equipped with computers and motors to assist an injured person to stand up and take steps. The most important feature of this technology is its ability to allow the paralysed body to join in if it recovers any function. Researchers believe standing up and working against gravity and using the body's sense of where it is in the world, a sense called ***proprioception***, is critical to any intervention aimed at recovery.

## The results

The results of the study were published in 2015 and detailed how Reggie's team of scientists had combined a number of interventions which allowed Mark to move his paralysed legs. The new intervention they used was a ***transcutaneous*** electrical stimulator. This device creates an electrical charge that the scientists can control. It then travels down a wire and into electrodes stuck onto Mark's skin over his lower back. The ***electrodes*** push electrical stimulation through Mark's skin and stimulate his spinal cord.

Mark regained some voluntary control over his legs and they found that spinal cord stimulation enhanced the level of effort that he could generate while stepping in the exoskeleton. This was accompanied by greater ***cardiac*** responses

MARK POLLOCK TRUST.ORG

The Mark Pollock Trust believes that the cure for spinal cord injuries simply requires enough of the right people having the will to make it happen. It is the Trust's mission to find and connect those people worldwide to fast-track a cure for paralysis.

This lesson was created thanks to the following individuals and their organisations who helped with the content and illustrations: Mark Pollock and Simone George from the Mark Pollock Trust; AG Education Services; Kate Willett, who allowed us to use extracts from her book *Don't Call it a Miracle*, which was produced with the support of the Christopher and Dana Reeve Foundation; and Wings for Life.

**Run in the Dark**

As darkness falls on a night in mid-November every year, as people settle down in front of their televisions, thousands of others pull on their running shoes and head for the door. As they run through their cities they are helping us fast-track a cure; a global community running and thinking about the impact paralysis has on people's lives.

To find out more go to www.markpollocktrust.org and www.runinthedark.org

*'There won't be a magic pill to fix spinal injury. I believe it will come from multiple sources; from exercise, robotics, drugs and electrical stimulation. Through the run, the trust aims to find the people working on spinal injuries around the world, and to connect them.'*
(Mark Pollock)

*Mark in the robot being stimulated*

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You can find out more about the work of the Mark Pollock Trust at **www.markpollocktrust.org**

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## Syllabus references

The main syllabus references for the lesson are:

### Leaving Certificate Biology

- Scientific Method and Experimentation: Process of the scientific method. Limitations of the scientific method. Principles of experimentation. (p. 7)
- Responses in the Human: 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. Synapse. (p. 37)
- Central nervous system: brain and spinal cord. Location and function of the following parts of the brain: cerebrum, hypothalamus, pituitary gland, cerebellum, and medulla oblongata. Cross-section of spinal cord indicating: white matter, grey matter and central canal (refer to their constituent bodies), three-layer protective tissue – the meninges. Dorsal and ventral roots of the spinal nerve. (p. 38)

***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:

- Outline the structure and function of the nervous system
- Describe how spinal injuries can occur and possible consequences
- Describe how people can overcome great difficulties by changing their attitudes and goals
- Outline some of the promising results of recent research into spinal cord injury
- Outline what is meant by 'neuroplasticity'.

## General Learning Points

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

- Paralysis is mainly caused by damage in the nervous system, especially the spinal cord. Other causes include stroke, poliomyelitis, cerebral palsy, spina bifida, and multiple sclerosis.
- Spinal cord injuries are described by levels of 'completeness' ranging from 'incomplete' to 'complete' which is a total loss of function.
- Studies undertaken in Dr. Reggie Edgerton's laboratory in have shown that the mammalian spinal cord, can learn complex motor tasks such as standing and stepping without any input from the brain.
- Almost until the end of the last century most neuroscientists believed that the nervous system was fixed after early childhood and that new neurons would not develop. It is now known that .many aspects of the brain remain plastic. The idea that brain functions may not be fixed was actually suggested by the famous psychologist William James in 1890 (*The Principles of Psychology*).

## Student Activities

1. Make a poster to show the basic structure of the central and peripheral nervous systems. Include the following: the brain, spinal column, motor and sensory neurons to and from the hand. Outline the function of the different parts.
2. Make a poster to show the different kinds of neurons: unipolar, bipolar and multipolar. Summarise the function of the different types.
3. The skeleton of insects is external. This exoskeleton encloses and protects the muscles and other body parts.
   Artificial exoskeletons are now being developed for use by soldiers, fire fighters, and other emergency personnel to enable them to carry heavy loads with minimal effort.
   Use available resources to find out more about exoskeletons. Describe the basic operation of an exoskeleton, summarising how it is powered and how it detects which way to move.
4. Describe why the type of research referred to in this lesson involves multiple disciplines including biology, biochemistry, physics, electronics, technology and physiology.
5. **Group Exercise:** Sadly, about 50 people in Ireland suffer serious spinal injuries every year. In the UK the number is about 1,200. Most of these are young people between 18 and 35 years of age.
   Such injuries have far-reaching consequences for the individuals themselves but also for their families. The majority never return to employment and the toll on their families is immense.
   Search the Internet for statistics on spinal injuries in Ireland. Make a poster highlighting the main causes of such injuries and how the number of such incidents might be reduced.
   Describe the kind of care that is typically required by people who suffer spinal injury.

## True/False Questions

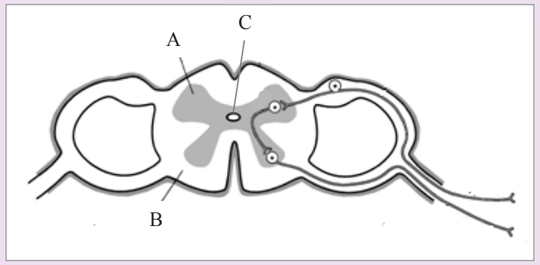
| | | | |
|---|---|---|---|
| a) | The motor function is one of the functions of the spinal cord. | T | F |
| b) | The spinal cord is contained in the vertebral column. | T | F |
| c) | Researchers have discovered that the spinal cord can receive instructions only from the brain. | T | F |
| d) | A person who can perform physical movement involving the muscles is said to possess motor skills. | T | F |
| e) | All types of spinal cord injury (SCI) result in complete paralysis. | T | F |
| f) | The lumbar region of the spine controls the upper limbs of the body. | T | F |
| g) | Before his accident mark pollock was a champion rower. | T | F |
| h) | Some nerve signals can travel at 100 m/s. | T | F |
| i) | Sensory neurons have five axons. | T | F |
| j) | The nucleus of a neuron is found in the axon. | T | F |
| k) | The human skeleton is a type of exoskeleton | T | F |
| l) | Neuroplasticity is the ability of neurons to continue to reorganise by forming new neural connections. | T | F |

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

## Examination Questions

**Leaving Certificate Biology (HL) 2015 Q. 14 b**

(i) Name the parts labelled A, B and C in the diagram of the cross section of the spinal cord.



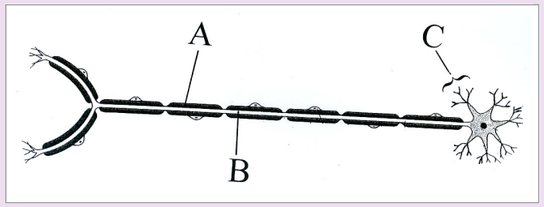

(ii) What is the main structural difference between A and B?

(iii) What is the function of the meninges?
How many layers are present in the meninges?

(iv) Reflex actions are very important in animals.
1. What is a reflex action?
2. Outline the mechanism of a reflex action.

**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 (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.

## Did You Know?

- The human spinal cord is about 43-45 cm long.
- Some 13,500,000 neurons transmit electro-chemical signals in the spinal cord.
- Christopher Reeve, who played Superman in the films, suffered from paralysis following a fall from his horse. He and his wife set up the Reeve Foundation which is dedicated to curing spinal cord injury.
- He has been named a Young Global Leader and has also won the People of the Year Award.
- Many animals that don't have a backbone, including insects such as spiders and beetles, have an exo-skeleton (meaning 'outside skeleton'). This is a hard covering that supports and protects the body. In the case of humans the exo-skeleton is often called a bionic suit.
- You can find out about Mark Pollock's experience with the exoskeleton at **http://projectwalk.com**.

## Biographical Notes

**Dr. V. Reggie Edgerton**

Dr. V. Reggie Edgerton received his Ph.D. in Exercise Physiology from Michigan State University. He has been a Professor at the University of California, Los Angeles, since 1968. His laboratory focuses on two main research questions — how do the neural networks in the lumbar spinal cord of mammals, including humans, regain control of standing, stepping and voluntary control of fine movements after paralysis, and how these motor functions can be modified by imposing activity-dependent interventions after spinal cord injury.

He showed that the walking movement could be facilitated was facilitated by tapping into circuitry in the spinal cord itself.

Dr. Edgerton received many award for his achievements. He has served NASA in a number of roles, and is currently on the Scientific Advisory Boards of the American Paralysis Association and the Christopher and Dana Reeve Foundation.

You can find out about his research at **www.ibp.ucla.edu/research/edgerton/**.

## Revise The Terms

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

axon, cardiac, central nervous system (CNS), detached retina, electrode, exoskeleton, interneurons, involuntary, motor neurons, nervous system, neurons, neuroplasticity, peripheral nervous system (PNS), proprioception, sensory neurons, spinal cord, synapse, transcutaneous, vertebrae

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