Physics

Pacemakers: Pulse to pump

This lesson is all about energy and the forms it can take.

In this lesson you will explore questions such as:

▪ What are some of the different types of energy?
▪ What is energy transformation?
▪ What is a Sankey diagram?
▪ What is energy efficiency?

Engage and immerse yourselves in the lesson and discover how your life depends on energy!

This is a print version of an interactive online lesson. To sign up for the real thing or for curriculum details about the lesson go to www.cosmosforschools.com
Imagine turning your body into a human generator that makes electricity. That’s what scientists have just done with a brand new invention that could make many people’s lives safer and easier.

Our hearts never sleep. Whether you are sitting at your desk, walking to the bus, running down the road or fast asleep, your heart is beating steadily, pumping blood around your body to deliver vital fuel to your cells to keep you alive.

But for some people there is a problem. Their hearts sometimes miss a beat, or beat irregularly. That means the flow of blood is not even, or too slow to keep all their organs operating efficiently.

Fortunately for them, doctors and scientists long ago invented a device called a “pacemaker”. It is inserted into a person’s heart during an operation and sends regular electrical impulses into the heart’s muscles to make them contract, so the heart can beat in time.

This has saved the lives of many, many people. But there is one problem. The pacemaker has to get its electrical power from somewhere – and it comes from batteries. As you know, batteries go flat and need changing. And that means another operation.

Now, scientists have come up with a brand new way to keep the pacemaker working with a battery that never goes flat by using the power of the person’s own heart to recharge it with every beat. Each beat of the heart is so powerful it produces a million times the energy that the tiny battery needs.

By using it, people with pacemakers would never have to have an operation to change the batteries again.

At the end of the lesson, you will meet John Rogers, the scientist who invented this amazing device.

Read the full *Cosmos* Magazine article [here](#)
Question 1

One of your grandparents has to be fitted with a pacemaker and the hospital offers them the opportunity to trial the new self-powered pacemakers. They ask you to help them decide - what advice would you offer and why?
Gather: Pacemakers (P1)

Video credit: Ted Ed / YouTube.

Question 1

Recall: List the types of energy that were mentioned in the clip, and any others that you know, below.

---

Question 2

Recall: Can the Universe ever lose or gain energy?

---
Question 3

Recall: Kinetic energy is the energy related to

☐ mass
☐ movement
☐ storage
☐ stretching

Question 4

Recall: A single heartbeat produces enough energy to run how many of the new pacemakers?

☐ one
☐ one thousand
☐ one million
☐ too many to count

Question 5

Describe: How are the temperature and kinetic energy of a group of molecules related?


Question 6

Describe: The clip described some of the energy changes involved in barbecuing corn and eating it. In your own words, summarise these energy changes below.


Question 1

Explain: From what you have learnt from the above clip, define what energy efficiency is. Use the graphical comparison of light globes below to illustrate your definition with an example.

Graphical comparison of energy consumption per second of light globes to produce the same brightness.
**Question 2**

**Calculate:** Using the data in the graphical comparison above, calculate how many times more energy efficient a compact fluorescent globe is compared to an incandescent globe.

---

**Question 3**

**Infer:** Work out the energy inputs and outputs of the relevant devices to complete the table below.

<table>
<thead>
<tr>
<th>Event</th>
<th>Energy input</th>
<th>Energy output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glowing light globe</td>
<td>Electrical</td>
<td></td>
</tr>
<tr>
<td>Wind up toy</td>
<td></td>
<td>Kinetic and heat (depending on the toy it could also have light and sound)</td>
</tr>
<tr>
<td>Boiling kettle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinning top</td>
<td>Kinetic</td>
<td></td>
</tr>
<tr>
<td>Climbing stairs</td>
<td></td>
<td>Gravitational potential and heat</td>
</tr>
</tbody>
</table>

---

**Question 4**

**Label:** The self-powered pacemaker takes a small fraction of kinetic energy from the heart to produce electrical energy. At the same time, the heart continues to transfer kinetic energy to your blood to pump it around your body.

Use this information to label the Sankey diagram below.
**Question 5**

**Sketch:** Use squares, arrows and text to draw a Sankey diagram representing the following energy transformations: A device is supplied with 100 Joules of electrical energy and it produces 50 Joules of kinetic energy, 20 Joules of sound energy and 30 Joules of heat energy.

*Hint: Each line represents 10 Joules of energy.*
The devices designed by Rogers include skin patches to monitor wound healing, helmets for monitoring head damage to footballers, soluble circuits to heat-sterilise wounds and the self-powered pacemaker.

Question 1

Imagine: You are a member of Rogers’ team and have been asked to develop and present two new device ideas. One device must improve the standard of living in a third world country and the other should address an issue that is important to you. You will need to include:

- A mind map of initial ideas so that the design process is clear to the team.
- A storyboard that shows how each device will work.
  - Hint: You may sketch this on paper and then upload a photograph of your sketch below.
- A list of the energy inputs and outputs of your devices.
  - Hint: A Sankey diagram may help you represent these.
Dr John Rogers isn’t just satisfied with knowing how things work. He also wants to create new things that work in different ways, like the self-powered pacemaker you read about in this lesson.

John has always been fascinated with understanding the world around him. It’s not surprising— his dad has a PhD in physics, and his mum is a well-published poet who wrote many poems about nature and space. An appreciation of the natural world was just part of his childhood.

After high school, John went to the University of Texas, where he decided to study both chemistry and physics. John says that chemistry taught him how to “make stuff”, and physics taught him to understand what he made. Nearly 20 years later, and John is still busy “making stuff”. He is especially interested in combining knowledge from a range of scientific fields to create new technologies that can help society.

Not all of John’s time is spent innovating in the lab. A big part of his job is supervising his PhD students and teaching classes at the University of Illinois. There is also the business end of things — John has to try to sell his technologies to commercial companies and earn research grants to fund the research in his lab.

When he is not at work, John loves spending time with his family.

**Question 1**

**Compose:** Write a letter to Dr Rogers telling him about one of your inventions from the previous activity. Make sure to describe your design choices, and what problems you hope the device will solve.