The Lindenbaum Memory Palace

by Stuart Lloyd

An Entry in the 2013 Windhammer Prize for Short Gamebook Fiction

The Lindenbaum Memory Palace

Warning! This is no normal book!

Welcome to this gamebook! Yes, this is a gamebook, which means that it is full of numbered paragraphs. You do not read the paragraphs in numerical order. Instead, you need to read a paragraph before being given options of another paragraph to turn to. You then turn to that numbered paragraph before reading that to see which paragraph you turn to again and so on.

Warning! This is no normal gamebook!

This gamebook is here to educate as well as provide a challenge. There are references in this gamebook which lead to websites that contain information that will help you with your challenge. If you see a superscript number by a word like this[0], then you will find the link at the back of this book. It is possible to continue without looking at the reference, but it may help you with the question you are on. The book is based on the idea of a memory palace[1] which is a mnemonic device used to remember certain information. You can construct a memory palace by imagining yourself walking around a building (it does not have to be a palace) and wandering into rooms that contain items or people related to the information you are trying to remember. There are many examples of memory palaces on the internet[2]. There are also plenty of places to get hints on building memory palaces[3].

In this gamebook, the memory palace has already been constructed for you, so it is down to you to explore it in order to gain information and assess yourself on your knowledge. The Lindenbaum Memory Palace has been built to help you revise how plants get their food.

The aim of this book

The aim of this book is to increase your understanding on how plants make their food. At the end of this book is a challenge where you can show off your new found knowledge on how plants make their food. You should take the challenge when you feel that you have obtained as much understanding as you can. Getting answers right in the test lead to you winning multi-coloured gems. The number of gems you get on the test will demonstrate how much you have learnt. You should read through the book first, however, to see how much you know already. Then, if you identify some weak areas, you can read through the book again in order to refine your knowledge. When you have learnt it all and answered all the questions correctly (you will know this when you have collected all the gems and have no items, see below), give the test a go to see what score you get.

Rules

The palace is laid out so that every room contains a concept to do with how plants get their food. When you first enter a room, you will be asked a question to do with that concept and you will have a number of options to choose from. If you get it right, you will receive an explanation of why you are right (in case you were right for the wrong reason or if you just guessed, or even if you decided to cheat, you cheater!) and you will also be given a gem of a particular colour to indicate that you got the question right. If you are wrong, you will be told why you were wrong and given the correct explanation. You will then be given an item to indicate that you need to revisit this concept.

Items and gems

The only thing that you need to keep track of in the Lindenbaum Memory Palace is an inventory list. This inventory is split into two sections, items and gems. You will receive a gem when you answer a question correctly. This indicates that you are secure in your knowledge of that concept.

If you answer a question incorrectly, you will receive something that is not a gem. It could be anything like a plank or a piece of metal. These things are items and they indicate that you have given an incorrect answer to a question. This means that you need to revise it further.

Your level of knowledge is higher when you have more gems and fewer items.

Replaying the Lindenbaum Memory Palace

Replaying is encouraged until you can answer every question in the memory palace correctly (i.e. collect all the gems). For this reason, when you replay the Lindenbaum Memory Palace after the first time, you should retain the items and gems that you have obtained after previous play throughs to indicate your level of knowledge. You should then try to replay all the rooms that you obtained items in, so that you can get the gems from that room. If you get a gem from a room, you may also lose the item that you would have obtained if you had answered a question incorrectly. This means that you can show your progress by increasing the number of gems you have and decreasing the number of items you have. You know you are ready for the assessment when you are carrying all the gems you could obtain and no items.

Assess yourself

At the end of the numbered sections is the Lindenbaum challenge which is an assessment where you can test your knowledge further. There is also a mark scheme where you get multi-coloured gems for your correct answers. The mark scheme cannot cover every possible wording of a correct answer, so you will have to use your own judgement in some cases, or maybe you could get someone else to mark it for you. Then you can see if there are any more concepts to revise further.

Further resources

The back of the book contains a list of links to provide further information on how plants make their food. Use them in order to expand your knowledge.

Character sheet

Gems (tick off each gem when you get it)

Blue gem_____
White gem_____
Turquoise gem_____
Red gem_____
Green gem_____
Yellow gem_____
Pink gem_____
Purple gem_____
Black gem_____
Number of multi-coloured gems (maximum 24)_____

Items (tick off each item when you get it)

Bottle of fizzy water_____
Helmet_____
Blue celery_____
Magnifying glass_____
Sandwich_____
Wooden balls_____
Bag of sweets_____
Piece of coral_____
Balance_____

You are sitting at one of those desks that you used to have at school. There is a thick exam paper in front of you entitled 'Plants and Photosynthesis exam'. You could have sworn that it was the electricity and circuits exam today and spent all night revising circuit symbols and voltage calculations. Beads of sweat start to form on your forehead and your hands start to tremble.

The stern looking examiner at the front of the hall packed full of dedicated students in smart school uniforms which contrast greatly with your reindeer jumper and announces 'You have one hour to complete this exam, which contributes towards the course that will determine what you do for the rest of your life. I must remind you that if you fail any exams in this course then you will be sentenced to a lifetime of menial jobs that no one else will do, such as searching for odd socks, finding and disposing of out of date items from peoples' fridges and clearing hair out sink traps. Good luck!'

And with a Cheshire cat grin, the examiner presses his big round red nose which starts the huge clock at the front of the hall ticking. You swear that the minute hand is moving as fast as a second hand, but you have no time to think about that. As the rest of the students start scribbling their answers down at what seems like light speed, you frantically search your pockets for some kind of pen. However, you pull out nothing but handfuls of fluff, buttons, pennies and sticky chewing gum.

Half an hour has past already. As you leaf through the exam, desperately seeking any words that look vaguely familiar to you, you hear the music from Countdown[4] play over the loud speakers. Each twang of the twangy instrument makes you more and more frantic. Your panic makes your teeth fall out of your mouth. The last one falls out just as the music stops.

The examiner's bow tie spins as he says 'Put your pens down!' The rest of the students all put their pens down and start to organise the massive wads of papers on which they have all written huge theses on the inner workings of a plant. The walks down the aisles, picking up each set of papers. You start to shake uncontrollably as he gets closer, thinking about how you have to explain to him, without the use of teeth, that you have written nothing.

He comes to you. His red nose and purple hair are glowing in an angry fashion. You look up at him in pleadingly, but your attempt at sympathy only makes his eyes glow red.

Then everything stops. Time stands still. You turn around and then see a sight that makes you jump.

There is a dwarf standing right next to you. He is like one of those fantasy dwarves that you have seen in Lord of the Rings if you are trying to be cool, or in Dungeons and Dragons manuals if you are allowed to be yourself. He is like most fantasy dwarves you have seen – short, big beard. dressed in chainmail armour and very grumpy looking. However, he carries no weapons and instead of a helmet, he wears a fez.

'Knew it. Exam hall, no pen, time moving quickly. I could smell the anxiety miles away.'

'What are you talking about?' You ask, confused.

'You're dreaming, you twonk. Couldn't you work that out by the time your teeth fell out? This can't be a real exam. There's not even a hog roast.'

'So I don't have a photosynthesis exam?' You ask.

'Oh, you do. It's in about three hours' time. Which is where I come in. You see, against all expectations, you have actually put a reasonable amount of effort into your revision whilst you were watching re-runs of Friends and the information is hiding away somewhere in this head of yours. It's my job to organise this information and make it memorable. Normally, your brain does this all in the background whilst you sleep, which is why it is good to get a full night's rest before an exam, but your anxiety is off the charts so I'm going to be a little more overt with my help.

'Why are you…I mean, did I make you look like..?'

'I am actually a dwarf, you know, not just a portion of your subconscious that has chosen this form because you like the look of it. And to answer your question, I'm not in any fantasy RPGs. Not my thing really. I mean, they're actually quite dangerous. Have you seen those spears? You could take an eye out with one of those. And those arrows are terrible. Do you know they don't clean them? You could get tetanus if you got shot by one. It might just be a number to you, but we've got to take the brunt of it. So I went to my boss, who gave me a job in education. Said I was good at getting down

the kids' levels or something. So here I am. Anyway, we've all got jobs to go to. Your seat is needed for the next anxious student soon, so I'd better take you to the palace.'

'The palace?'

'Yes. The memory palace. Where we give form to all of your knowledge about photosynthesis. I'll explain when we get there.'

And with that, the dwarf clicks his fingers and there is a blinding flash of light.

Turn to 1…

1

You appear before a magnificent palace, made of pure white marble. Vines and ivy climb up the walls. Behind them, you can see an elegant building with flying buttresses. You can see that a huge tree towers over the palace from the centre. . There are two large wide open wooden doors nearby. You turn to the dwarf.

'So what is this place?'

'This is the Lindenbaum Palace. Inside is a whole load of information about how plants get their food.'

'And why is it a palace?'

'This thing was invented by the ancients to help them remember their speeches[1]. They figured out that if you wanted to remember something, say for a test, then you would imagine yourself walking through a palace. Each room of the palace would contain something that would help you remember a chunk of information. The more ridiculous something is, the easier it is to remember. There is an example here[2].'

'Is that why you wear the fez?' You ask.

'What are you trying to say about my fez? I think fezzes are cool.' Grumpily replies the dwarf 'Do you want your help or not?'

'Sure. Anyway, what's your name?'

'I'm Steve. Nice to meet you.' He says as he shakes your hand.

'OK Steve. Where shall we begin?'

Without waiting for an answer, the dwarf walks off towards the gates. You follow him through some beautiful grounds, tended by various gardeners. Then you follow him through some corridors, past several ornate doors.

If you have a blue gem and a white gem, turn to 6. Otherwise, read on.

You wonder what is behind each one, but instead of going through the doors, he takes you to the square in the middle of the building. You wonder at the huge tree that towers over the both of you. Next to it, there is an old man, carrying a pot full of soil. In the pot is a young sapling.

'This huge tree has grown bigger every year for many centuries, yet once it was tiny, like this sapling. Think about this question very carefully, for your instinctive answer may be wrong. Where will this sapling get the materials to one day become this mighty tree?'

What is your answer?

The soil? Turn to 39.
Water? Turn to 4.
The air? Turn to 37.

2

'I guess you said that because plants release oxygen gas and so that the left over elements are that make up glucose. Well, only *some* of the oxygen in the carbon dioxide and water is released as gas and some becomes part of the glucose molecule. Carbon dioxide is made up of carbon and oxygen. Water is made up of hydrogen and oxygen. Some of the oxygen is released from the leaf as oxygen gas and some stays in the glucose molecule. It's glucose in my sweets that makes them taste sweet. Here have a bag.'

The shopkeeper gives you a bag of sweets. *Add the bag of sweets to your items list.*

Summary: Glucose is made up of carbon, hydrogen and oxygen.

As you turn to leave, the kindly old shopkeeper calls out 'If you want to know more about the elements in glucose go through the door with the scales!'

You thank the old man and leave. Turn to 10.

3

You walk through the door to find yourself in a large deserted canteen with several long tables. Steve is sitting one a chair with his feet up on the table whilst reading the latest issue of The Economist. Occasionally, he sips some coffee from a white mug with a cat on it. He then sees you and drops the magazine.

'Oh hello! Finished then? How did you do?'

You tell him about your exploration.

'That's great. Well, I have a challenge for you at the end of the book if you feel like you are ready. The more gems you have the more ready you will be. You could also retry your walk through the palace again if you want. It should be shorter than the last one as if you have a gem for a room, then you won't have to repeat it. You just have to go through the rooms where you got an item or rooms that you never entered. And if you get a gem, then you can get rid of the item that you got from the room originally. Or you can leave the memory palace and take your test.'

If you decide to go through the palace again, turn to 1.

If you decide to take the challenge, turn to 42.

If you decide to wake up and end your time in the memory palace, turn to 41.

4

'That is correct. This plant gets a lot of its mass from water, which it sucks up from the soil with its roots.'

Steve pulls a blue gem out of his pocket and gives it to you. 'That's for working it out.'

Add the blue gem to your gems list. If you have a helmet, remove it from your items list.

If you now have a blue gem and a white gem, turn to 35. Otherwise, Steve goes on.

'However, there is another place that a plant gets its mass from as well as the water. Do you know where that is?'

The soil? Turn to 39.

The air? Turn to 37.

5

'Correct!' Says Cicero 'all living things need oxygen to make energy which is used for movement and other things . It's called respiration.'

'Hang on,' Plants need oxygen, but so do all other living things and they don't make their own, so how can there be enough oxygen? There's loads of living things that just take in oxygen and don't make any themselves.'

'Good question[5]. Plants don't use all the glucose they make in respiration. Some of it is used to make the substances that make up the plant. This means that plants give off about ten times more oxygen than they take in, which is good for all of us creatures that can't use photosynthesis.'

'It certainly is!' Says Cicero 'And that means that I can go deep sea diving and have a look at this lovely coral reef down here. Last week, I found the wreck of a 17th Century Spanish treasure ship and we helped ourselves to the treasure. Now we have more than we know what to do with.'

Summary: Plants release oxygen which is needed by all living things for a process called respiration, which is used to obtain energy for movement. However, whilst plants do respire and use up some oxygen, some of the glucose is used to make new plant materials and so plants release more oxygen gas than they use up.

Cicero flip flops over to a bench on the deck and picks up a purple gem and offers it to you. *Add the purple gem to your gems list. If you have a piece of coral, remove it from your items list.*

He then puts his headgear back on before Mike lowers him into the sea using the crane. You return through the door and head back to the room. Turn to 10.

6

Steve leads you back to the room with several doors. 'You know all about where plants get their food, so you can start from here. I won't go into what to do. Come and find me when you're finished.' Steve then leaves you and heads through the fez door. You consider your options. Turn to 10.

7

'Correct! Chlorophyll is the green pigment in leaves that absorbs sunlight so that the plant can break down carbon dioxide and water. It can then use these substances to make glucose.'

Phil then snaps his fingers and two pots of cress appear on the floor. One is looking green and healthy, whilst the cress in the other pot is yellow and tall.

'The yellow cress has no chlorophyll in it. Chlorophyll is a substance in a plant's leaf that makes it green. It is used to absorb sunlight which helps make glucose. The cress is taller because it has been searching for the Sun.'

Phil then snaps his fingers and a green gem appears, suspended in the air. 'Here you go. Enjoy it!' *Add the green gem to your gems list. If you have a sandwich, cross it off your items list.*

Summary: chlorophyll is a green substance in a plant that absorbs sunlight so that its energy can be used to break down carbon dioxide and water in order to make glucose.

You return to the central room. Turn to 10.

8

The sweet shop owner shakes his head 'I'm afraid not. It's actually carbon, *hydrogen* and oxygen in glucose. People always get hydrogen and nitrogen mixed up. I think it's something to do with them sounding similar. So there you are. Carbon dioxide is made up of carbon and oxygen. Water is made up of hydrogen and oxygen. Some of the oxygen is released from the leaf as oxygen gas and some stays in the glucose molecule. It's glucose in my sweets that makes them taste sweet. Here have a bag.'

The shopkeeper gives you a bag of sweets. *Add the bag of sweets to your items list.*

Summary: Glucose is made up of carbon, hydrogen and oxygen.

As you turn to leave, the kindly old shopkeeper calls out 'If you want to know more about the elements in glucose go through the door with the scales!'

You thank the old man and leave. Turn to 10.

9

You walk through the door and walk straight into a frantic melee of sizzling, chopping and shouting. You are in a restaurant kitchen. You walk amongst a gang of chefs chopping, frying and boiling. One chef is trying to cut a miniature chicken. You see the head chef shouting orders at his beleaguered assistants. He then sees you and stops what he is doing.

'Good evening!' He shouts. 'I guess you want to know about chemical equations! Step this way!'

You follow the head chef into his office which is full of cook books. 'So, you want to know about chemical equations, then?' He asks in a cheerful tone. 'Well I'm Gordon Ramsbottom, and I don't like profanity. Pleased to meet you!'

'Yes please.' You say politely.

'Well, there is not much to remember. Basically, a chemical equation is like a recipe. You have your ingredients that you start with. In chemistry, we call these reactants. Then, you do something, such as add heat and they turn into one or several new substances, which in chemistry, we call products. For example, if you get some flour, water and yeast, mix them up and stick them in an oven for a bit, you get bread.'

'And yummy bread indeed.' You add.

'Thanks. It's my own special recipe. Here, have some bread.' Gordon offers you some bread which you take and stuff into your mouth. He then continues

'So if we wanted to write that like a chemical equation, we would write this:

flour + yeast + water -> bread.'

'What about the heat?'

'Well, we don't write that in. We only usually write in the actual substances, not what we do to them.'

'And what's that thing with the arrow? Why not an equals sign?'

'Good question! Well an equals sign means that two things are the same. 1 + 1 = 2 means that 1 + 1 is the same as 2. A mixture of flour, yeast and water is not the same as bread. Instead, it *turns into* bread. So the arrow means that a bunch of reactants turn into products.'

'Oh, I see.' You say, spitting out crumbs.

'Exactly. So with photosynthesis, you start with carbon dioxide and water and you end up with glucose and oxygen, so the equation is carbon dioxide + water -> glucose + oxygen.'

'That's great,' You say 'but if you've just told me the equation, what's your question going to be about?'

'Well, I haven't gone into symbol equations yet. That's where the hard stuff starts. If you want a gem, you are going to have to tackle symbol equations. Otherwise, you can leave now.'

Summary: When you write an equation, you put the things you start with (the reactants) on the left hand side, followed by an arrow and then the things you end up with (the products) on the right hand side i.e.

Reactants -> Products

If you would like to leave now, turn to 10.

If you would like to try your hand at symbol equations, turn to 34.

10

You are back in front of the doors, each one leading you to a room where you can revise another aspect of photosynthesis. Or you could take the door with the fez symbol and leave this place. Which one will you choose?

The jug (water)? Turn to 23.
The burning bush (carbon dioxide)? Turn to 11.
The leaf (chlorophyll)? Turn to 32.
The Sun (sunlight)? Turn to 31.
The sugar cube (glucose)? Turn to 40.
The wind (oxygen)? Turn to 24.
The scales (equation for photosynthesis)? Turn to 9.
The fez (exit)? Turn to 3.

11

You walk into a huge dome and feel lighter. You are surrounded by all kinds of trees and plants. Then you look up and see the dark sky of space.

'Hullo.'

You look around you to see a man in an astronaut's suit, but without the helmet.

'Where am I?' You ask.

'You're on the Moon, of course. I'm Neil Slaughter, the founder of the Moon colony. I thought everyone knew about this place.'

'Sure, sure I do. I was just expecting something else.'

'You're from that memory palace, aren't you? Well, it's 2062 and we're living on the Moon. Now I know why you're here, I'll tell you about how we can survive here. You see all of these plants?'

'Yes.'

'Well they keep us alive. You use oxygen for your body and you breathe out carbon dioxide. Well, plants use carbon dioxide for their photosynthesis and give out oxygen. We have a nice little cycle here, but we need a lot of plants. We have four domes of plants and a dome containing phytoplankton and we use a lot of electricity to keep the lights going, but we use helium-3 for that. Enough of that, though. Which part of the plant does carbon dioxide enter?'

The leaf? Turn to 30.
The root? Turn to 18.
The stem? Turn to 33.

12

'Just the roots, huh? So you think the plant takes in water from the roots and then stores it there? Well, you're half right. Simon pulls another pot plant to reveal that its stem and leaves are also blue[6].

'You see, the water goes go through the roots, but then it also travels up the stem and then to the leaves. Every part of the plant needs water. Some of the water is used for photosynthesis and some is just used to keep the plant upright.'

Simon pulls another plant out from under the table. This plant is wilted and has a floppy stem.

'A plant wilts when it doesn't get enough water because the cells that the plant is made up of need to be filled with water to be hard. If you fill a balloon with water, it feels quite solid. If you half fill a balloon with water, it is quite floppy. Plants are like that. Also, some water just flows from the roots, to the stem, then the leaves and then out through the top of the plant. This is important as then more water comes in through the roots to take its place. This whole process is called transpiration[7].

Summary: Water goes up through a plant's roots, through the stem and then to the leaves. Some of the water is used in photosynthesis to make glucose, some is used to keep the plant upright and some just leaves through the top of the plant, but that helps keep the flow going.

Simon gives you a stick of blue celery to remember him by. *Add the blue celery to your items list.* He then bids you farewell. You leave the room to try another door. Turn to 10.

13

'So you think the plant uses the sunlight to grow bigger? It is true that plants can't grow without sunlight, but sunlight helps only a small, yet crucial part of the process. Let me show you.'

Nina holds her hands out face up. On her hands appears what appears to be three wooden balls held together by strong. The middle on is black and the two on either side of it are red.

'This is model of carbon dioxide. Plants need to break this molecule apart in order to use the parts to make glucose. Why don't you have go at breaking it up?'

You take the model and try to pull the balls apart. Eventually, you break the string but it takes some effort.

'There you go. I bet if you did that a lot you would be hungry. You would need a lot of energy to do it. Well, the sunlight provides the energy to break the molecules up. Then the plant can use them to make glucose and then the glucose is use for various things including helping the plant grow.'

'I see. Thanks for the help.' You say.

Summary: Plants use the energy from sunlight to break up carbon dioxide and water so that it can then use them to make glucose. This glucose is then used for several things including helping the plant grow.

'No problem!' Says Nina cheerfully. she walks over to you and gives you a kiss on the cheek. 'Before you go, take the model to remember me by.'

Nina hands you the three wooden balls. *Add the wooden balls to your items list.*

You then return to the main room. Turn to 10.

14

The dwarf leads you through another door. The room here is like a lab. There are several benches here covered in bottles, circuits and other apparatus. Inside this room is a man dressed as a priest. He holds a burning candle in one hand and a plant in the other. Steve introduces you. 'This is joseph Priestly, who was actually a member of the clergy, but did lots of other things besides.'

'Yes, I did!' Said Joseph. You notice that he has a stutter. I once trapped this plant in a glass jar with a burning candle. I didn't know this at the time, but I now know that the burning candle used up all the oxygen gas in the jar produced a gas called carbon dioxide. This made it go out. However, I left this jar as it was and after a few weeks, I tried lighting the candle again. And it worked! The plant had taken all the carbon dioxide away and released more oxygen into the jar. And that's how we know that plants need carbon dioxide.'

'Cheers, Joe!'

'Before you go, I've got a little present to remember me by. I used this carbon dioxide and put it in water. This game me fizzy water. I hope you enjoy it!'

Joseph Priestly grabs a glass bottle from a bench and offers it to you. You open it and try a bit. It tastes very good. You never would have thought that there were fizzy drinks in the 18th century, but there you go.

Add the bottle of fizzy water to your items list.

Summary: Plants do not get mass from soil. They get it from air and one other thing…

Steve the dwarf leads you back into the palace. You follow him as he rushes through the corridor, looking for another room.

If you have no gems, turn to 21.

If you have a blue gem, turn to 35.

15

'Absolutely right. Every chemical reaction needs energy to get it started. The energy is used to break the molecules down, so that they can then be rebuilt differently. The sunlight is used to break down the carbon dioxide and water so that they can be turned into glucose and oxygen. This is because the carbon dioxide is made up of one carbon bonded to two oxygen atoms. The energy is needed to break those bonds.'

Summary: Plants use the energy from sunlight to break up carbon dioxide and water so that it can then use them to make glucose. This glucose is then used for several things including helping the plant grow.

Nina walks up to you and gives you a kiss on the lips.

'For being so clever, you can have this.' Nina presses a yellow gem into your hand. *Add the yellow gem to your gems list. If you have wooden balls, cross them off your items list.*

You then return to the main room. Turn to 10.

16

'You've got the big numbers correct, but there should be small numbers in your equation. You have to say how many atoms there are that are bonded together. This equation says that there is one large molecule with six carbons and twelve oxygens reacting with another large molecule with twelve hydrogens and six oxygens to make glucose, which is correct and a molecule with twelve oxygens in it. This is the correct answer…'

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

'If we multiply the big and small numbers, we get the same number of atoms as you, but this equation also shows us that the carbon dioxide is split into six molecules. Equations are tough. There are plenty of websites to practice them, such as here[8] and there are more in the links page at the end of this book.

'How do you know I'm reading a book?' You ask the chef.

'I know everything!' Announces the chef.

There is a flash and a puff of smoke which fills the room. Once it has cleared, the chef has vanished and in his place, there is a small balance. You take the balance.

Add the balance to your items list.

Summary: Balancing equations involves two numbers. The small numbers are the number of atoms in a molecule which are bonded together and the large numbers are the number of molecules. The big numbers indicate that the molecules are not bonded together.

When you have finished, you return to the main room. Turn to 10.

17

'Why that's right! Don't we have a clever one here. I've got something very special for you.' Says the sweet shop owner as he rummages around with his jars. He then pulls out a sparkling pink gem. *Add the pink gem to your gems list. If you have a bag of sweets, remove them from your items list.*

'There you go. You are right with your answer. Carbon dioxide is made up of carbon and oxygen. Water is made up of hydrogen and oxygen. Some of the oxygen is released as oxygen gas and the rest

bonds with the carbon and hydrogen to make a glucose molecule. You'll go a long way with know how like that.'

The kindly old man then gives you some sweets to eat. You enjoy their lovely flavours and also the fact that since you are dreaming, they won't rot your teeth or make you put on weight.

Summary: Glucose is made up of carbon, hydrogen and oxygen.

You then return to the central room. Turn to 10.

18

'I'm afraid not. You need sunlight, chlorophyll and water in addition to the carbon dioxide for the plant to make glucose and since sunlight hits the leaves and that's where the chlorophyll is and water eventually has to make its way to the leaves, it makes sense that the carbon dioxide enters the leaves too. It enters them through little holes called the stomata.'

The astronaut picks a lead from one of the plants and grabs a magnifying glass from under a nearby tree. He shows you the stomata in the leaf.

Summary: Plants take in carbon dioxide through small holes in their leaves called stomata.

'Keep the magnifying glass so you can look at other leaves.' Says the astronaut. *Add the magnifying glass to your items list.*

You return to the main room. Turn to 10.

19

Cicero grins 'You're right, us animals do need oxygen, which is why I've got this tank to help me go diving with.' He says, patting the oxygen tank on his back.

'However, you're only half right.' Says Mike 'Plants need oxygen too. In fact all living things need oxygen for a process called respiration. In this process, glucose reacts with oxygen to release energy that we need for movement.'

'Hang on,' You say 'If all living things need oxygen, but only plants and some other organisms make it, then how can there be enough oxygen? there's loads of living things that just take in oxygen and don't make any themselves.'

'Good question[5]. Plants don't use all the glucose they make in respiration. Some of it is used to make the substances to help the plant grow. This means that plants give off about ten times more oxygen than they take in, which is good for all of us creatures that can't use photosynthesis.'

'It certainly is!' Says Cicero 'And that means that I can go deep sea diving and have a look at this lovely coral reef down here. We've been taking turns for a while, now. Why don't you have a piece of coral?'

Cicero flip flops over to a bench on the deck and picks up a piece of coral from it. He then gives it to you. *Add the piece of coral to your items list.*

Summary: Plants release oxygen which is needed by all living things for a process called respiration, which is used to obtain energy for movement. However, whilst plants do respire and use up some oxygen, some of the glucose is used to make new plant materials and so plants release more oxygen gas than they use up.

He then puts his headgear back on before Mike lowers him into the sea using the crane. You return through the door and head back to the room. Turn to 10.

20

'I'm afraid not. Flowers are on plants for them to reproduce. They are not involved with photosynthesis.'

Phil then snaps his fingers and two pots of cress appear on the floor. One is looking green and healthy, whilst the cress in the other pot is yellow and tall.

'The yellow cress has no chlorophyll in it. Chlorophyll is a substance in a plant's leaf that makes it green. It is used to absorb sunlight which helps make glucose. The cress is taller because it has been searching for the Sun.'

Phil then snaps his fingers to make an egg sandwich appear out of thin air. He picks some of the yellow cress and puts it on the sandwich before offering it to you. *Add the sandwich to your items list.*

Summary: chlorophyll is a green substance in a plant that absorbs sunlight so that its energy can be used to break down carbon dioxide and water in order to make glucose.

You return to the central room. Turn to 10.

21

Steve leads you back through the corridors and out into the palace grounds. There is a van parked outside and a man wearing a smart suit stands in front of it. He is also wearing visored helmet, like the type that medieval knights wore. Steve introduces you.

'This is Jean Baptiste Van Helmont[9], who was alive in the 16th and 17th centuries.'

'Pleased to meet you Van Helmont.' You say as you shake his hand 'I get it! You've given him a van to drive and he's wearing a helmet, so I can remember him.'

'Exactly.' Says the Steve 'We do this for all the science related people we can such as Max Planck and Fritz Haber.'

'I see. So what did you do, Van Helmont?'

'Ah. Well, one day, I took a young willow sapling and weighed it. It had a mass of 2kg. I then weighed some dirt and planted the willow in it. The mass of the soil and the pot together, had a mass of 90kg.'

'So the sapling and the pot weighed 92kg together.'

'Yes. I then watered the willow and weighed it every day for five years. After that time, the willow had a mass of 76kg. The pot and the soil still weighed 90kg.'

'So the tree could not have got its mass from the soil.' You chip in.

'Exactly.' Said Van Helmont 'Since I had given the willow nothing but water, I deduced that the mass that the tree had gained must have come from the water.'

'Good deduction, eh?' Said Steve 'It is,' Said Van Helmont 'Here, take my helmet to remember me by.'

The scientist removes his helmet and offers it to you.

Add the helmet to your items list.

Summary: Plants do not get mass from soil. They get it from water in the soil and from carbon dioxide in the air

Steve the dwarf leads you back into the palace. You follow him as he rushes through the corridor, looking for another room. Turn to 35.

22

'Absolutely right.' Simon pulls a potted plant out from under the table to show you that the whole thing has turned blue[6].

'You are right that the whole plant needs water. Some of the water is used for photosynthesis and some is just used to keep the plant upright.'

Simon pulls another plant out from under the table. This plant is wilted and has a floppy stem.

'A plant wilts when it doesn't get enough water because the cells that the plant is made up of need to be filled with water to be hard. If you fill a balloon with water, it feels quite solid. If you half fill a balloon with water, it is quite floppy. Plants are like that. Also, some water just flows from the roots, to the stem, then the leaves and then out through the top of the plant. This is important as then more water comes in through the roots to take its place. This whole process is called transpiration[7].

Summary: Water goes up through a plant's roots, through the stem and then to the leaves. Some of the water is used in photosynthesis to make glucose, some is used to keep the plant upright and some just leaves through the top of the plant, but that helps keep the flow going.

'For showing your knowledge, you can have this.'

Simon pulls out a clear turquoise gem from his pocket and hands it to you. *Add the turquoise gem to your gems list. If you have blue celery, remove it from your items list.* He then bids you farewell. You leave the room to try another door. Turn to 10.

23

You walk into a room where a green man is sitting at a table. There are several glasses of coloured liquids on the table and several sticks of celery on a plate. There is also a plant in a pot at the table. The man sits in front of a glass of water. He is sucking the water up through a straw.

'Oh hello! Look what has transpired! My name is Simon, an I'm here to tell you about plants and water.'

Simon, the green man grabs the potted plant and a glass containing blue liquid and pours it onto the soil.

'Right! This blue liquid is water with blue food dye in it. Now, wherever the water goes, the plant will start to look blue. My question is, if we leave this plant for a few days, which parts of the plant would turn blue to indicate that there is water from the soil in it?'

What is your answer?
The roots? Turn to 12.
The stem? Turn to 28.
The whole plant? Turn to 22.

24

You walk onto the deck of a ship. The sun is shining and the sky is clear blue. You can see some land in the distance. There are two men on the deck. One is wearing a diving suit and looks like he is about to jump over the side, while the other man is watching him . They then see you on the deck. The man in the diving suit starts to remove his head gear.

'Welcome aboard!' Says the first man, who offers you his hand to shake. 'I am Mike and this is Cicero.' Cicero has now removed his headgear to reveal a lantern jawed man with dark curly hair. 'Hi!' Says Cicero.

Mike addresses you.

'You're just in time to see Cicero dive and you're probably wondering why you're here when you want to know about oxygen. Well, I have a question for you. Plants release oxygen when they make glucose, but is this oxygen useful to anyone, and, if it is, who is it useful for?'

What will your answer be?

The oxygen is not useful to anyone? Turn to 29.
The oxygen is useful to animals? Turn to 19.
The oxygen is useful to animals and plants? Turn to 5.

25

'You are right that glucose is needed for energy. You are also right that sunlight breaks up molecules, but sunlight is needed to break up the carbon dioxide and water in order to make the glucose.'

'I see. Thanks for the help.' You say.

Summary: Plants use the energy from sunlight to break up carbon dioxide and water so that it can then use them to make glucose. This glucose is then used for several things including helping the plant grow.

'No problem!' Says Nina cheerfully. she walks over to you and gives you a kiss on the cheek. 'Before you go, take this to remember me by.'

Nina holds out her hand and three wooden balls appear on it. Two are red and one is black. The black one is in the middle and attached to the red ones with string.

'This is a model of carbon dioxide. Enjoy!'

Add the wooden balls to your items list.

You then return to the main room. Turn to 10.

26

Gordon Ramsbottom is very pleased 'That is correct!' Each carbon dioxide has one carbon and two oxygens and there are six of them. Each water has one oxygen and two hydrogens and there are six of them. Each oxygen molecule has two oxygens and there a six of them and each glucose molecule has six carbons, six oxygens and twelve hydrogens and there is one glucose molecule. If you can balance equations, then you can do very well. If you want more practice, then there are several websites that you can use such as this one[8] and the others in the back of this book.'

How do you know I'm reading a book?' You ask the chef.

'I know everything!' Announces the chef.

There is a flash and a puff of smoke which fills the room. Once it has cleared, the chef has vanished and in his place, there is a large black gem. You take the gem.

Add the black gem to your gems list. If you have a balance, remove it from your items list.

Summary: Balancing equations involves two numbers. The small numbers are the number of atoms in a molecule which are bonded together and the large numbers are the number of molecules. The big numbers indicate that the molecules are not bonded together.

When you have finished, you return to the main room. Turn to 10.

27

'Wilting is a problem, but that is due to lack of water, not lack of chlorophyll. Chlorophyll is the green stuff in plants that captures sunlight.'

Phil then snaps his fingers and two pots of cress appear on the floor. One is looking green and healthy, whilst the cress in the other pot is taller, and yellow in colour.

'The yellow cress has no chlorophyll in it. Chlorophyll is a substance in a plant's leaf that makes it green. It is used to absorb sunlight which helps make glucose. The cress is taller because it has been searching for the Sun.'

Phil then snaps his fingers to make an egg sandwich appear out of thin air. He picks some of the yellow cress, then puts it on the sandwich. He puts the sandwich in a box before offering it to you. *Add the sandwich to your items list.*

Summary: chlorophyll is a green substance in a plant that absorbs sunlight so that its energy can be used to break down carbon dioxide and water in order to make glucose.

You return to the central room. Turn to 10.

28

'The stem? Well water does travel up the stem, but there is more to it than that.' Simon pulls another pot plant to reveal that its roots and leaves are also blue[6].

'You see, the water goes through the roots and up the stem but then it also travels into the leaves. Every part of the plant needs water. Some of the water is used for photosynthesis and some is just used to keep the plant upright.'

Simon pulls another plant and two balloons out from under the table. This plant is wilted and has a floppy stem. One of the balloons is full of water. The other one is half filled with water. Simon gives you the full balloon. You try to squash it, but the water pushes pack and stops you from doing so. He then gives you the half-filled balloon which is very floppy.

'A plant wilts when it doesn't get enough water because the cells that the plant is made up of need to be filled with water to be hard. If you fill a balloon with water, it feels quite solid. If you half fill a balloon with water, it is quite floppy. Plants are like that. Also, some water just flows from the roots, to the stem, then the leaves and then out through the top of the plant. This is important as then more water comes in through the roots to take its place. This whole process is called transpiration[7].

Simon gives you a stick of blue celery to remember him by. *Add the blue celery to your items list.*

Summary: Water goes up through a plant's roots, through the stem and then to the leaves. Some of the water is used in photosynthesis to make glucose, some is used to keep the plant upright and some just leaves through the top of the plant, but that helps keep the flow going.

Simon bids you farewell. You leave the room to try another door. Turn to 10.

29

Cicero grins when he hears this answer 'Then what do you think this has in it?' He asks, pointing to the tank on his back.

'Exactly' Says Mike. 'Every living thing needs oxygen in order to turn the food they eat into energy to move. It's called respiration. That's why Cicero's tank has oxygen in it.'

'Hang on,' You say 'If all living things need oxygen, but only plants and some other organisms make it, then how can there be enough oxygen? there's loads of living things that just take in oxygen and don't make any themselves.'

'Good question[5]. Plants don't use all the glucose they make in respiration. Some of it is used to make the substances that make up the plant. This means that plants give off about ten times more oxygen

than they take in, which is good for all of us creatures that can't use photosynthesis.'

'It certainly is!' Says Cicero 'And that means that I can go deep sea diving and have a look at this lovely coral reef down here. We've been taking turns for a while, now. Why don't you have a piece of coral?'

Summary: Plants release oxygen which is needed by all living things for a process called respiration, which is used to obtain energy for movement. However, whilst plants do respire and use up some oxygen, some of the glucose is used to make new plant materials and so plants release more oxygen gas than they use up.

Cicero flip flops over to a bench on the deck and picks up a piece of coral from it. He then gives it to you. *Add the piece of coral to your items list.*

He then puts his headgear back on before Mike lowers him into the sea using the crane. You return through the door and head back to the room. Turn to 10.

30

'Correct!' Says the astronaut 'Yup, there are little holes in the leaves of a plant called the stomata where the carbon dioxide enters and the oxygen leaves.' After all, the leaves catch the sunlight and water has to go up through them, so it makes sense that the carbon dioxide enters the plant there.

The astronaut pulls off a glove and shakes it a bit until a red gem falls out onto his hand. He offers the red gem to you. *Add the red gem to your gems list. If you have a magnifying glass, remove it from your items list.*

Summary: Plants take in carbon dioxide through small holes in their leaves called stomata.

'Good luck with the exam! You'll be great. And thanks for the research. We wouldn't be here if it wasn't for…oh yes, you haven't done that yet, have you. Well, good luck!' Says Neil as he turns to leave. You exit through the door.

Turn to 10.

31

You walk into a brightly lit room to find a beautiful and extremely happy looking woman with long blond hair, clear blue eyes and wearing a flowing yellow dress. 'Welcome to the sunshine room! I am Nina.' She announces cheerfully. 'I'm here to tell you all about how sunshine makes plants' lives and our lives better!'

You notice that there are several potted plants on the floor of the room. Nina picks one up.

'This lovely little plant loves this room as it gets all the light it wants. But do you know what plants do with the sunlight?'

The plant turns the sunlight into materials to make it grow bigger? turn to 13.

The plant uses the sunlight to break down the carbon dioxide and water so that it could be used to make glucose? Turn to 15.

The plant uses the sunlight to break down the glucose so that it can release its energy? Turn to 25.

32

You walk into a room with green walls. In the room is a man in a dinner jacket. 'Pleased to meet you! My name is Phil! I'm here to talk to you about chlorophyll in plants, but first of all, I have a question for you. Do you know what a plant would look like if it did not have chlorophyll in it?'

What is your answer?

It would have no flowers? Turn to 20.
It would wilt? Turn to 27.
It would have yellow leaves? Turn to 7.

33

'I'm afraid not. You need sunlight, chlorophyll and water in addition to the carbon dioxide for the plant to make glucose and since sunlight hits the leaves and that's where the chlorophyll is and water eventually has to make its way to the leaves, it makes sense that the carbon dioxide enters the leaves too. It enters them through little holes called the stomata.'

Neil picks a leaf from one of the plants and grabs a magnifying glass from under a nearby tree. He shows you the stomata in the leaf.

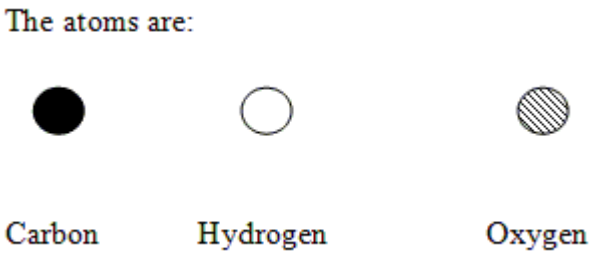
'Keep the magnifying glass so you can look at other leaves.' Says Neil. *Add the magnifying glass to your items list*

Summary: Plants take in carbon dioxide through small holes in their leaves called stomata.

You return to the main room. Turn to 10.

34

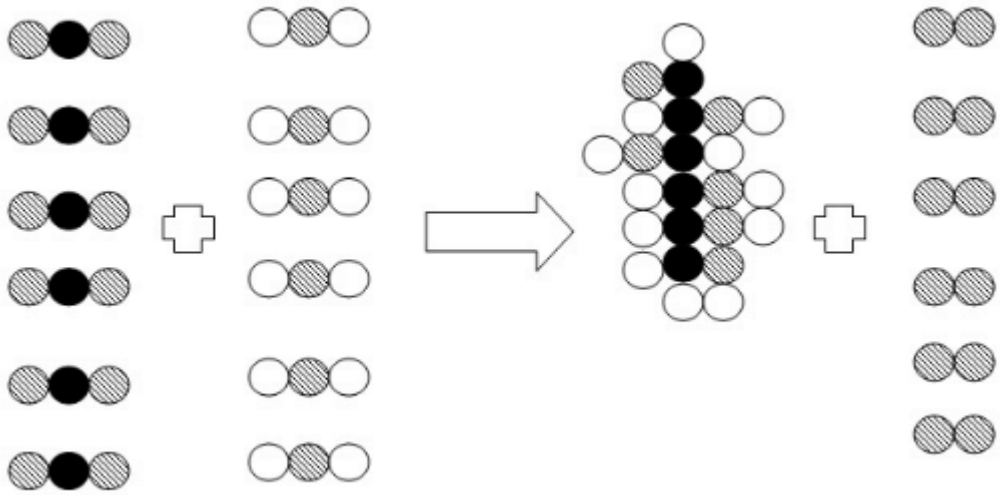
'Follow me,' Says the chef as he stands up from his desk and walks back through the door to the kitchen. You follow him through the busy kitchen as he briskly walks past the chefs, stopping only to berate one for overcooking the quail's eggs. He then leads you to a room where there are several balls. There seem to be three types of balls, with different symbols on them. 'That one represents the element carbon,' says the chef pointing to the one on the left. He then points to the middle one 'And that one represents hydrogen,' He then points to the one on the right 'And that one represents oxygen.'



You then realise that some of them are joined by strong string. There are four types of groups of balls. One of them is made up of a carbon joined to two oxygens. There are six of them. 'That's carbon dioxide,' Says the chef. One of them is made up of an oxygen joined to two hydrogens. There are also six of them 'That's water,' explains the chef. One of them is made up of six carbons, twelve hydrogens and six oxygens all joined together. There is only one of them 'That's glucose.' the chef tells you. And the last one is made up of two oxygens joined together. There are six of them 'And that's oxygen.' Says the chef.

'These are the reactants - what you start with,' Says the chef pointing at the carbon dioxide and water 'And these are the products.' He says pointing to the glucose and oxygen.

So, we have the following:



'My question is,' Says the chef 'How would you show this process as a chemical equation?'

What is the symbol equation for photosynthesis?

C_6O_{12}+ $H_{12}O_6$ -> $C_6H_{12}O_6$ + O_{12}? Turn to 36.

$6CO_2$ + $6H_2O$ -> $C_6H_{12}O_6$ + $6O_2$? turn to 26.

6CO + 6HO -> CHO + 6O? Turn to 16.

6C + 18O + 12H -> $C_6H_{12}O_{18}$? Turn to 38.

35

'Right,' Says Steve. 'Plants get their mass from carbon dioxide in the air and from water. They do need soil for minerals which help them work, but they don't actually use the soil to grow bigger. Now we've sorted out where plants get their mass from, we shall move onto the next step. He rushes through corridors, telling you to keep up. Eventually, you come to a circular room with several doors. Each door has a symbol on it.

'We've gone through the basic things that plants need, but each room here goes into more detail. I'll tell you why plants need carbon dioxide and water.'

Steve takes off his fez and pulls a remote control from out of it. He pushes a button and an image of a plant forms on the wall[10]. Arrows start pointing towards the plant and away from the plant.

'So a plant needs a load of stuff. It needs water and carbon dioxide, but it also needs sunlight and chlorophyll. With these things, a plant makes a sugar called glucose which it uses to grow and oxygen gas which the plant releases. This whole process is called photosynthesis. Make sure you look up any words you don't understand before we continue.'

Steve then points towards the doors. 'Behind each of these doors is some information about photosynthesis. Most of them focus on one of the things I've mentioned, but there is also a room about chemical equations, if you're feeling advanced. When you've finished here, just go through the door with the fez and I'll be there for the next stage.' Steve then presses a button on his remote control and vanishes.

You look at the symbols on each door to work out where you want to go. Which door will you try?

Summary: A plant uses carbon dioxide, water, sunlight and chlorophyll to make glucose and oxygen. This process is called photosynthesis.

The jug (water)? Turn to 23.
The burning bush (carbon dioxide)? Turn to 11.
The leaf (chlorophyll)? Turn to 32.
The Sun (sunlight)? Turn to 31.
The sugar cube (glucose)? Turn to 40.
The wind (oxygen)? Turn to 24.
The scales (equation for photosynthesis)? Turn to 9.
The fez (exit)? Turn to 3.

36

'Well, you have the numbers right, but you haven't got any large numbers. This equation says that there is one large molecule with six carbons and twelve oxygens reacting with another large molecule with twelve hydrogens and six oxygens to make glucose, which is correct and a molecule with twelve oxygens in it. This is the correct answer…'

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

'If we multiply the big and small numbers, we get the same number of atoms as you, but this equation also shows us that the carbon dioxide is split into six molecules. Equations are tough. There are plenty of websites to practice them, such as here[8] and there are more in the links page at the end of this book.

'How do you know I'm reading a book?' You ask the chef.

'I know everything!' Announces the chef.

There is a flash and a puff of smoke which fills the room. Once it has cleared, the chef has vanished and in his place, there is a small balance. You take the balance.

Add the balance to your items list.

Summary: Balancing equations involves two numbers. The small numbers are the number of atoms in a molecule which are bonded together and the large numbers are the number of molecules. The big numbers indicate that the molecules are not bonded together.

When you have finished, you return to the main room. Turn to 10.

37

'Someone isn't fooled. Well done! People don't normally say that plants get what they need from the air, but they do. Yup, they're sucking in carbon dioxide right now through little holes in their leaves called stomata.'

Steve pulls a white gem out of his pocket and gives it to you. 'That's for working out the answer.'

Add the white gem to your gems list. If you have a bottle of fizzy water, remove it from your items list.

If you now have a blue gem and a white gem, turn to 35. Otherwise, Steve goes on.

'However, that's not the only place plants get their mass from. There is one other place. What is it?'

The soil? Turn to 39.
The water? Turn to 4.

38

'Well the numbers are all right, but chemical equations of taking all the elements and putting them together into a compound. These elements go around in their own little groups either and they don't just form one big compound. They form different compounds. This equation says that there is one large molecule with six carbons and twelve oxygens reacting with another large molecule with twelve hydrogens and six oxygens to make glucose, which is correct and a molecule with twelve oxygens in it. This is the correct answer…'

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

'If we multiply the big and small numbers, we get the same number of atoms as you, but this equation also shows us that the carbon dioxide is split into six molecules. Equations are tough. There are plenty of websites to practice them, such as here[8] and there are more in the links page at the end of this book.

'How do you know I'm reading a book?' You ask the chef.

'I know everything!' Announces the chef.

There is a flash and a puff of smoke which fills the room. Once it has cleared, the chef has vanished and in his place, there is a small balance. You take the balance.

Add the balance to your items list.

Summary: Balancing equations involves two numbers. The small numbers are the number of atoms in a molecule which are bonded together and the large numbers are the number of molecules. The big numbers indicate that the molecules are not bonded together.

When you have finished, you return to the main room. Turn to 10.

39

'Classic answer. Most people say that.' Says Steve, the fez wearing dwarf 'But it is in fact completely wrong. Plants don't get their mass from the soil. They do need the soil for minerals which help the plant work, but it takes very little mass away from the soil. Let me introduce you to someone to explain how plants get their mass.'

If you have a white gem, turn to 21.

If you have a blue gem or no gems, turn to 14.

40

You walk through the door and come to a sweet shop. There is a kindly old man with gold rimmed spectacles standing behind the counter, surrounded by jars full of sweets of all kinds.

'Hello, there.' Says the man 'What can I do for you?'

'I'm here to know about sugar in photosynthesis.' You say.

'You are, are you? Well, there are actually lots of different types of sugar. Plants make sugar called glucose which is good for releasing energy and growth. Plants store glucose by sticking the glucose molecules together in a chain. We call this chain starch.'

The sweet seller goes on. 'Glucose is made from carbon dioxide and water. Do you know what elements are in glucose?'

What is your answer?

Carbon, hydrogen and oxygen? Turn to 17.
Carbon, nitrogen and oxygen? Turn to 8.
Just carbon and hydrogen? Turn to 2.

41

'Well, it's time for you to wake up, then.' Says Steve.
'Like in those stories when the twist is that you wake up and it's all just a dream?' You ask.
'No, because you knew this was a dream from the beginning.' Replies Steve, rolling his eyes.
'Well, will I wake up and all the stuff I've collected will be in my room?'
'Of course it's not!' growls Steve 'This is dream stuff! I'm a dwarf, I'm not magical!'
'Oh, OK.' You sound a bit disappointed. 'Will I see you again for some more revision.'
'Maybe' Replies Steve 'I've applied for a job as a king in a game.'
'I thought you thought RPGs were too dangerous.'
'Yeah, but this is a strategy game and I'll be boss. You know what they're like - The boss never gets killed. They just sit there and boss people around.'
A rectangular white door slides open in the air. 'Right, I'm off to America where the interview is. Good luck with the test.'

42

Steve snaps his fingers and the whole place dissolves into blackness. You are in a small room with a desk and a chair. Upon the desk is a sheet of paper with 'Photosynthesis Challenge' written as the title. There is a pen by the piece of paper. On the floor is a sealed jar, containing multi-coloured gems. The label on the jar says 'You will get these gems for answering the questions on the challenge correctly. The challenge is split into three sections – easy questions, hard questions and balancing equations. Each section will be assessed separately, so you could do one, two or all three of these sections. You may choose to take the challenge or wake up and leave the memory palace.' As you read the last line, a black rectangle appears in the wall. This is the exit from the palace. When you take it, you will wake up. Or you could stay a bit longer, do the challenge and try to get some multi-coloured gems. You feel a bit cheated that the challenge is actually just another test. You were expecting something a little more strenuous and exciting than a test, especially in this dream world where anything seemed possible. You then hear Steve's voice in the room 'We have a limited budget and there's a recession on, you know. Gems and doors to space colonies don't come cheap.' You decide to stop thinking about the financial ins and outs of the dream world and focus on photosynthesis instead.

Go on to the next page for the assessment of photosynthesis.

When you have completed and marked the challenge, turn to 41.

The Lindenbaum Memory Palace Challenge. Will you survive?*

Answer the questions, then mark them using the mark scheme on the next page to see how many multi-coloured gems you get. Some questions are worth more than one multi-coloured gem. This means that you will have to write as many points as there are gems.

Basic questions – what materials do plants need

1) What is the name of the process that plants use to turn carbon dioxide and water into glucose and oxygen? (1 multicolour gem)
2) Where does the plant get the water from? (1 multicolour gem)
3) Where does a plant get carbon dioxide from? (1 multicolour gem)
4) This process requires energy. Where does this energy come from? (1 multicolour gem)
5) What substance in the plant's leaves allow it to obtain this energy? (1 multicolour gem)
6) Name the solid product from this process. (1 multicolour gem)
7) Name the gaseous product from this process. (1 multicolour gem)

More advanced questions – things you need to think about more

1) If you leave a plant in the dark for a while, it eventually grows to be very tall and turns yellow. Come up with an explanation for both of these processes. (2 multicolour gems)
2) If a plant's leaves are covered in wax, it will eventually die. Explain what covering the leaves does and what substance the plant can no longer obtain. (2 multicolour gems)
3) Joseph Priestly put a mouse and a plant in a sealed container. The mouse managed to survive inside the sealed container despite it not being open the air. Explain how the mouse was able to breathe for a long time in the container. (2 multicolour gems)
4) During the day, plants produce more oxygen than carbon dioxide. At night, they produce more carbon dioxide than oxygen. Explain what processes are making this happen. (2 multicolour gems)

Advanced questions to do with formulae and balancing equations

1) Sucrose is another type of sugar besides glucose. It has the formula $C_{12}H_{22}O_{11}$. How many carbon, hydrogen and oxygen atoms are there in sucrose? (3 multicolour gems)

2) Ammonia has the formula NH_3. It is used to make fertilisers for plants. Ammonia is made from nitrogen and hydrogen. The equation for making ammonia is:

$$N_2 + H_2 \rightarrow NH_3$$

Balance the equation. (3 multicolour gems).

3) Yeast from plants is added to glucose in water to make ethanol (the alcohol in alcoholic drinks with the formula C_2H_6O). The equation for making ethanol is:

$$C_6H_{12}O_6 \rightarrow C_2H_6O + CO_2$$

Balance the equation. (3 multicolour gems).

*Of course you will. It's a test paper, not a life or death struggle.

The Lindenbaum Memory Palace answers

Basic questions – what materials do plants need

1) What is the name of the process that plants use to turn carbon dioxide and water into glucose and oxygen? (1 multicolour gem). **Photosynthesis.**
2) Where does the plant get the water from? (1 multicolour gem) **The soil.**
3) Where does a plant get carbon dioxide from? (1 multicolour gem) **The air.**
4) This process requires energy. Where does this energy come from? (1 multicolour gem) **Sunlight.**
5) What substance in the plant's leaves allow it to obtain this energy? (1 multicolour gem) **Chlorophyll.**
6) Name the solid product from this process. (1 multicolour gem) **Glucose.**
7) Name the gaseous product from this process. (1 multicolour gem) **Oxygen.**

More advanced questions – things you need to think about more

1) If you leave a plant in the dark for a while, it eventually grows to be very tall and turns yellow. Come up with an explanation for both of these processes. (2 multicolour gems)
The leaves turn yellow because the plant no longer produces chlorophyll as it would not do anything in the dark. (1 multicolour gem)
The plant grows taller as it is 'searching' for light (1 multicolour gem)

2) If a plant's leaves are covered in wax, it will eventually die. Explain what covering the leaves does and what substance the plant can no longer obtain. (2 multicolour gems)
The wax covers the stomata (small holes) in the plant's leaves (1 multicolour gem)

Since the leaves are covered, they can no longer take in carbon dioxide (1 multicolour gem)

3) Joseph Priestly put a mouse and a plant in a sealed container. The mouse managed to survive inside the sealed container despite it not being open the air. Explain how the mouse was able to breathe for a long time in the container and how the mouse helped the plant produce food. (2 multicolour gems)

The plant produced oxygen which the mouse could breathe (1 multicolour gem)

The mouse produced carbon dioxide (and water) for the plant to use in photosynthesis (1 multicolour gem).

4) During the day, plants produce more oxygen than carbon dioxide. At night, they produce more carbon dioxide than oxygen. Explain what processes are making this happen. (2 multicolour gems)

During the day, plants are using photosynthesis because of the sunlight (1 multicolour gem).

At night, since there is no sunlight, plants are respiring and produce carbon dioxide (1 multicolour gem).

Advanced questions to do with formulae and balancing equations

1) Sucrose is another type of sugar besides glucose. It has the formula $C_{12}H_{22}O_{11}$. How many carbon, hydrogen and oxygen atoms are there in sucrose? (3 multicolour gems)

Sucrose contains:
12 carbons (1 multicolour gem)
22 hydrogens (1 multicolour gem)
11 oxygens (1 multicolour gem)

2) Ammonia has the formula NH_3. It is used to make fertilisers for plants. Ammonia is made from nitrogen and hydrogen. The equation for making ammonia is:

$$N_2 + H_2 \rightarrow NH_3$$

Balance the equation. (3 multicolour gems).

N_2 (no number in front of the nitrogen) (1 multicolour gem)
$3H_2$ (1 multicolour gem)
$2NH_3$ (1 multicolour gem)

The correct equation for 3 multicolour gems is:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

3) Yeast from plants is added to glucose in water to make ethanol (the alcohol in alcoholic drinks with the formula C_2H_6O). The equation for making ethanol is:

$$C_6H_{12}O_6 \rightarrow C_2H_6O + CO_2$$

Balance the equation. (3 multicolour gems).

$C_6H_{12}O_6$ (no number in front of the glucose) (1 multicolour gem)
$2C_2H_6O$ (1 multicolour gem)
$2CO_2$ (1 multicolour gem)

How did you do?

Basic questions – what materials do plants need

6-7 Well done – you have an excellent knowledge of the materials that plants need to create their food.
4-5 You have some knowledge, but you will need to revise this more thoroughly before you move on to more advanced questions.
3 or less You need to go back and revise this in its entirety.

More advanced questions – things you need to think about more

7-8 Congratulations! You are able to deduce explanations from information provided. Keep up your way of thinking.
5-6 You have some good talent in terms of your deduction skills. With a little more practice, you can do very well at it.
4 or less You need to put more practice into using information and making explanations from it.

Advanced questions to do with formulae and balancing equations

7-9 Congratulations! Your skills at balancing equations are second to none! Keep it up!
4-6 You have some skill in balancing equations and working out formulae. With more practice, you can improve to be able to balance any equation. Use the links on the further resources page to help you.
3 or less You need more practice in order to balance equations correctly. Use the links in the further resources page to help you.

References

0 This is an example, but now you know where the references page is.

1 The Wikipedia page on method of loci also known as a memory palace. http://en.wikipedia.org/wiki/Memory_palace

2 An example on building a memory palace http://blog.pricelesseternity.com/2013/01/memory-palaces-memory-techniques.html

3 A Wikihow page on building a memory palacehttp://www.wikihow.com/Build-a-Memory-Palace

4 The Countdown clock and music
http://www.youtube.com/watch?v=e32kaa9TzeE

5 Why do plants produce oxygen even though they use oxygen for respiration?
http://scienceline.ucsb.edu/getkey.php?key=2860

6 Details on an experiment to make blue celery
http://www.craftoart.com/2012/01/how-plants-absorb-water-celery-science.html

7 More details on BBC Bitesize about transpiration
http://www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/greenworld/planttransportrev2.shtml

8 A game about balancing chemical equations
http://funbasedlearning.com/chemistry/chemBalancer3/default.htm

9 Video about Van Helmont's experiments with plants
http://www.bbc.co.uk/learningzone/clips/van-helmonts-experiments-on-plant-growth/12895.html

10 Diagram of the things a plant needs for photosynthesis from BBC Bitesize
http://www.bbc.co.uk/bitesize/intermediate2/biology/images/100/032_bitesize_intermediate2_biology_livingcells_chlorophyll.png

Further resources

A brief history of discoveries relating to photosynthesis
http://www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_gateway/green_world/photosynthesisrev2.shtml

A video about the life of Joseph Priestly
http://www.bbc.co.uk/learningzone/clips/joseph-priestley-the-discovery-of-gases/2078.html

Summary of photosynthesis with a word equation
http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/plants/plants1.shtml

You can do some exercises on balancing equations at the following two websites
http://www.sciencegeek.net/Chemistry/taters/EquationBalancing.htm
http://www.files.chem.vt.edu/RVGS/ACT/notes/scripts/bal_eq1.html

A virtual experiment to discover how the rate of photosynthesis of a plant is affected by how close it is to a light
http://www.reading.ac.uk/virtualexperiments/ves/preloader-photosynthesis-full.html

Further reading on photosynthesis and plants, not covered in this gamebook

How the rate of photosynthesis is affected by light intensity, carbon dioxide concentration and temperature
http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/plants/plants2.shtml

A page on common minerals that plants need and what happens if they don't get them
http://www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/greenworld/plantmineralsrev1.shtml

Information on biofuels
http://www.bbc.co.uk/schools/gcsebitesize/science/edexcel_pre_2011/oneearth/fuelsrev4.shtml