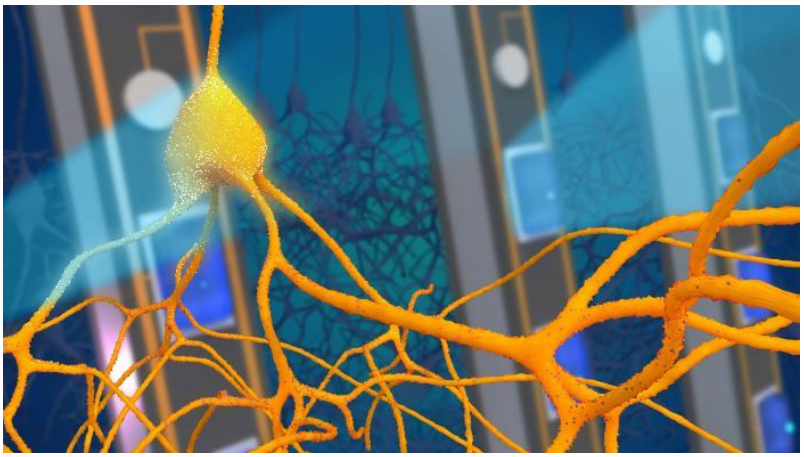
Optogenetics – A new dawn for treating disease?

The Newcastle University-led CANDO project is using a new technology called optogenetics to try and treat the neurological condition epilepsy. But what, if anything, do you know about this cutting edge technology? Read the following text from the CANDO project website (www.cando.ac.uk) and then answer the questions.

In 1979, Francis Crick, one of the scientists attributed with discovering the double helix structure of DNA, said the greatest challenge facing neuroscientists was the need to control and manipulate one type of brain cell whilst leaving the others undisturbed. Solving this challenge would help explain the roles of different types of brain cells, something that the current electrical techniques are unable to achieve.

The answer has come in the form of 'optogenetics', a type of gene therapy involving naturally occurring light-sensitive proteins called opsins. These proteins, which can be found across all types of life, change shape when illuminated with light. In fact, it is the opsins in our eyes that allow us to see. There are many types of opsins and some form channels or pumps between the inside and the outside of cells. Shining light on these opsins causes charged atoms, or ions, to move in and out of the cells. The flow of charged ions generates electrical currents, which play a key role in how brain cells communicate with one another. Opsins can be used to turn on or off communication, and thereby influence patterns of brain activity.



One advantage of using light, rather than drugs, to control brain activity is that light can be turned on only when needed. By simultaneously recording electrical signals associated with seizures, light can be delivered at precisely the right moments to achieve optimal therapeutic effect. This is known as 'closed-loop stimulation' because the brain signals control the light, which in turn controls the brain in a continuous feedback loop. A common example of a feedback loop is a thermostat, which only turns the heating on when necessary and thereby stabilises the temperature of a room. Similarly, by applying feedback to the brain using optogenetics, we can stabilise brain activity and prevent seizures developing.

Questions

1. According to Francis Crick, what was the greatest challenge facing neuroscientists? **(1 mark)**

2. What are opsins? **(2 marks)**

3. Opsins can be channels or pumps for ions. What is the difference between a channel and a pump? **(1 mark)**

4. Opsins are also found in algae. They are involved in coordinating the movement of algae around water. Why do you think it is beneficial for algae to have opsins? **(2 marks)**

5. How do brain cells communicate with one another? **(1 mark)**

6. What is the advantage of using light compared to drugs? **(1 mark)**

7. Optogenetics is referred to as closed-loop stimulation. The alternative to closed-loop is open-loop stimulation. How do you think stimulation is decided in an open-loop system? **(1 mark)**

8. Optogenetics would control the brain through a feedback loop. A thermostat is given as an example of a feedback loop. Provide an example of another feedback loop. **(1 mark)**

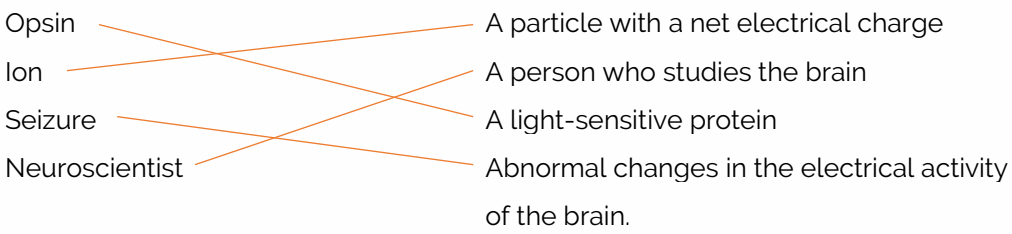
9. Match the word with its definition: **(3 marks)**

Opsin	A particle with a net electrical charge
Ion	A person who studies the brain
Seizure	A light-sensitive protein
Neuroscientist	Abnormal changes in the electrical activity of the brain.

10. What do you think are the challenges of using optogenetics in the brain? **(2 marks)**

Answers

1. According to Francis Crick, what was the greatest challenge facing neuroscientists?
   The need to control and manipulate one type of brain cell whilst leaving the others undisturbed. (1 mark)
2. What are opsins?
   Opsins are naturally occurring light-reactive proteins. (1 mark)
   They change shape when illuminated. (1 mark)
3. Opsins can be channels or pumps for ions. What is the difference between a channel and a pump?
   A pump requires energy to move ions whereas a channel doesn't. (1 mark)
4. Opsins are also found in algae. They are involved in coordinating the movement of algae around water. Why do you think it is beneficial for algae to have opsins?
   Anything around allowing the algae to move towards light. (1 mark)
   So that they can increase rates of photosynthesis. (1 mark)
5. How do brain cells communicate with one another?
   Brain cells communicate via electricity. (1 mark)
6. What is the advantage of using light compared to drugs?
   Light can be turned on only when it is needed. (1 mark)
7. Optogenetics is referred to as closed-loop stimulation. The alternative to closed-loop is open-loop stimulation. How do you think stimulation is decided in an open-loop system?
   In an open-loop system stimulation is delivered in a preprogrammed manner / regular pattern (eg every hour). (1 mark)
8. Optogenetics would control the brain through a feedback loop. A thermostat is given as an example of a feedback loop. Provide an example of another feedback loop.
   Any example where the system responds to changes brought about by the system. Eg body temperature, self-driving cars, light-tracking solar panels. (1 mark)
9. Match the word with its definition:



   (1 mark for each correct answer, up to maximum of 3 marks)
10. What do you think are the challenges of using optogenetics in the brain?
    Any two ideas around the need to introduce opsins and a light source into the brain. Other acceptable answers include that the brain is delicate and easily damaged. Also scientists don't fully understand how the brain works. (2 marks)