Write your name here

Surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number	Candidate Number

Biology A (Salters-Nuffield)

Advanced

Paper 3: General and Practical Applications in Biology

Specimen Paper for first teaching September 2015

Time: 2 hours 30 minutes

Paper Reference

9BN0/03

You may need a ruler, pencil and a calculator.

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Show your working in any calculation questions and include units in your answer where appropriate.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- You may use a scientific calculator.
- In questions marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically showing how the points that you make are related or follow on from each other where appropriate.

Information

- The total mark for this paper is 100.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

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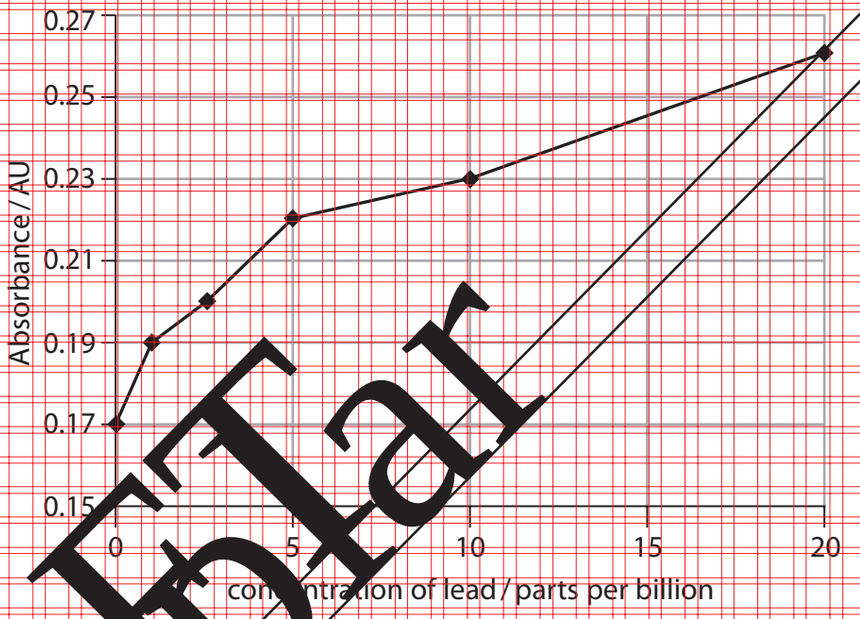
Answer ALL questions.

Write your answers in the spaces provided.

1 Lead is a toxic metal that can affect the structure of proteins. Lead affects protein in a similar way to changing pH.

Beetroot vacuoles contain a pigment. The absorbance of a solution is proportional to the concentration of the pigment in the solution.

The graph shows the results of a scientific investigation to study the effect of increasing lead concentration on the permeability of the membranes of beetroot cells.



(a) State the name of the membrane that surrounds the vacuole in beetroot cells.

(1)

.....

(b) Calculate the difference in percentage increase in absorbance between the lead concentration of 0–10 parts per billion and 10–20 parts per billion.

(3)

Answer ..... %

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(c) (i) Explain the effect of lead on membrane permeability in beetroot cells.

(2)

(ii) Devise an investigation to determine whether pH has a similar effect to lead on the permeability of the membranes of beetroot cells.

(4)

Partial

(Total for Question 1 = 10 marks)

2 A dead human body can supply a variety of evidence to support the time of death.

The table shows the relationship between the mean rectal temperature, calculated from a number of human bodies, and time after death. All bodies were at the same ambient temperature.

Time after death / hours	Mean rectal temperature / °C	Range of rectal temperature / °C
4	36	± 1.8
8	31	± 2.5
12	28	± 3.3
16	26	± 4.3
20	24	± 5.1
24	22	± 5.6

(a) Deduce the maximum ambient temperature.

(2)

(b) Analyse the data to explain why a more reliable estimate of time of death could be given if the dead body has a higher rectal temperature.

(2)

Exemplar

(c) State **two** features of these bodies that could account for the variation in the data.

(2)

(d) Explain why recording rectal temperature is more reliable than measuring skin temperature.

(2)

(e) In addition to body temperature, forensic scientists would look for other evidence of time of death.

Give **two** other pieces of evidence from a body that allow for an estimation of the time of death.

(2)

(Total for Question 2 = 10 marks)

Partial Replica

3 DCMU is a herbicide that can disrupt one of the carrier proteins in the electron transport chain of chloroplasts.

A student carried out an investigation to study the effect of DCMU concentration on the Hill reaction.

The student ground up some spinach leaves in an isolation mixture containing sucrose solution at a concentration of 0.4 mol dm^{-3}. The mixture was filtered and then spun in a centrifuge. The chloroplasts were extracted.

These chloroplasts were divided equally into eight different tubes containing a solution of distilled water, DCPIP and a buffer.

A small volume of DCMU was added to each tube and the time taken for the blue DCPIP to decolourise was recorded.

(a) (i) Explain why the isolation mixture contained sucrose at a concentration of 0.4 mol dm^{-3} rather than at a concentration of 0.8 mol dm^{-3}.

(2)

(ii) The isolation mixture had a temperature of 4 °C and pH of 7.

Explain why this temperature and pH are appropriate.

(3)

Exemplar

(b) The time taken for the DCPIP to decolourise was converted to a rate of colour change. The results are shown in the table.

Concentration of DCMU / μmol dm^{-3}	Rate of colour change / $\times 10^{-4}$ s^{-1}
0	23.5
1	12.5
2	6.3
3	4.2
4	3.2
5	2.6
6	2.2
7	2.3

(i) Analyse the data to deduce a null hypothesis for this investigation.

(1)

.....

.....

.....

Partial Redacted

(ii) The student started to analyse the data using a statistical test, called the Spearman's rank correlation coefficient (r_s), to see if there was a correlation.

Complete the table by filling in the empty boxes.

(1)

Concentration of DCMU / mol dm^{-3}	Concentration ranked (R_1)	Rate of colour change / 10^{-4} s^{-1}	Rate ranked (R_2)	Difference in ranks d ($R_1 - R_2$)	Difference squared d^2
0	1	23.5	8		
1	2	12.5	7	5	25
2	3	6.3	6	3	9
3	4	4.2	5	1	1
4	5	3.2	4	1	1
5	6	2.6	3	3	9
6	7	2.2	1	6	36
7			2	6	36

(iii) Calculate r_s by using the equation

$$r_s = 1 - \frac{6\Sigma d^2}{n(n^2 - 1)}$$

Where $\Sigma(d^2)$ is the sum of the values for d^2 and n is the number of pairs of data.

(3)

r_s = ...

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(iv) The table shows some of the critical values for the Spearman's rank correlation coefficient.

Number of pairs of data (*n*)	*p* value			
	0.10	**0.05**	**0.02**	**0.01**
6	0.829	0.866	0.943	1.000
8	0.643	0.786	0.833	0.881
10	0.564	0.648	0.746	0.794
12	0.506	0.591	0.712	0.777
14	0.456	0.544	0.645	0.715
16	0.425	0.506	0.601	0.665
18	0.399	0.475	0.564	0.625

Explain the outcome of the statistical test.

(3)

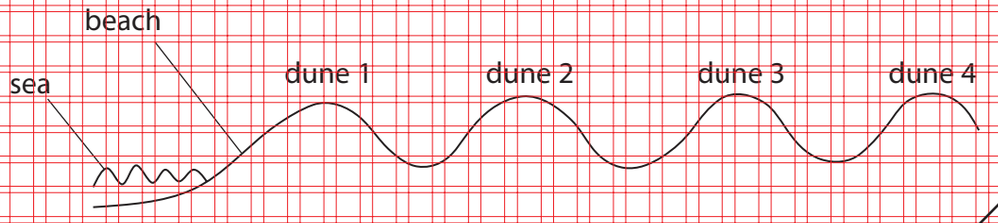
Rapidar

(Total for Question 3 = 13 marks)

4 Sand dunes are a habitat that can often be found by the edge of the sea.

(a) An investigation was carried out to study the variety of plant species found on sand dunes.

Four adjacent sand dunes from the sea to further inland were selected, as shown in the diagram.



Each species of plant present on dune 1 was recorded along with the total number of each species of plant present. This was repeated for dunes 2, 3 and 4 and the results are shown in the table.

Plant species	Number of each plant species present			
	dune 1	dune 2	dune 3	dune 4
A	169	9	0	0
B		123	19	0
C	0	0	126	182
D	1	44	0	0
E	0	0	5	2
F	0	0	20	10
G	0	0	86	35
H	0	0	0	62
I	0	0	32	17
J	0	0	0	119

Exemplar

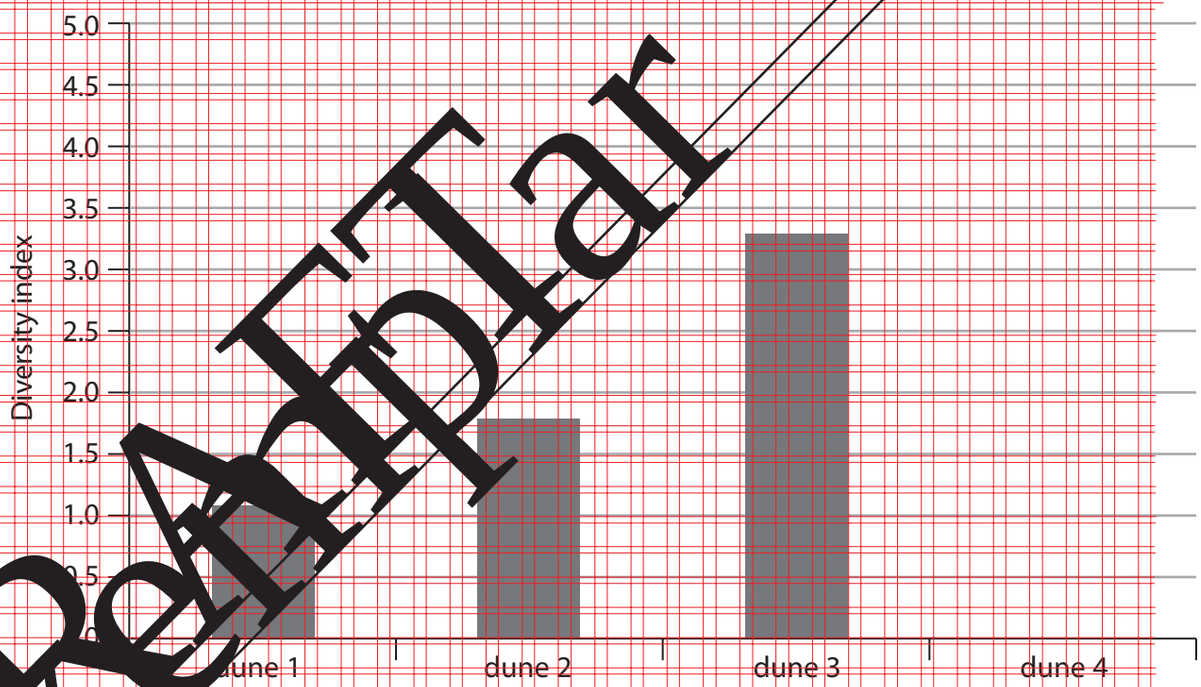
(i) The diversity index was calculated for dunes 1, 2 and 3 using this equation.

$$\text{Diversity index } (D) = \frac{N(N-1)}{\Sigma n(n-1)}$$

Where N is the total number of all individuals of all species in each dune.
Use the table and diversity index equation to calculate the diversity index for dune 4.

Plot your answer on the bar chart.

(3)



Partial Redacted

(ii) Explain how the data demonstrate the process of succession.

(5)

(b) Devise a procedure that you could use to find out if the percentage cover of species B is different on the tops of dunes than in between the dunes.

(5)

(Total for Question 4 = 13 marks)

DRAFT

5 The phenotype of an organism can be influenced by a variety of factors.

Phenotypic plasticity is the mechanism that many organisms use to phenotypically alter due to a change in environmental conditions.

An investigation to study phenotypic plasticity was carried out using a species of freshwater snail.

Newly hatched freshwater snails were used. These snails were divided into three groups and each group was placed in a tank with a different set of conditions.

Three different conditions were used. One was a control and the other two are described in the table.

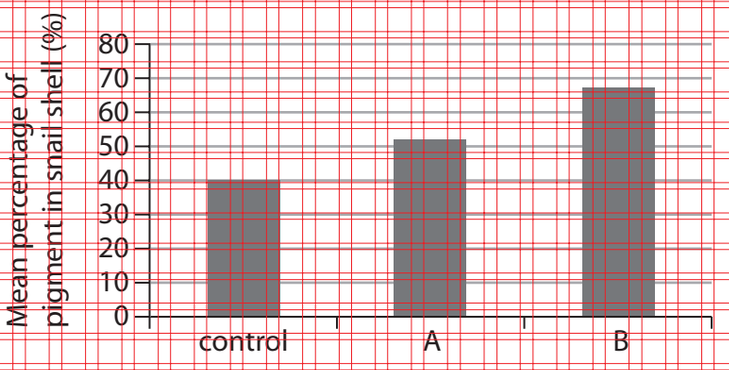
Condition	Description
A	In water taken from a tank containing predator fish that had eaten some of the snails
B	In water in a tank exposed to ultraviolet light (UV)

(a) Describe a suitable control to be used with the third group of snails.

(2)

Reflar

(b) The snails were allowed to grow for eight weeks and then the mean percentage of pigment in the snail shells was assessed for each group. The results are shown in the graph.



(i) Scientists predicted that the snails exposed to both UV light and water from a tank of predator fish would have 80% shell pigmentation.

Explain how this prediction was made.

(2)

(ii) It is thought that an increase in shell pigmentation levels provides protection against UV light. UV is a form of radiation that can damage DNA.

Explain how the DNA of the snail could be damaged.

(2)

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(c) The phenotype is influenced by the activation of genes.

(i) Describe how a gene can be activated.

(4)

(ii) Epigenetic changes can modify the activation of certain genes.

State **two** types of epigenetic changes that can occur.

(2)

(Total for Question 5 = 12 marks)

Rapid

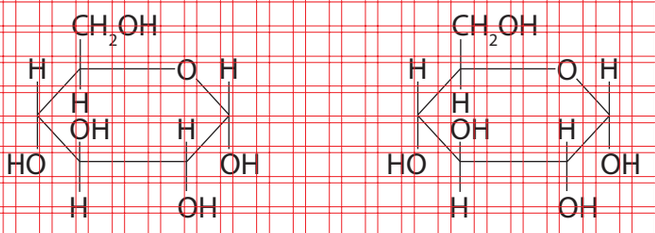
6 There are a number of reactions that regularly occur in cells.

(a) Condensation reactions can be used to join a number of molecules together.

(i) The diagram shows two substrate molecules.

Draw the products when a condensation reaction occurs between the two substrate molecules.

(2)



Exemplar

(ii) Name the larger product formed in this reaction.

(1)

.....

*(b) Another reaction that regularly occurs in cells is phosphorylation.

Phosphorylation plays a significant role in a wide range of cellular processes. Over a quarter of a million scientific articles have been written on this subject.

Using your knowledge of biology, discuss the roles of phosphorylation in cells.

(9)

REMPLAR

(Total for Question 6 = 12 marks)

7 The scientific article you have studied is adapted from articles from Nature, Scientific American and the ScienceDaily website.

Use the information from the scientific article and your own knowledge to answer the following questions.

(a) Give the name of the 'simpler molecules' produced by the breakdown of glucose that can enter the mitochondria (paragraph 3).

(1)

(b) (i) Describe the role of oxygen in the 'last reaction' involved in aerobic respiration in the mitochondria (paragraph 3).

(1)

(ii) Explain how carbon monoxide reduces the production of ATP in the electron transport chain (paragraphs 3 and 4).

(3)

Exemplar

(c) Explain how nitric oxide (NO) released by nerve endings could result in vasoconstriction of blood vessels (paragraphs 7 and 9).

(3)

Rapid

(d) Explain how free radicals may be involved in the production of P53 in the cell (paragraph 17).

(3)

(e) Describe **three** structural differences between the inner mitochondrial membrane and the outer mitochondrial membrane (paragraphs 18 and 19).

(3)

Exemplar

(f) Long wavelengths of light, in the near infrared (NIR) spectrum, appear to be able to modulate cell respiration by affecting cytochrome oxidase (paragraph 30).

Deduce how this may explain why NIR phototherapy has 'shown promise' in reducing cell death caused by myocardial infarction (paragraph 34).

(4)

Rapid

(g) (i) Describe how scientists could have produced 'genetically modified neurons' described in paragraphs 38 and 39.

(4)

(ii) A light sensitive protein is channelrhodopsin-2. This is a channel protein that spans membranes. When exposed to blue light these channel proteins open and allow sodium ions to flow through.

Explain how a brief flash of light could cause a neurotransmitter to be released by 'the genetically modified neurons' (paragraphs 38 and 39).

(5)

Draft

(h) Explain how fMRI allowed Vandewalle to make the observations described in paragraph 50.

(3)

(Total for Question 7 = 30 marks)

TOTAL FOR PAPER = 100 MARKS

Sample

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Power Games

1 Seventy-five years ago, Otto Warburg's star was at its zenith. The pioneering German biochemist delivered his Nobel address in December 1931. He described the ingenious experiments by which he had unmasked the enzyme responsible for the critical step of cell respiration, the process that turns the energy in chemical compounds into energy the cell can use. His work on respiration in the early 1930s nearly earned him a second Nobel, ultimately denied him by Hitler. Then his star began sinking. His ideas on the importance of cell respiration in cancer led many to dismiss him as a crank. And the rise of molecular genetics in the 1960s put such ideas into a far distant orbit.

2 But now, Warburg's star is rising again. A new generation of researchers is returning to his ideas about respiration in cancer cells. Recent findings suggest that the enzyme he identified, cytochrome oxidase, is a key player in a new understanding of how the cell's energy metabolism affects health and disease. And surprisingly they show that light has a profound effect on how the enzyme works – and could even be used to treat degenerative disease.

3 To extract energy from molecules, the cell first breaks down glucose into simpler molecules via a process called glycolysis. It then feeds these molecules into energy-producing structures called mitochondria, which strip electrons from them to produce energy with the help of oxygen. As Warburg showed, cytochrome oxidase governs the last reaction in this process.

4 Perhaps the most surprising aspect of the renaissance of Warburg's ideas is that the methods he used to make this discovery matter again. They exploit two chemical quirks: carbon monoxide (CO) can block respiration by binding to cytochrome oxidase in place of oxygen; and a flash of light can displace it, freeing up the site for oxygen to bind again.

Self control

5 By measuring oxygen consumption at different wavelengths of light, Warburg worked out that the enzyme belonged to a group of proteins that include haemoglobin and chlorophyll. But for Warburg, the binding of CO to the enzyme was just an oddity he could put to good use. He had no inkling that biology might use the same trick.

6 Yet over the past decade, researchers have come to appreciate that cells often use CO, and to an even greater extent NO (nitric oxide), to block respiration. Not only that, but light has striking counter-effects on cytochrome oxidase. And all these suitors to the enzyme turn out to be critical to our understanding not just of cancer, but practically all degenerative diseases.

7 Nitric oxide is emitted by nerve endings and can act on an enzyme called guanylate cyclase to relax blood vessels. The impotence drug Viagra manipulates this system. For a long time, scientists thought that guanylate cyclase was NO's only target. But in the mid-1990s, they found that the molecule can also bind to cytochrome oxidase and hinder respiration. What's more, it could do so at levels found in the body's tissues.

8 The finding that the body could poison one of its own enzymes was initially shrugged off as an imperfection – an example of how evolution cobbles organisms together with no forethought. But a few years later, several groups reported that mitochondria harboured an enzyme that synthesizes NO. Why would cells go out of their way to cook up NO right next to the respiratory enzymes?

DRAFT

9 According to cell biologist Salvador Moncada of University College London, evolution really has crafted cytochrome oxidase to bind not only oxygen but also NO. "One effect of slowing respiration in some locations is to divert oxygen elsewhere in cells and tissues," he says. This prevents oxygen levels sinking dangerously low. Moncada, for example, has shown that NO blocks respiration in the cells lining blood vessels and that this helps to transfer oxygen into smooth muscle cells in these vessels. Fireflies use a similar trick to flash light.

Flashing the gauntlet

10 Firefly flashes have lit up the human imagination since antiquity. Light is produced by the action of the luciferase enzyme, which uses ATP to activate luciferin to a luciferyl adenylate intermediate. This in turn reacts spontaneously with oxygen to emit a photon, giving rise to bioluminescence.

11 The sequence of flashes, which often beam complex messages to potential mates, clearly requires exquisite nervous control. But no nerve cells connect directly to the 'lantern' cells that produce the light, suggesting that some kind of intermediary is needed to ferry messages from the nerve endings.

12 Barry Trimmer and his colleagues at Tufts University in Medford, Massachusetts, have shown that this is likely to be NO and suggest it works by binding to cytochrome oxidase. To do so, it exploits a neat feature of the firefly's breathing system.

13 Insects breathe through tubules, called trachea, that connect the outside world to cells in the body via a network of increasingly fine branches. The ends of these, called tracheoles, abut cells and allow oxygen to diffuse outwards. In fireflies, when oxygen passes from tracheoles into the lantern cells, it must run the 'gauntlet' of a dense ring of energy-producing structures called mitochondria in the periphery of the lantern cell.

14 Normally, the oxygen would bind to cytochrome oxidase in the mitochondria and be used in respiration. But when NO is released from the nerve endings, it binds to cytochrome oxidase, blocking respiration and diverting oxygen through the gauntlet into the lantern cell.

15 There, oxygen reacts with the luciferyl intermediate to produce a flash of light. The glory is that the flash switches itself off. Light dissociates NO from cytochrome oxidase, allowing oxygen to bind again. Now the mitochondria consume oxygen once more, allowing the luciferyl intermediate to build up until another wave of NO arrives.

16 But the consequences of blocking respiration go beyond diverting oxygen. Respiration, Moncada argues, is not just about generating energy, it's about generating feedback that allows a cell to monitor and respond to its environment. Blocking respiration generates chemical signals, in the form of highly reactive molecules called free radicals. These are normally associated with cell damage, but now it seems they can interact with the proteins that control gene activity and adapt cells to changing circumstances. "Free radicals had a bad reputation," says pathologist Victor Darley-Usmar, of the University of Alabama, Birmingham. "But we now see them as signals."

In the past few years, researchers have compiled a list of these proteins, or transcription factors, the activity of which depends, at least in part, on interactions with free radicals. These include many proteins known to be linked to cellular life and death, such as P53, a protein that kills cells if they show signs of turning cancerous. "The question is," says Darley-Usmar, "how is the whole system controlled?"

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18 The answer lies in the tens of thousands of protein machines that line each mitochondrion. Organized into chains, they pass electrons extracted from broken-down glucose on to each other. The end-point of the chain is cytochrome oxidase, which catalyses the final step of respiration, in which electrons and protons are transferred onto oxygen to form water. Energy released by this process is used to pump protons over a membrane, creating an electrical charge. The cell can then use this charge to power an enzyme that makes ATP, a molecule that fuels chemical reactions in the cell.

19 The cell can suppress the number of free radicals coming from these respiratory chains by allowing protons to leak back though the membrane without driving the synthesis of ATP, a process known as uncoupling.

Undercover radicals

20 But if uncoupling doesn't bring free-radical leak under control, the signal may be amplified. "There's a cross-talk, known as the retrograde response, between the mitochondria and genes in the nucleus, which we're only just beginning to explore," says cell biologist Keshav Singh of the Roswell Park Cancer Institute in Buffalo, New York, who helped uncover this mechanism. "If we can modulate this signalling, we might be able to influence the life or death of cells in many pathologies, even ageing."

21 In cancer cells, something goes awry with this pathway. Free radicals can trigger two steps in carcinogenesis, chromosomal instability and metastasis, by hindering DNA repair and promoting the activity of genes involved in cancer spread. "We've found that damaged mitochondria, which overproduce free radicals, under-mine the integrity of the nuclear genome in otherwise normal cells," says Singh.

22 Ultimately, however, the most intractable problem with cancer cells is their failure to undergo apoptosis (cell suicide). There are echoes of Warburg here, for he argued that cancer cells revert to a primitive type that has little or no need for oxygen or mitochondria, depending instead on anaerobic forms of ATP energy generation such as glycolysis. Whether cells really 'revert' is a moot point, but Moncada has shown that cells' ability to switch to glycolysis is critical to their survival.

23 Moncada's findings suggest that cells that can do without mitochondria – many stem cells, for example, which have been implicated in cancer – can have their resistance to apoptosis stiffened by NO binding to cytochrome oxidase, making cancer more likely. At the same time, cells that depend on mitochondria for energy, such as neurones, may be pushed to apoptosis by NO binding, making degenerative disease more likely.

24 Any solution to excessive NO binding might lower the risk of both cancer and degenerative diseases, as it would make apoptosis more likely in cancer cells and less likely in normal cells. And there is an essential feature of Warburg's experiments – light – might do just that.

25 Light has long been known to promote wound healing, but the detailed molecular mechanisms have only recently been studied. Light's effects are more than skin deep: at long wavelengths, in the near infrared (NIR) spectrum, photons may penetrate several centimetres into the body.

26 And according to photobiologist Tiina Karu, at the Russian Academy of Sciences in Moscow, NIR rays in exactly this range modulate cell respiration and the signals it generates.

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Light works

27 Karu's group has explored a number of changes taking place in cultured cells in response to NIR rays. The immediate effect is an energy 'buzz', in which ATP levels are stoked up and the electrical charge across the mitochondrial membrane is strengthened. A few hours later, the activity of as many as 110 genes shifts in concert. These genes orchestrate a prolonged rise in mitochondrial energy production, as well as stress resistance. They also prompt cells to cling more strongly to their surroundings, an important factor in wound healing.

28 Exactly how NIR light interacts with the enzyme to bring about these changes is unclear, and difficult to measure. One idea is that phototherapy might work by dissociating NO from the enzyme, so reversing the signalling consequences of excessive NO binding.

29 "We have shown that light can indeed reverse the inhibition caused by NO binding to cytochrome oxidase, both in isolated mitochondria and in whole cells," says biochemist Guy Brown, at the University of Cambridge, UK. "And what's more, we found that light can protect cells against NO-induced cell death."

30 He has a reservation, however. These experiments used light in the visible spectrum, with wavelengths from 600 to 630 nm. Although Brown acknowledges that cytochrome oxidase absorbs NIR photons from 700 to 900 nm, he points out that the absorption takes place in part of the enzyme not involved in NO binding. NIR also seems to have effects on cytochrome oxidase in conditions where NO is unlikely to be present. Presumably then, says Brown, NIR must also have a direct effect on the enzyme.

31 Regardless of the exact mechanism, the effect is to relieve a blockade of the enzyme, whether by NO or any other molecules. According to toxicologist Janis Eells, at the University of Wisconsin, Milwaukee, such relief lowers the likelihood of apoptosis in many conditions.

32 Eells and her colleagues found that NIR phototherapy counters methanol poisoning, which injures the retina and optic nerve, often causing blindness. The toxic metabolite is formic acid, which inhibits cytochrome oxidase. "In a rat model, NIR phototherapy is able to restore virtually normal retinal function, at least as judged by the electroretinogram," says Eells.

33 And neurobiologist Margaret Wong-Riley and her colleagues at the Medical College of Wisconsin in Milwaukee have shown that NIR phototherapy can also oppose the effects of cyanide on cell cultures. Cyanide poisons by binding to cytochrome oxidase. Wong-Riley's team showed that phototherapy could halve the rate of apoptosis in cultured neurones, even when given before cyanide treatment.

34 Can NIR phototherapy relieve not just acute toxicity, but more chronic inflammatory conditions? The signs augur well. Eells and her colleagues have shown that NIR phototherapy could cut the rate of apoptosis by 50% in a rat model of retinitis pigmentosa, in which photoreceptors die by apoptosis during postnatal development causing retinal degeneration and blindness. The use of NIR phototherapy on other conditions in which cells die by apoptosis, including acute ischaemic stroke and myocardial infarction, has also shown promise in animal models, and should soon enter clinical trials.

35 So will it work? "The trouble is that if you enthuse about light as a therapy, clinicians and even researchers tend to back away," says Eells. "Perhaps if the physical interactions of photons with cytochrome oxidase and NO are better known, people will begin to appreciate the huge potential benefits of this technique."

DRAFT

How to Use Light to Control the Brain

36 In the film *Amèlie*, the main character is a young eccentric woman who attempts to change the lives of those around her for the better. One day Amèlie finds an old rusty tin box of childhood mementos in her apartment, hidden by a boy decades earlier. After tracking down Bretodeau, the owner, she lures him to a phone booth where he discovers the box. Upon opening the box and seeing a few marbles, a sudden flash of vivid images come flooding into his mind. Next thing you know, Bretodeau is transported to a time when he was in the schoolyard scrambling to stuff his pockets with hundreds of marbles while a teacher is yelling at him to hurry up.

37 We have all experienced this: a seemingly insignificant trigger, a scent, a song, or an old photograph transports us to another time and place. Now a group of neuroscientists have investigated the fascinating question: Can a few neurons trigger a full memory?

38 In a new study, published in *Nature*, a group of researchers from MIT showed for the first time that it is possible to activate a memory on demand, by stimulating only a few neurons with light, using a technique known as optogenetics. Optogenetics is a powerful technology that enables researchers to control genetically modified neurons with a brief pulse of light.

39 To artificially turn on a memory, researchers first set out to identify the neurons that are activated when a mouse is making a new memory. To accomplish this, they focused on a part of the brain called the hippocampus, known for its role in learning and memory, especially for discriminating places. Then they inserted a gene that codes for a light-sensitive protein into hippocampal neurons, enabling them to use light to control the neurons.

40 With the light-sensitive protein in place, the researchers gave the mouse a new memory. They put the animal in an environment where it received a mild foot shock, eliciting the normal fear behavior in mice: freezing in place. The mouse learned to associate a particular environment with the shock.

41 Next, the researchers attempted to answer the big question: Could they artificially activate the fear memory? They directed light on the hippocampus, activating a portion of the neurons involved in the memory, and the animal showed a clear freezing response. Stimulating the neurons appears to have triggered the entire memory.

42 The researchers performed several key tests to confirm that it was really the original memory recalled. They tested mice with the same light-sensitive protein but without the shock; they tested mice without the light-sensitive protein; and they tested mice in a different environment not associated with fear. None of these tests yielded the freezing response, reinforcing the conclusion that the pulse of light indeed activated the old fear memory.

43 In 2010, optogenetics was named the scientific Method of the Year by the journal *Nature Methods*. The technology was introduced in 2004 by a research group at Stanford University led by Karl Deisseroth, a collaborator on this research. The critical advantage that optogenetics provides over traditional neuroscience techniques, like electrical stimulation or chemical agents, is speed and precision. Electrical stimulation and chemicals can only be used to alter neural activity in nonspecific ways and without precise timing. Light stimulation enables control over a small subset of neurons on a millisecond time scale.

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44 Over the last several years, optogenetics has provided powerful insights into the neural underpinnings of brain disorders like depression, Parkinson's disease, anxiety, and schizophrenia. Now, in the context of memory research, this study shows that it is possible to artificially stimulate a few neurons to activate an old memory, controlling an animals' behavior without any sensory input. This is significant because it provides a new approach to understand how complex memories are formed in the first place.

45 Lest ye worry about implanted memories and mind control, this technology is still a long way from reaching any human brains. Nevertheless, the first small steps towards the clinical application of optogenetics have already begun. A group at Brown University, for example, is working on a wireless optical electrode that can deliver light to neurons in the human brain. Who knows, someday, instead of new technology enabling us to erase memories á la *Eternal Sunshine of the Spotless Mind*, we may actually undergo memory enhancement therapy with a brief session under the lights.

Study of totally blind people shows how light helps activate the brain

46 Light enhances brain activity during a cognitive task even in some people who are totally blind, according to a study conducted by researchers at the University of Montreal and Boston's Brigham and Women's Hospital. The findings contribute to scientists' understanding of everyone's brains, as they also revealed how quickly light impacts on cognition. "We were stunned to discover that the brain still respond significantly to light in these rare three completely blind patients despite having absolutely no conscious vision at all," said senior co-author Steven Lockley.

47 "Light doesn't just allow us to see, it tells the brain whether it's night or day which in-turn ensures that our physiology, metabolism and behaviors are synchronized with environmental time." "For diurnal species like ours, light stimulates day-like brain activity, improving alertness and mood, and enhancing performance on many cognitive tasks," explained senior co-author Julie Carrier. The results indicate that their brains can still "see," or detect, light via a novel photoreceptor in the ganglion cell layer of the retina, different from the rods and cones we use to see.

48 Scientists believe, however, that these specialized photoreceptors in the retina also contribute to visual function in the blind even when cells in the retina responsible for normal image formation have lost the ability to receive and process light. A previous study in a single blind patient suggested that this is possible but the research team wanted to confirm this result in different patients. To test this hypothesis, the three participants were asked to say whether a blue light was on or off even though they could not see the light. "We found that the participants did indeed have a non-conscious awareness of the light – they were able to determine correctly when the light was on more frequently than chance without being able to see it," explained first author Gilles Vandewalle.

49 The next steps involved looking closely at what happened to brain activation when light was flashed at the eyes at the same time as their attentiveness to a sound was monitored. "The objective of this second test was to determine whether the light affected the brain patterns associated with attentiveness -- and it did," said first author Olivier Collignon.

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50 Finally, the participants underwent a functional MRI brain scan as they performed a simple sound matching task while lights were flashed in their eyes. "The fMRI further showed that during an auditory working memory task, less than a minute of blue light activated brain regions important to perform the task. These regions are involved in alertness and cognition regulation as well being as key areas of the default mode network," Vandewalle explained. Researchers believe that the default network is linked to keeping a minimal amount of resources available for monitoring the environment when we are not actively doing something. "If our understanding of the default network is correct, our results raise the intriguing possibility that light is key to maintaining sustained attention" agreed Lockley and Carrier. "This theory may explain why the brain's performance is improved when light is present during tasks."

Study of totally blind people shows how light helps activate the brain, October 28, 2013
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