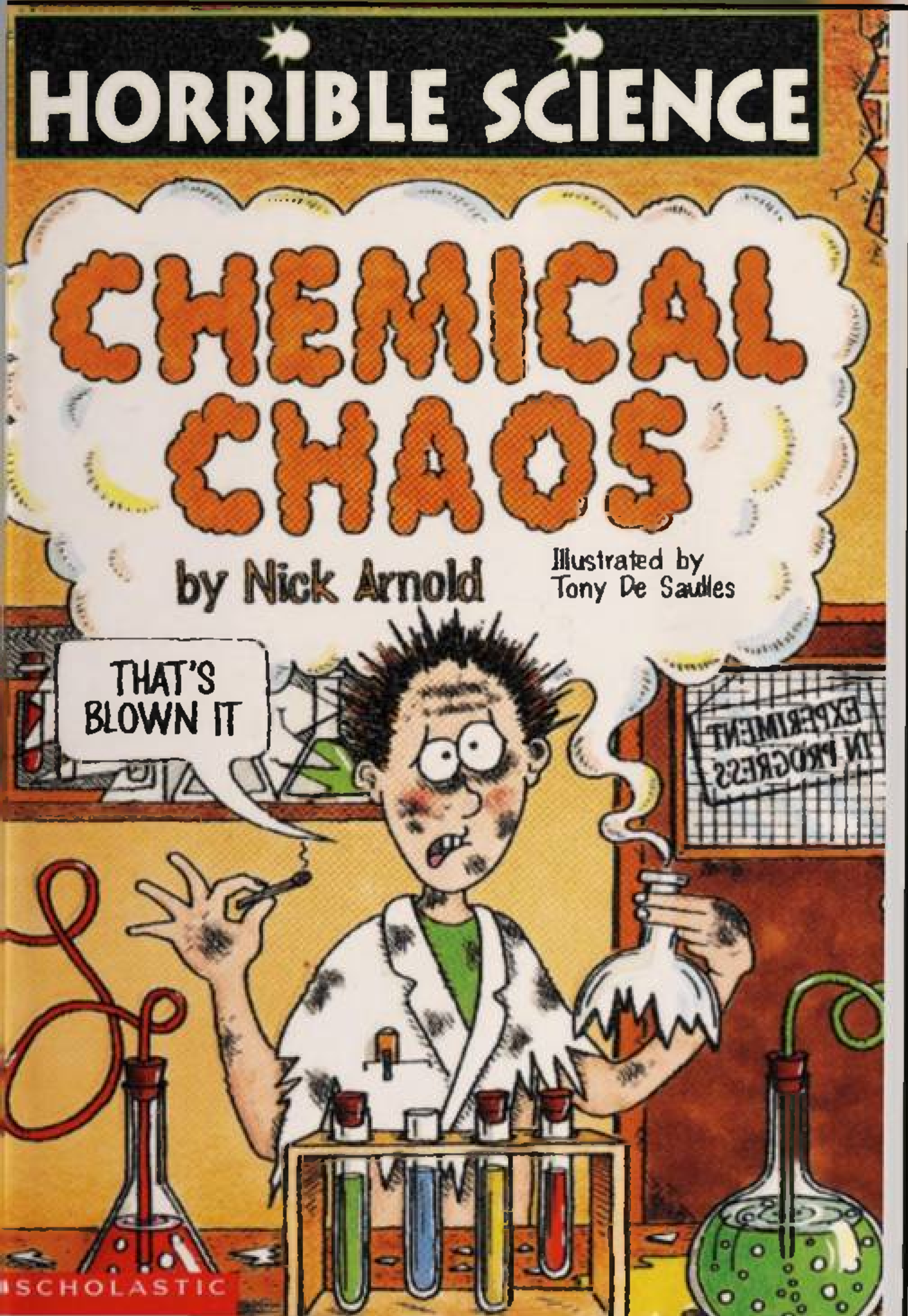
HORRIBLE SCIENCE
CHEMICAL CHAOS
by Nick Arnold
Illustrated by Tony De Saulles
THAT'S BLOWN IT
EXPERIMENT IN PROGRESS
SCHOLASTIC

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HORRIBLE SCIENCE

CHEMICAL CHAOS

by Nick Arnold

Illustrated by
Tony De Saulles

SCHOLASTIC INC.
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Other titles in this series include:

Ugly Bugs
Blood, bones and body bits

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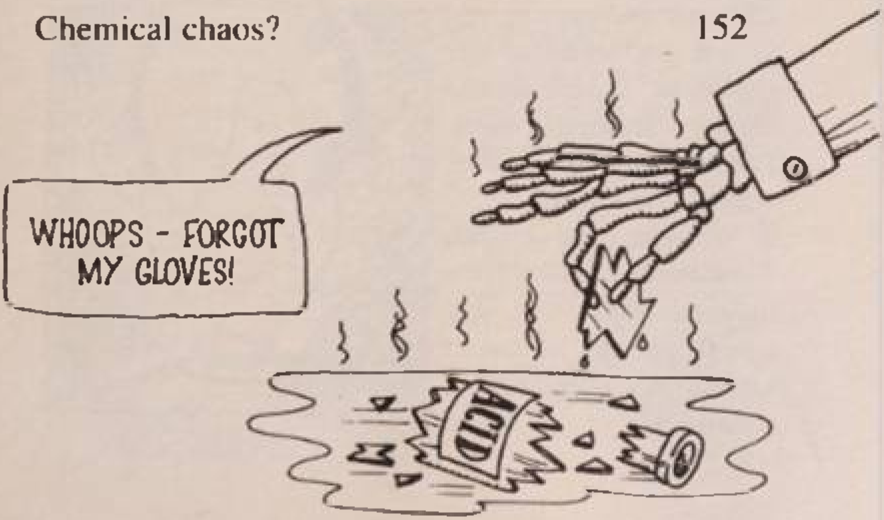


Nick Arnold has been writing stories and books since he was a youngster, but never dreamt he'd find fame writing about Chemical Chaos. His research involved being blown up, sucking helium out of balloons and cooking up revolting substances and he enjoyed every minute of it.

When he's not delving into Horrible Science, he spends his spare time teaching adults in a college. His hobbies include eating pizza, riding his bike and thinking up corny jokes (though not all at the same time).

Tony De Saulles picked up his crayons when he was still in diapers and has been doodling ever since. He takes Horrible Science very seriously and even agreed to test out some of our explosive experiments before drawing them. Fortunately, his injuries weren't too serious.

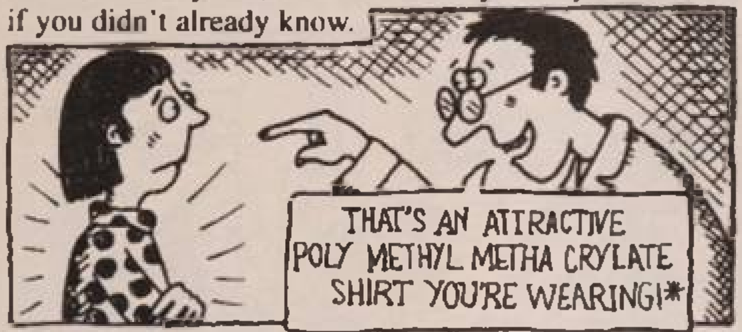
When he's not out with his sketchbook, Tony likes to write poetry and play squash, though he hasn't written any poetry about squash yet.

Introduction

Chemistry can be summed up in a single word – "UGH!" It's that part of science dealing with chemicals and test tubes. "Ugh!" is the best word for it! It's the most *horrible* part of Horrible Science.

And why is it so horrible? Well – if you find science confusing you'll find chemistry as clear as mud. It can cause chaos in your brain.

For starters, there are those chaotic-sounding chemical names. Like poly methyl metha crylate* (say polly me-thile-me-tha-cry-late). *That's the acrylic in your sweater, if you didn't already know.



*TRANSLATION – I LIKE YOUR ACRYLIC SWEATER

These long words are mainly Latin or Greek. Fine for ancient Romans – but horribly confusing for the rest of us. Sometimes chemistry turns totally chaotic. That's when chemists talk their own chaotic code language.

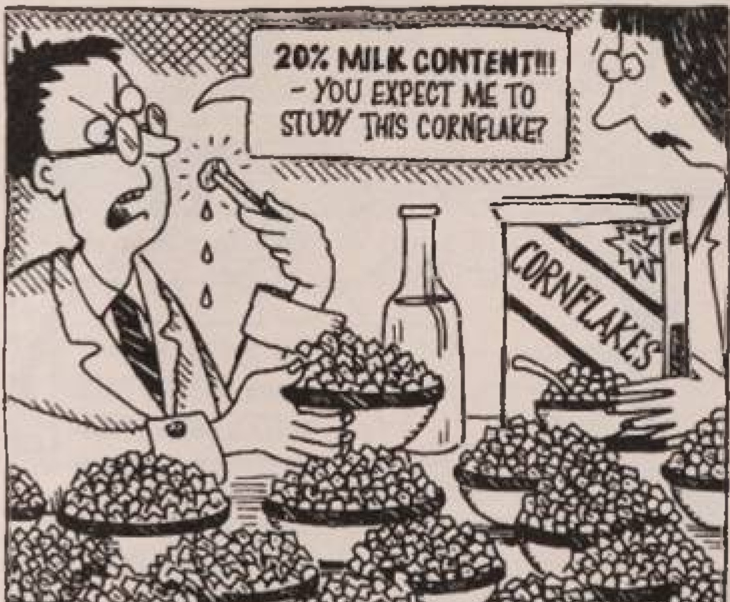
Translation:

1 The water hasn't boiled.

2 Pass the sugar.

3 Lactic acid = sour milk: the milk's gone bad!

Even a chemist's brain seems pretty chaotic. How else would they come to investigate soggy cornflakes? (Chemists have reported that a cornflake with more than 18% milk content is just too soggy to study.)



But funnily enough that's what this book is about. Not the parts you learn in school – but the funny parts and the fascinating parts, the parts you really want to find out about ... nasty bubbling green mixtures, vile and sometimes poisonous potions, test tubes, horrible smells, bangs, blasts and dubious discoveries.

But *Chemical Chaos* might just help you see through the confusion that is chemistry, then you might just end up causing chaos in your chemistry teacher's day, by getting your own experiments to work...

Chaotic chemists

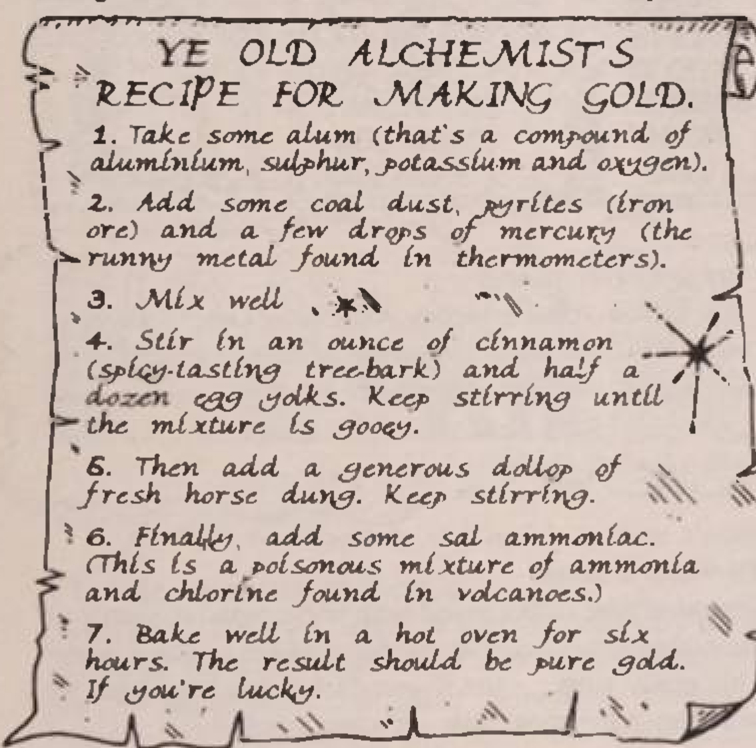
Chemists are curiously chaotic. Their knowledge of chemicals used to be chaotically confused and their messed-up experiments caused chaos too. The first chemists were called alchemists and they were pretty chaotic. And strange.

Imagine it's a particularly boring chemistry lesson, and you are feeling ver-r-ry sleepy. The next thing you know you are in a mysterious room.... You see an old man reading a book. He is surrounded by oddly shaped flasks, the stumps of candles and dirty beakers. On a nearby table there are bottles of ink, old goose feather pens, oily rags and old musty books – full of ancient dust and secrets. In the chaotic shadows stand row upon row of bottles filled with weird potions. On the floor lie the rat-nibbled remains of several meals. The old man laughs to himself. Then in a thin crackly voice he reads a magical spell...

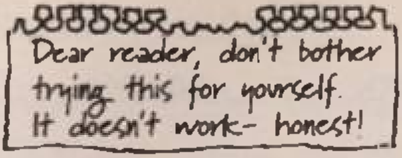
Confused? Don't worry this is **NOT** your chemistry teacher! You've just slipped back 500 years to meet your local chemist. Except 500 years ago chemists weren't called chemists – they were called alchemists.

Appalling alchemists

As far as we know, alchemy started in Ancient Greece and China. It's a mixture of chemical knowledge, magic and philosophy about how materials are formed. On a more practical level, alchemists tried to turn cheap metals into gold. Here's one of their more unusual recipes.



A note to the reader:



Although some people poked fun at its more curious notions – alchemy was fashionable. Even kings wanted to try it. It has been suggested that the British King Charles II was poisoned by the mercury he used for alchemy experiments. His scientist pal Sir Isaac Newton used this substance for experiments and went mad for two years.

Bet you never knew!

One famous alchemist was the Arab writer Geber (or Jeber). Now old Geb had lots of ideas but he was a lousy writer. In fact, his boring books of experiments gave rise to the word "gibberish." Sadly, Geber wasn't the last scientist to come out with a load of old gibberish.

Here's another alchemist's trick you shouldn't try.

To warm a liquid

Surround a jar of the liquid with horse manure. Germs in the dung cause chemical reactions which produce heat. This really works – but if you do want to keep your tea warm try a thermos flask – it's less smelly!

Get-rich Rutherford?

Despite many failures the alchemists kept going. They believed a substance called the "philosopher's stone" would turn cheap metals into gold. No one knew what the philosopher's stone was exactly or where to find it. But alchemists were convinced that the person who found the stone would live for ever. Of course, no one ever discovered the real answer. Until quite recently...

In 1911 New Zealander Ernest Rutherford (1871-1937) found out how to change metals into gold. This involved the metals' atoms, which are the minuscule objects that make up all substances. To make the gold, you zap bits off the atoms with a high-energy ray. By changing the atoms you can change the metal they form.

But Rutherford had bad news for alchemists:

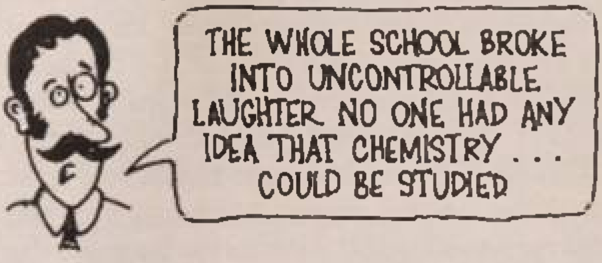
1 Atoms are so tiny they're easy to miss with your zapping ray.

2 The easiest metal to turn into gold is platinum. But that's even more expensive than gold!

3 So if you want gold it really is cheaper to buy some from your local jeweller!

Chaotic chemists of the past

By 1700 scientists were becoming curious about chemicals for reasons other than alchemy. They dropped the "al" bit as well, and called themselves "chemists" instead. "Al" only means "the" in Arabic anyway. But many people thought chemistry was a strange idea. One scientist, Justus von Liebig (1803-1873) was scolded at school for not doing homework. His teacher asked him what job he wanted to do and Justus said he wanted to be a chemist whereupon...



One man played a vital role in begining to change their minds. His name was Antoine Lavoisier (1743-1794). Some people even called him the "Father of Modern Chemistry." But in 1789 revolution swept France and Lavoisier found himself in a seriously chaotic situation.

An enemy of the people?

It was a time of terror but no one dared use the word. No one was safe from arrest. In the Square of the Revolution there were daily executions for the old women to watch as they sat knitting in the spring sunshine.

"Pass me ze papers," said the Public Prosecutor to his newly-appointed clerk. "Yes, the ones about Citizen Lavoisier."

The young man hurriedly searched his desk. It was unwise to waste the Prosecutor's time. The Prosecutor, Antoine Fouquier-Tinville, was always in a hurry.

"*Merci* – thank you," said the Prosecutor, and he hastily examined the paper. "Aha, Antoine Lavoisier – the collector of taxes..."

"He's a great scientist too..." ventured the clerk.

"WHO dares say so!" screamed the Prosecutor.

The clerk dropped his quill pen and papers in a shower of ink. "I mean, I didn't mean that!" he stammered. "I meant Lavoisier is a great traitor! Oh, silly me!"

"Well," said the Prosecutor, "let's see what the file says." He began reading the document in the harsh voice he used to terrify prisoners in court:

"Antoine Lavoisier. Born 1743 and brought up by his aunt, father and grandmother ... Hmm – he was a goody-goody at school. Spent one year in which his only lessons were science and math. Pah! Two more years learning nothing but philosophy. Pah! Pah! Wrote his first scientific paper at the age of ten – what a little creep! Later found gypsum has water in it and mineral water has tiny bits of salt. Very useful ... I *don't* think. Ha, ha!"

"I ... I know," said the clerk from the floor in a small voice, "that Lavoisier *is* a traitor ... but ... he did find that water contains hydrogen and oxygen chemicals. Then he discovered gases in the air. Then he found you can't destroy chemicals – only change them around and then..."

"Stop, you fool!" spat the Prosecutor. "Do you think I need ze chemistry lesson?! Ah – here's the juicy bit. In 1768 Citizen Lavoisier became a *tax* collector. One of his friends said, 'The dinners he will give us will be so much the better!' All the tax collectors are the enemies of the people. Thanks to the revolution they're in prison now!"

The Prosecutor smiled unpleasantly. "Let's see if they enjoy their fine dinners without their heads on!" He drew his finger across his throat and made a choking sound.

"Excuse me – I've got some papers to file!" said the clerk as he fled the room in panic. He just missed a thin man in a green coat. The visitor was plainly dressed apart from his white powdered hair. He certainly didn't look like the most powerful man in France. But that's who he was.

"Citizen Robespierre," said the Public Prosecutor with a false smile. "This is indeed a pleasure and an honour. The papers await your signature."

"More enemies of the people?" enquired Robespierre. He seated himself without being asked and read the document. "Lavoisier. Yes, I remember him. He supported the revolution at first. Helped with the new metric weights too. He did good work for France running gunpowder factories before the revolution. He would be a great loss."

The Prosecutor frowned. He was unsure if Robespierre was testing his loyalty and replied nervously, "Our revolutionary hero, Citizen Marat, called

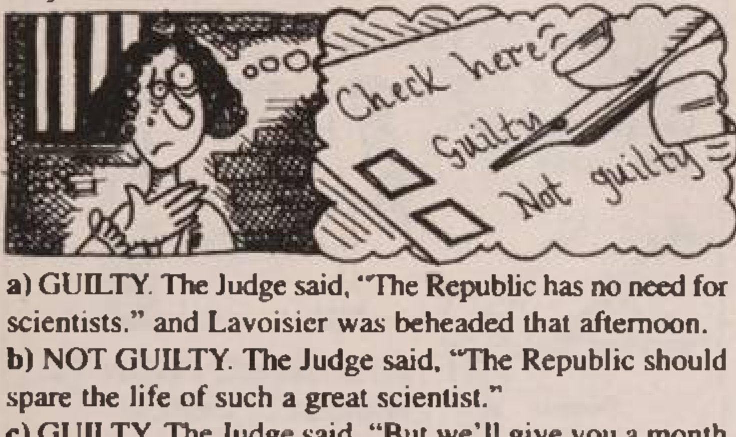
Lavoisier a traitor in his newspaper articles."

"Yes, I know," said Robespierre. "But Marat was a failed scientist and Lavoisier was rude enough to say so. That's why Marat hated him so much."

"So. You mean us to spare Citizen Lavoisier?"

Robespierre merely smiled coldly and gazed out of the window. The pen was poised like a dagger in his hand.

Antoine Lavoisier's trial began on 8 May, 1794. The scientist looked pale and tired after six months in prison. He pleaded for more time to finish a vital chemistry experiment. Would Robespierre take pity on him? What do *you* think the verdict was?



a) GUILTY. The Judge said, "The Republic has no need for scientists." and Lavoisier was beheaded that afternoon.
b) NOT GUILTY. The Judge said, "The Republic should spare the life of such a great scientist."
c) GUILTY. The Judge said, "But we'll give you a month to finish off your experiment."

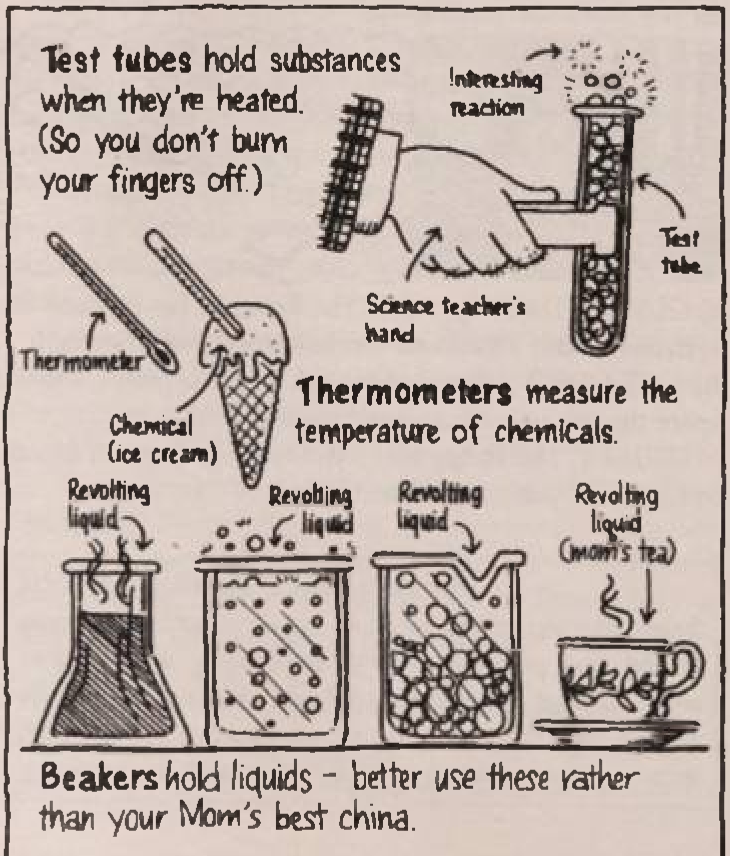
Answer: a) One of Lavoisier's friends said, "It took them only an instant to cut off that head, and another hundred years may not produce another like it." Two months later Robespierre lost power and was put to death. Fouquier-Tinville was executed the following year. And Lavoisier's work lives on...

Chaotic contemporary chemists

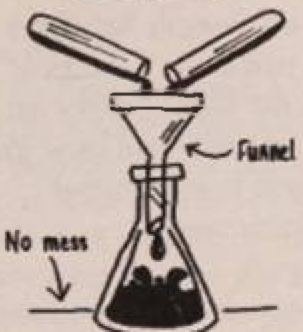
Nowadays, there are thousands of chemists. In the USA alone there are over 140,000 chemists trying to discover new chemicals! Some are looking for ultra-light metals or new kinds of plastics. Others are looking for new food ingredients or medical drugs. Here's where they work.

A Chemistry Lab

At first sight all these bits and pieces look a bit funny. But they all have their uses.

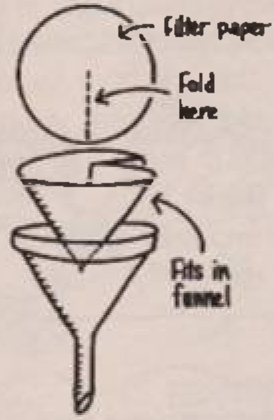


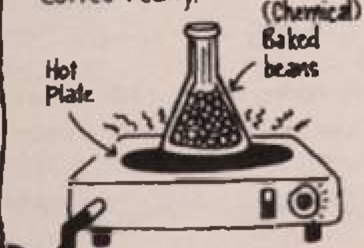
Flasks are for mixing chemicals in. They're usually conical in shape - that means they're shaped like a cone - and have flat bottoms.



Funnels for pouring mixtures into flasks without dropping them all over the floor (see above).

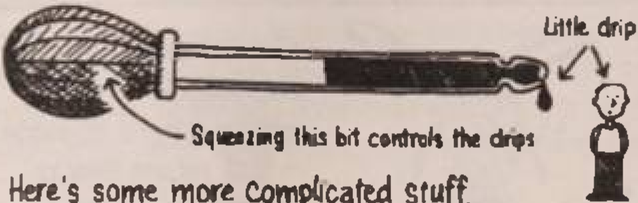
Filter paper - a paper sieve for separating solid chemicals from a liquid. The runny part passes through paper and solid lumps get caught. It's like making filter coffee really.



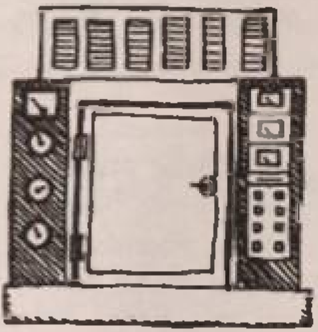


Hot plates - a bit like stove tops. Ideal for heating and cooking dinner too.

Droppers for measuring little drips of chemicals.

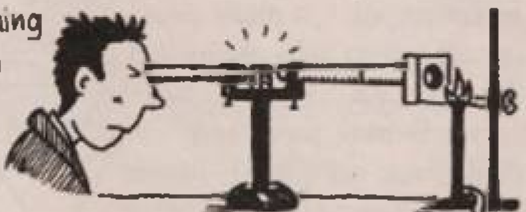


Here's some more complicated stuff.



A gas chromatograph
Inside this mysterious machine are chemicals that absorb and separate the chemicals in your favorite stinky gas. That way you'll know what goes to make up that lovely smell.

A spectroscope allows you to identify a burning chemical from the color of its flame. It's a bit like watching your own mini fireworks display.



Bet you never knew!

These days robots do many of the boring jobs in a lab such as testing samples. Too bad they can't get robots to do science homework, too!

Dare you discover ... your own secret substance?

If being a chemist sounds like fun here's your chance to make a laughably easy discovery.

You will need:

2 teaspoons of cream of tartar (available from supermarkets)
1 cup of salt
2 cups of plain flour
2 cups of water
2 tablespoons of cooking oil

All you do is:

1 Mix the flour and salt in a large saucepan.
2 Add the water and mix well.
3 Add the cream of tartar and the cooking oil and mix well.
4 Ask an adult to help you heat the saucepan on a low heat and stir it until the mixture thickens. Leave to cool.

Like any other inventor you'll need to find a use for your new discovery. That's up to you – here are a few crazy ideas.

Finally, you'll need to dream up a name for your new substance ... any suggestions?

Chaotic chemical expressions

Were chemists just joking around when they thought up names like polyvinylidenechloride? What do you think they were talking about?

Answer: That's plastic wrap to you.

What's in a name?

So, how do scientists decide on a name for all these new substances? And do they have to be so long and complicated?

1 In 1787 Lavoisier suggested that scientists should agree on names for chemicals. Before then scientists made up their own mysterious names. Chemical names still sound pretty mysterious but you can be sure your teacher didn't make them up.

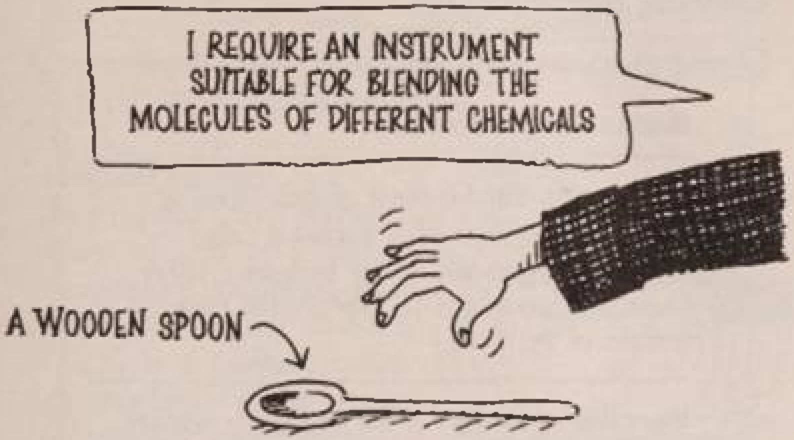
2 Swedish scientist Jöns Jakob Berzelius (1779-1848) had the idea of using letters of the alphabet to stand for each chemical atom. So hydrogen became "H" and oxygen became "O" – simple isn't it?

3 The scientific Swede's second brainwave was to use numbers to show the number of atoms in each chemical. So H_2 means "two hydrogen atoms." Brilliant – huh?

4 When you get two or more atoms joined together it's called a molecule. $2H_2$ means two parts of two hydrogen atoms; H_2O is a molecule of the two hydrogen atoms and an oxygen atom joined together.

5 In fact H_20 is just the chemists' code for plain boring old water.

But anyone can be a chemist. In fact, you may be one without even realizing it. And if that sounds incredible – consider this: you use chemistry every time you cook or wash. Shocking, isn't it?



Chaotic kitchen chemistry

How can cooking possibly be chemical? Actually, it would be impossible to cook without chemistry. It's what cooking's all about – from the suspect substances that call themselves school lunches, to the revolting reaction that makes your dad's homemade ice cream stick to its dish.

Cooking chemicals fact file

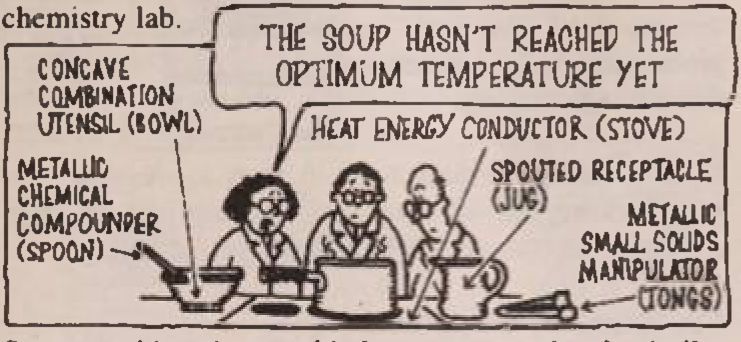
Name: Food chemicals

The basic facts: Most of your food is made up of atoms of a chemical called carbon arranged into larger molecules. Other chemicals are added to improve the taste or texture of the food.

Horrible details: In the nineteenth century mysterious things were added to food to make it go further. For example, ground-up bones were mixed into flour. And wooden strawberry seeds were added to "strawberry" jam to make it look more real!

Kitchen chemistry lab

It's a strange thought, but your kitchen is a bit like a chemistry lab.



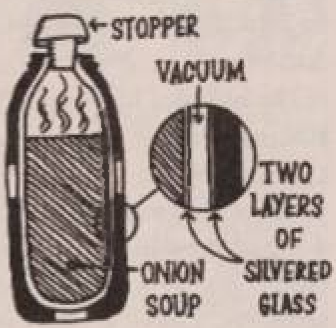
Some machines in your kitchen are mysteriously similar to instruments used by scientists.

Pressure cooker

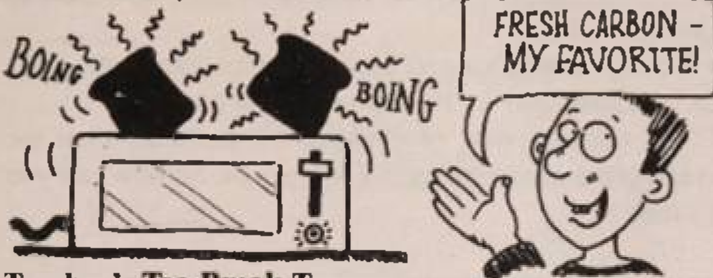
This works by allowing water to boil at a higher temperature than usual, so it cooks things faster. But it's similar to a machine called an autoclave that kills germs on scientific instruments.

Thermos flask

This is handy for keeping your soup hot or a drink cold on a summer's day. But the flask was originally invented by a chemist. In 1892 Sir James Dewar invented the double-walled container to keep his chemicals cold.



5 Vinegar is made from wine that has gone disgustingly sour. This chemical reaction is caused by the waste products produced by germs. Yuck!
6 Toast is bread in which the carbon has been partly burned. The smoke that sometimes pours from the toaster is made from tiny bits of carbon.



Teacher's Tea-Break Teasers
If you are very brave (or foolhardy) knock on the door of the staffroom and try this question on your teacher.

Answer: It does make a difference. Milk contains a chemical called casein (case-in). When tea mixes with milk its chemicals break down the casein into smaller molecules. If you add the milk to the tea it means that more casein gets broken down. This makes the tea taste of boiled milk. That's why chemists in the know add tea to milk and not the other way around!

Oven

This is simply a machine for heating food chemicals to produce the chemical reactions that we call cooking.

Here are some fascinating food facts to impress your friends during school lunchbreak. (You'll impress them even more if you can work out what you're eating.)

Six mixed-up food facts

1 The burning sensation you get if you eat chilli peppers is due to a chemical called capsaicin (cap-say-kin). According to experts the best remedy for a fiery mouth is a generous helping of ice-cream! That's tragic!

2 The smell of raspberries found in most yogurts is due to an added chemical called ionone. It's made from violets. Aah!

3 The bubbles in a cooked cake mixture are made by gas! Baking powder contains an acid and a chemical rich in carbon. When they're heated, a chemical reaction produces a gas called carbon dioxide.

4 Salad dressing is an emulsion. No, that's not a type of paint. It's a mixture of two chemicals that don't mix properly. Leave a salad dressing for a few hours and it will turn into a layer of oil above a layer of vinegar.

Amazing changes

Like tea making, cooking is about heating chemicals until they change in some way. For example, fries cook at 374°F and meringues need several hours at 158°F. But what causes these dramatic changes?

Try these terrible trick questions on your unsuspecting cooking teacher!

1 When you are trying to boil milk why does it suddenly go "whoosh" and try to leap out of the pan?

2 The boiling point of cooking oil is hotter than the temperature needed to melt a frying pan. So how can you fry food?

Answers: 1 The milk contains fat globules that form a layer on the top of the liquid as it heats. At about 212°F the milk under the fat layer is a frenzy of boiling bubbles. Suddenly the fat layer splits allowing the milk to whoosh! **2** The food contains water that boils at its usual temperature. This boiling water cooks the food and the oil doesn't boil at all.

Foul fertilizers

Even your vegetables are not free from the mysterious activities of the chemical industry. There's a whole array of herbicides, insecticides, fungicides and pesticides sprayed on the growing plants to deter ugly bugs and weeds. Then there are *fertilizers* to make crops grow.

Phosphorous may be poisonous for humans but it's good for making fertilizer chemicals called phosphates. One traditional type of naturally phosphate-rich fertilizer is guano. It's found several feet deep on islands off the coast of Peru. And the origin of this special substance ... do you really want to know? Old seabird droppings full of digested fish bones. Oh yes – bones are rich in phosphates and ground-up bones are ideal for growing plants.

Nowadays fertilizers are made by mixing sulphuric acid with phosphates found in rocks. But the chemists have not just stuck to fertilizers. Some *foods* were practically invented in a test-tube.

A slippery story – margarine

French Emperor Napoleon III organized a competition to invent a cheap butter-substitute for poor people.

Scientist Hippolyte Mége-Mouriez reckoned that anything a cow could do HE could do better.

In 1869 he came up with his magic marg ingredients:

Method

1 Simply heat the beef fat to the body temperature of a cow.
2 Gradually pour in pigs' stomach juices.
3 Stir in the water and milk.
4 Now churn the ingredients together in a handy barrel.
5 Add ice to cool the mixture.
6 Squelch it all together.

Mouriez hoped to get rich and he opened a factory to make margarine. Unfortunately, war broke out between France and Prussia and his factory had to close down.

Two years later the idea was bought by a couple of Dutch merchants. Soon they were churning out margarine and profits.

In 1910 a shortage of animal fat led to the use of vegetable oils or smelly fish oil.

Looking at the ingredients

Most foods you can buy in a supermarket have the ingredients on the side. Some sound a bit weird. Margarine, for example usually contains...

- hydrogenated oils
- emulsifier
- anti-oxidants
- vitamins
- water

Emulsifiers are chemicals with two ends. One likes oils and one likes water. So this marvellous molecule cleverly joins the water and the oil molecules together.

Anti-oxidants stop the margarine from going bad, or rancid. Sage and rosemary plants include natural anti-oxidants often used by food manufacturers.

Hydrogenation means adding a type of chemical called hydrogen to the margarine. This makes the marg harder and more like butter.

Vitamins are a group of different chemicals you can get from different foods. Vitamins keep your body healthy. Margarine doesn't contain some vitamins so they are added to make it healthier to eat.

Bet you never knew!
The advertisements are true! A large percentage of people in independent tests can't tell the difference between butter and margarine.

Chaotic chemical cooking

Besides margarine, lots of chemists have made food from chemicals you definitely wouldn't want to eat.

1 Alexander Butlerov (1828-1886) found that formaldehyde (for-mal-de-hide) can be treated to make a type of sugar called glucose. Formaldehyde is a horrible smelly chemical used to preserve bits of dead body.

2 During the Second World War German chemists discovered how to make fat from oil – not cooking oils but the sort of oil you put in a car! Mmm, tasty!

Dare you discover ... some chemical cooking?

Try creating a little bit of chemical chaos in your kitchen with these experimental recipes.

1 ***Yucky yeast***

Yeast is no mere chemical. It's ALIVE! Yes – yeast is a tiny fungus like the mold that grows on stale bread. Ugh! Yeast is harmless but its horrible relatives can cause skin infections and some diseases of the lungs and guts.

You will need:

some dried yeast (you can get packets from supermarkets)
2 teaspoons and a tablespoon
a small bowl or mug
sugar
warm water

View Page 00

All you do is:

1 Mix 2 teaspoons of yeast with 2 tablespoons of warm water in the bowl.

2 Stir in a tablespoon of sugar until it dissolves.

3 Stir in a teaspoon of dried yeast.

4 Leave the bowl in a warm place for an hour and check what's happened.

a) The mixture has turned bright red.

b) The liquid froths up and has a funny smell.

c) Small crystals have formed in the mixture and it stinks.

Answer: b) The yeast eats up the sugar and produces alcohol and carbon dioxide – that's the froth. This is also what happens when people make wine from grape juice.

2 ***Terrific toffee***

Sugar is a complicated compound (mixture) of chemicals including carbon, hydrogen and oxygen atoms. Many sweets are simply sugar that's been heated to a particular temperature. For example, fudge is made at 241°F, caramel at 248°F, and the hottest of all ... toffee. Here's how to make it.

You will need:
an adult to help you
1 ounce butter
4 ounces granulated sugar
0.23 ounces water
a sugar thermometer
a tablespoon and saucepan
a bowl of ice-cold water
some chopped apple with skin attached
enough cocktail sticks for every bit of apple

All you do is:

1 Stick a cocktail stick in each of the chopped apple pieces.

2 Mix the sugar, water and butter in the saucepan.

3 Heat the mixture to 320°F. Stir it gently. Notice how the sugar turns into a brown, melted, messy mass on the way.

4 Dip some apple in the mixture. Be careful – it's very hot! Then dip the apple into the cold water for about 20 seconds to cool it down.

5 Eat it!

And after that there's nothing else for it – you've got to wash up. It's a mystery where half the washing-up comes from. Never mind, even the really great scientists had to do this. And luckily, there's lots of chemical cleaners to help you!

Squeaky cleaners

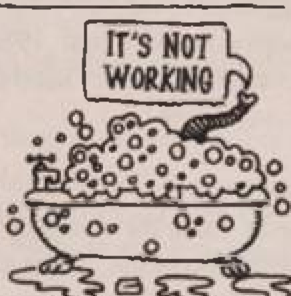
There's bound to be a few squeaks of protest when it comes to washing greasy dishes or getting soggy in a boring old bath. But it's got to be done, so where would we be without cleaning chemicals? Somewhere disgustingly dirty – that's where!

Soapy secrets fact file

Name: Soap

The basic facts: Soap is a salt made from acids and alkalis taken from fats. Soap is the layer you skim off the top of the mixture.

Horrible details: The Romans washed in soap to treat elephantiasis, a truly disgusting disease in which tiny worms get under the skin. The soap was useless as a cure.



A soap opera

1 The first soap was mixed-up fat and wood ash. It was probably invented when someone's cooking went chaotically wrong.

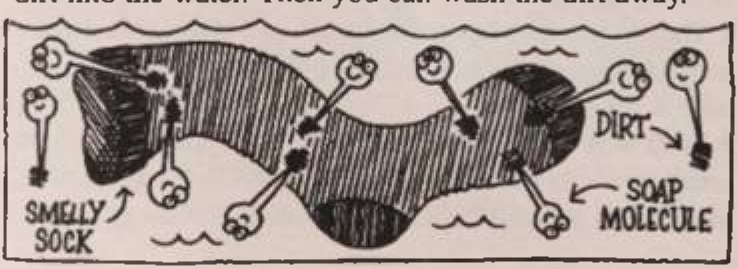
2 Soap was used in France about 2,000 years ago by an ancient people called the Gauls. They claimed that soap made from goat fat kept their hair nice and shiny.

3 Eighteenth-century soap was made by mixing boiling fat and soda. The alkaline soda makes the fat turn into soap. But too much of the alkali dissolves the skin! Nasty.
4 Luckily, before 1853 soap was so heavily taxed that many people couldn't afford to use it.

5 In 1900 people washed clothes using soap. (Washing powder hadn't been invented then.) The soap turned clothes yellow, so clothes were then dyed blue. This had the effect of making them appear white again.
6 Between 1911 and 1980 British people doubled the amount of soap they used each year. Did that mean twice as many baths?

Super soap

Soap is great for washing things because of the shape of the soap molecule. It has a long tail that sticks to dirt and a head end that's attracted to water molecules by an electrical force. The result? The soap molecule yanks the dirt into the water. Then you can wash the dirt away.



Dare you discover ... a slippery soap experiment?

You will need:

two mirrors

a bathroom

soap

All you have to do is:

1 Rub one mirror with a thin layer of soap.

2 Run the hot water. Only one of the mirrors steams up. Which one is it ... and why?

a) The soapy mirror steams up because soap attracts the water in the steam.

b) The soapy mirror doesn't steam up or get wet because the soap stops the water getting to the glass.

c) The soapy mirror gets wet but doesn't steam up. The soap stops the water in the steam forming droplets on the glass.

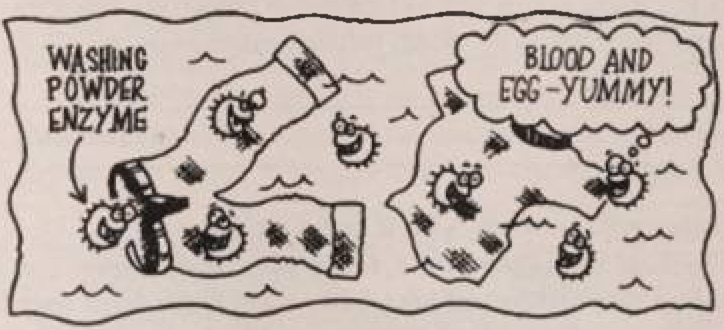
Answer: c)

Detergent – what's in it for you?

The first detergents were developed by the Germans during the First World War. They were made from soap powders and salt. During that war the Germans had a smelly problem owing to a shortage of soap, so they used detergents instead. But these were useless – you had to rub really hard before you got any froth. But as luck would have it – the new detergent worked wonders on their clothes!

Eating up the dirt

It's amazing what they fit in a box of washing powder. For example, "biological" washing powders include enzymes. These are chemicals often found in living creatures that cause reactions between other chemicals. Washing powder enzymes help to gobble up nasty stains such as blood and egg and disgusting little bits of food. The enzyme molecules stay the same.



Action-packed powders

Here are some other things you'll find in a packet of washing powder.

Builders – these are nothing to do with construction workers! These are chemicals that remove dirt and stop it sticking to anything else in the wash.

Anti-rusting chemicals stop rust from eating away your washing machine's vital insides.

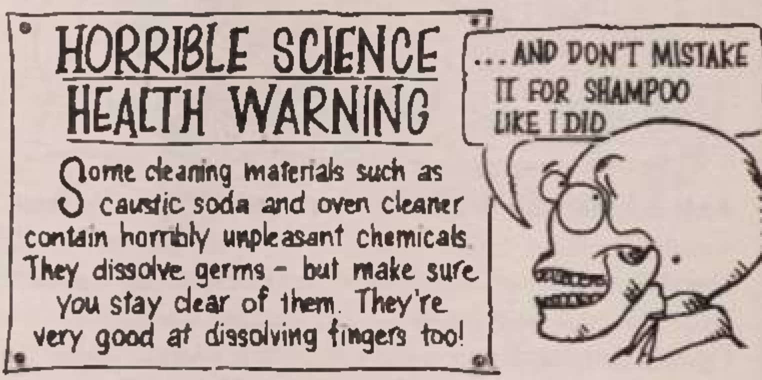
Conditioners stop the grains of powder sticking together and help them to dissolve in the washing water.

Optical brighteners are chemicals that soak up ordinary light and reflect back bluish light. This makes your underwear appear whiter than white. Just a clever chemical trick, really.

Dirt-bouncers are other chemicals that give dirt a tiny electrical force, making it bounce off your laundry.

Bet you never knew!

Before detergents, people used washing soda to clean clothes. This is more or less the same as natron – the stuff that ancient Egyptians used for preserving dead bodies. They used the natron to dry out bodies before wrapping them in bandages. The Egyptians could have used natron to wash the bandages!



Chemical chaos in the bathroom

Your bathroom is filled with amazing chemicals.

1 The water in your faucets contains salt. It also contains calcium and magnesium salts dissolved from rocks in the ground.

2 If there is a lot of calcium and magnesium in the water it is called "hard water" and forms a revolting scum when you try to lather soap.

3 Boiling hard water changes the dissolved chemicals into chemicals that *won't* dissolve. That's how you get a disgusting deposit of limescale. Limescale is actually calcium carbonate – the same chemical found in chalk. You may find it lurking inside electric kettles too.

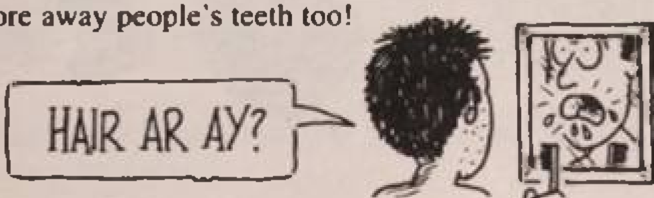
4 The first toilet cleaners were made from explosives! They were invented in 1919 when heating engineer

Harry Pickup was removing explosive waste from an ammunition factory. He dropped some in a toilet and found that the substance – nitrecake – is great for cleaning. Flushed with his success, Harry opened a factory and soon became rich.

5 Talcum powder comes from volcanoes. Yes – it's true. Talc is a chemical called magnesium silicate. It's found in rocks that have been chemically changed by underground heat.

6 Toothpastes sometimes contain pumice which is another rock produced by volcanoes. (You may find pumice lurking in your bathroom anyway. It's used for scrubbing away at hard skin.)

7 Toothpaste is designed to brush away germs and stray bits of food. The first toothpastes were made from gritty substances such as chalk and jeweller's polish. They certainly wore away those nasty little stains – but they wore away people's teeth too!



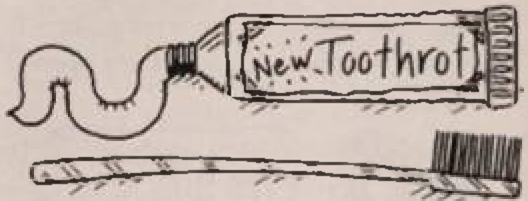
Dare you discover ... how to make your own toothpaste?

You will need:

salt

sugar

a bowl and spoon



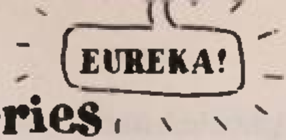
All you do is:

1 Mix the salt and sugar with a little water to make a paste.

2 Try it on your teeth.

Note: These ingredients really were used in the nineteenth century to make toothpaste. But don't *you* try them more than once. The sugar's not good for your teeth. In fact, you'd better use some proper toothpaste to remove your home-made version! Some experiments should never be repeated.

Toothpaste is just one of a huge array of strange but useful substances dreamed up by chemists. Funnily enough, chemical chaos often led to some amazing accidental discoveries.



Dubious discoveries

A chaotic combination of muddles, mishaps and mix-ups – that's how many a vital substance has been discovered. Scientists have to keep their minds open to anything that might happen during an experiment, but sometimes they might set out to answer one question, and end up solving another.

Chaotic chemists' comments...

Here's how some chaotic chemists describe their discoveries. Test them out on your science teacher.

"No great discovery is ever made without a bold guess."

Sir Isaac Newton (1642-1727)
discoverer of gravity and big fan of alchemy.

"Failure is the mother of success."

Hideki Yukawa (1907-1981)
who discovered what some of the tiny bits of atoms are made of.

"The most important of my discoveries have been suggested by my failures."

Sir Humphrey Davy (1778-1829)
discoverer of many new chemicals.

Many surprising substances all owe their discovery to happy accidents.

Eight dubious discoveries

1 *Teflon,* the stuff used to coat non-stick pans was only used for this purpose after 1955 because the inventor's wife was a bad cook. She kept getting her food stuck to the bottom of the saucepan.

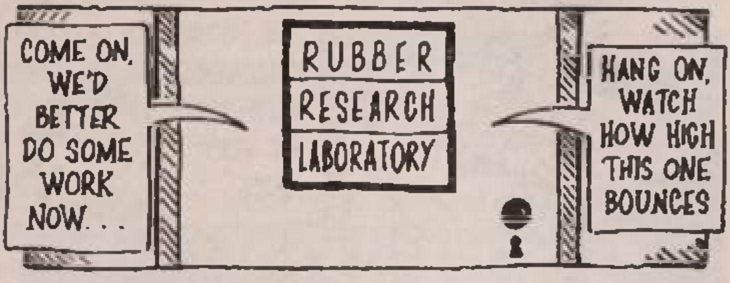
2 *Tracing paper* was invented by mistake in the 1930s because a worker at a paper factory put too much starch in a vat of wood pulp. The result was strong but see-though paper.

3 *Paper tissues* were designed as a new kind of make-up remover. In 1924, they were sold as disposable handkerchiefs after people wrote in saying the pads were ideal for blowing their noses.

4 *Vulcanized rubber* Early rubber boots melted in hot weather. But in 1844 Charles Goodyear spilt some boiling rubber and sulphur. He found that the resulting sticky mess didn't melt so easily.

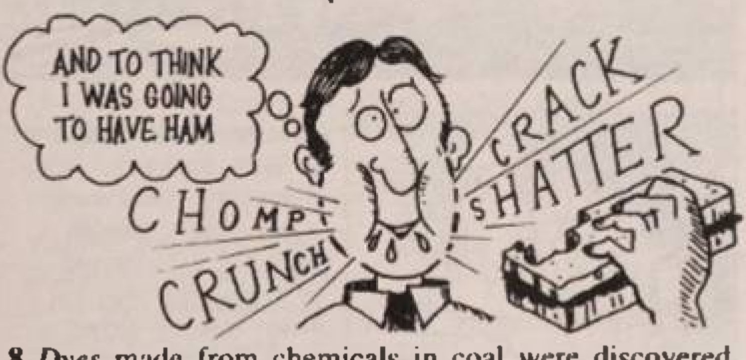
5 *Silly Putty* the bouncy modelling clay, was discovered in 1943 when scientists attempted to make artificial rubber from silicon. The substance was no good for tires

but the chemists had a lot of fun playing with it. A sharp-eyed salesman spotted the opportunity to develop a new toy and sold 750,000 Silly Putty balls in three days.



6 *Lubricating oil* was first sold in 1690 as a cure for the painful joint disease, rheumatism. The chaotic idea was that if it makes hinges move easily then it could do the same for the joints!

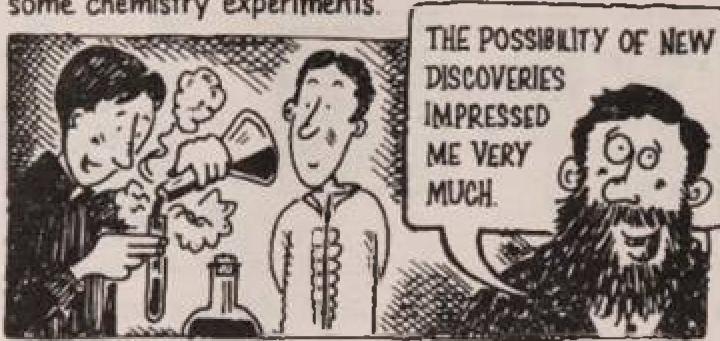
7 *Bakelite*, a type of plastic, was invented in 1907 by Leo Baekeland (1863-1944) by accident. The American chemist was experimenting with formaldehyde. On the lab bench was a cheese sandwich intended for his lunch. Unfortunately Leo spilt the chemical over the sandwich and the cheese turned to plastic!



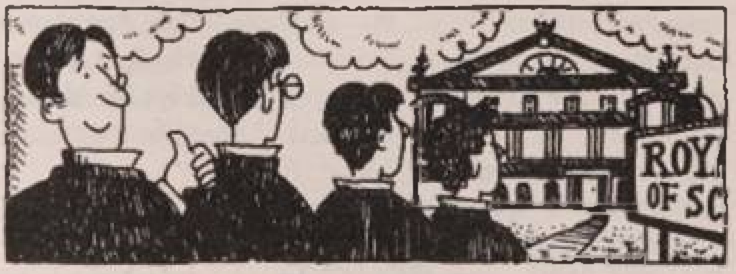
8 *Dyes* made from chemicals in coal were discovered accidentally in 1856 by a young whiz-kid – William Perkin (1837-1907).

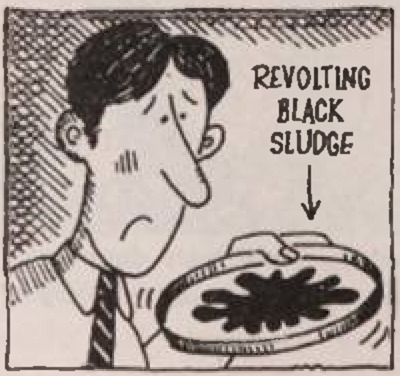
A colorful character

1. When Perkin was twelve a friend showed him some chemistry experiments.



2. Young William decided to try a few chemistry experiments and a few years later enrolled in the Royal College of Science.



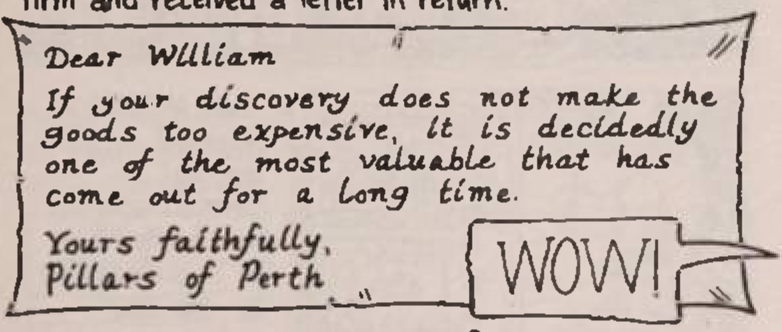


3. One Easter vacation he was doing chemistry homework in his dad's garden shed. He was trying to make the medical drug, quinine, using a coal tar chemical as raw material. The result was a revolting black sludge.

4. Many scientists would have given up at this point but Perkin was intrigued. So he added alcohol, and some lovely purple crystals appeared.

5. This type of purple was a brand new color. Nothing like it had ever been seen before. So Perkin tried making the crystals into a dye. They turned out to be ideal for dying silk.

6. Perkin sent a sample of dyed silk to a Scottish firm and received a letter in return.


Dear William

If your discovery does not make the goods too expensive, it is decidedly one of the most valuable that has come out for a long time.

Yours faithfully,
Pillars of Perth

What could be more encouraging?

7. Young William talked his dad into putting up the money for a factory to make the purple dye he called "mauvine".

8. Mauve turned out to be popular and fashionable. Soon everyone wanted to wear it. It was even used for stamps.

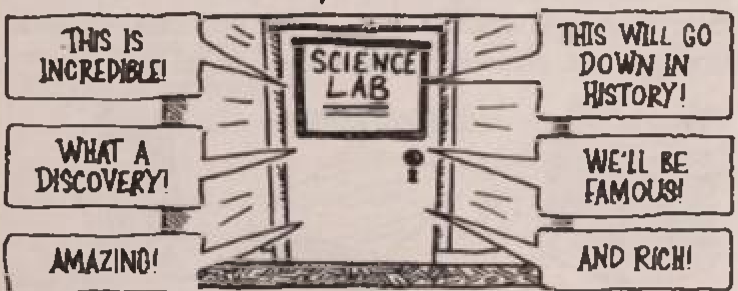
9. William became so rich that he was able to retire at the ripe old age of 35. He built a new house complete with private lab.

10. In 1869 he invented a red dye but a German scientist had beaten him to this discovery by one day!

11. In 1906 a celebration was held to commemorate the discovery of mauve. It was attended by the world's most distinguished scientists and business tycoons. And the guest of honor was 68-year-old William Perkin.

12. Sadly Perkin died soon afterwards. The excitement had been too much for him!

Meanwhile scientists were experimenting with plastics to find more man-made substances. And making more discoveries . . . by accident.

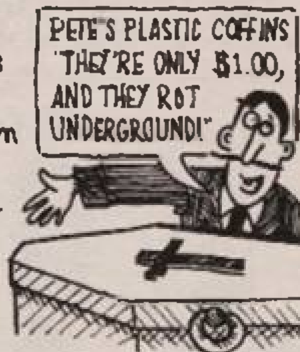


Plastic fact file

Name: Plastic

The basic facts: Plastics are long chains of molecules based on carbon atoms. They're often made from chemicals found in petrol, but some come from coal, natural gas, cotton or even wood. Plastics are strong but bendy because the molecules are tangled up.

Horrible details: Nowadays some plastics are designed to rot in soil. They are made from carbon-dioxide and water inside microscopic germs. The plastic is removed and the germs are boiled away!



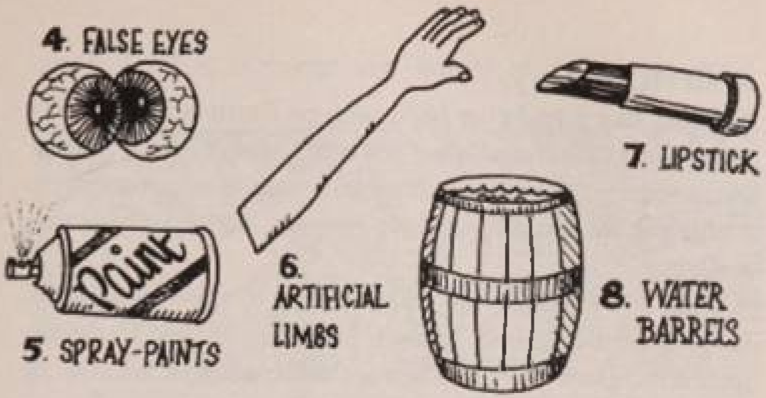
Fantastic plastics quiz

It's amazing the sheer variety of things that can be made from plastics. Which of these items do you think are made from plastics, and which sound too comical to be true?

1. DRUMS

2. BOOK COVERS

3. DRINK CARTONS



Answers: 1 TRUE – polyethylene. **2** FALSE – a resin-based lacquer stops the cover from getting soggy if you spill a drink on it. Don't try this! Not on your Horrible Science book, anyway. **3** TRUE **4** TRUE – they contain acrylic so they don't break if they fall out of the eye socket! **5** TRUE – they contain acrylics. **6** TRUE **7** FALSE **8** TRUE

Chaotic chemical expressions

A chemist tells his best friend: My underwear is made from polyhexamethyleneadipamide (polly-hexa-meeth-ile-ne-adi-pam-ide).

Is this dangerous?

Answer: No – he has nylon underpants.

Bet you never knew!

You're probably wearing plastic clothes! Many materials used in clothes such as polyester, acrylic, viscose and nylon are made from plastics. But nylon was discovered by accident, too. Here's what happened.

A stretchy story

Nothing like it had ever been seen on Earth before. It was as strong as steel and ideal for bullet-proof vests. Yet its fibers were no thicker than a spider's web. It was made from nothing more sensational than gasoline, natural gas, water, and air.

The story began in 1928 when a mild mannered, bespectacled chemist named Wallace Hume Carothers joined the giant DuPont Chemicals company in the state of Delaware.

"Young man," said Company Vice-President Charles Stine. "I've got a special job for you. We're looking at ways to make silk from minerals."

Most of us would say, "Yikes, that's a tall order!" But Corothers looked thoughtful. "I'll need to look at polymers. I mean those stringy molecules that make silk so strong and flexible. I wonder if it's possible?"

"I guess the best way," said Carothers, "is to invent some new molecules."

"Well – that's your job, son. Just give it whatever it takes."

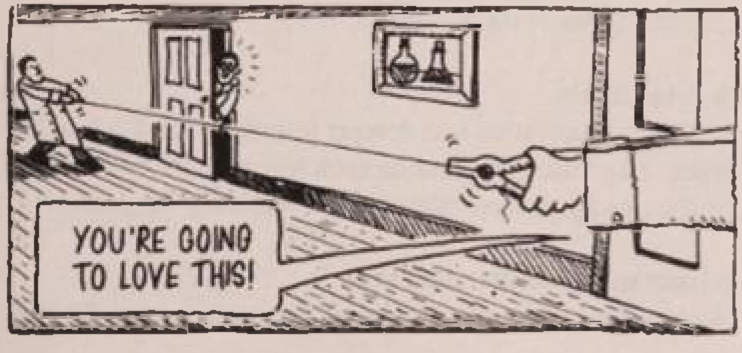
Carothers' lab was a chaotic maze of oddly-shaped flasks. There were tripods, jars filled with strange fluids and glass bottles with unreadable labels. But this is where he felt at home and where he made his great discovery.

After five years of research Carothers came up with his own substance – nylon. It was useless! Nylon was a clear plastic blob at the bottom of a test-tube. But it wouldn't melt unless you heated to a high temperature. So how could it be made into fibers suitable for a fabric?

Carothers turned his attention to polyamide. One day Julian Hill, one of Carothers' assistants, was playing around with some polyamide in a test tube. He was amazed to find that he could pull strands of it out on a rod – like gooey mozzarella cheese on a cooked pizza.

"Let's wait till the boss goes out," he told the others. "I wanna try a little test."

They pulled the stringy polyamide as far as they could. It must have been a strange sight as they managed to stretch it several feet down a corridor.



But this process locked the polyamide molecules into place to form strong fibers. Maybe they could do the same for nylon? Yes, they certainly could.

This dramatic breakthrough made it possible to create amazing new fabrics. Carothers' reaction when he got back wasn't recorded but he might well have said, "It's good to see you're working at full stretch. Ha ha!"

Nylon stockings were launched at the World Trade Fair in 1938. A female audience heard Charles Stine declare, "It's the first man-made organic textile fiber ... yet it's more elastic than any common natural fibers."

And the best news of all: nylon was going to be a lot cheaper than silk so more people could afford it. The audience was delighted and erupted into wild applause. They shouted and cheered until the ceiling shook. But Carothers wasn't there to see it...

A fatal finale

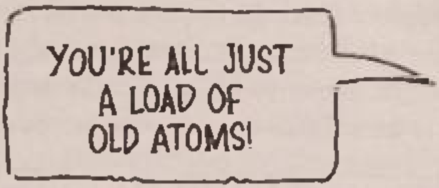
In 1936 he had fallen into despair following the death of his sister. The following year he took his own life with a dose of the deadly poison cyanide. He was only 41 years old.

More man-made marvels

Within a few years the world would be at war and nylon was to prove itself a vital war-winning material. It was used to make countless parachutes and the used parachutes were then recycled to make stockings.

Nowadays, nylon is used to make not only stockings but everything from ropes and carpets to toothbrush bristles. Yet nylon is just one of hundreds of man-made substances. From A-Z they range from acrylic paints and zinc oxide (particularly useful for treating diaper rash).

Funnily enough – all these chemicals have something in common. They're made from atoms – those pesky little things that make chemists curious. Yep – it's time to get down to basics.



Awesome atoms

Atoms are awesome. Awesomely small that is. And awesomely important. After all, everything in the universe is made of them ... including you.

The incredible shrinking teacher

The machine stands ready. It's an awesome jumble of tubes and lasers all polished and ready for use. All that's required is a brave and perhaps foolhardy volunteer to venture into the unknown. This person will experience the awesome power of the incredible shrinking ray – and hopefully live to tell the tale.

The volunteer is ready. A person with nerves of steel. In the cause of Horrible Science she is about to embark on what might prove to be a one way trip. This heroic volunteer is none other than ... your science teacher.

She stands under the ray and seems to be disappearing. Soon she is no larger than a doll and she's still shrinking. In the blink of an eye she's become FIFTY times smaller. Now she's small enough to fit in your pocket! Then ... is it an ant or a gnat? No, it's your teacher – and she's smaller than ever. Now she's FIVE HUNDRED times smaller. Hey – where's she gone now?

The smallest object you can see is about four thousandths of an inch long. Your teacher is now tinier than this. If you had a microscope you might still see your teacher if she was 400 times smaller. But already she's too small for this. Now she's smaller even than the tiniest droplet sprayed from an aerosol can – 1/50,000 of a millimeter! And that's pretty small!

Your incredible shrinking teacher is falling, plunging headlong towards a mass of balls churning like a stormy sea. Every ball looks like a tiny planet surrounded by clouds of chaos. She's arrived in the weird world of atoms.

It's a small world

• You can stretch one million atoms in a line and they'd just about cover the period at the end of this sentence.

• If you squeezed them a bit you'd fit one billion billion – that's 1,000,000,000,000,000,000 atoms – onto a pin-head.

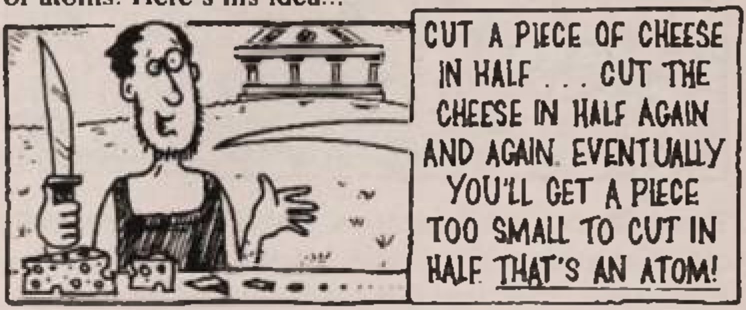
• You can fit 600,000,000,000,000,000,000,000 (that's six hundred billion trillion) atoms into a thimble.

But if atoms are so small, how do we know they exist?

Chaotic chemists' hall of fame

Democritus (c. 460-370 BC) Nationality: Greek

This ancient Greek was known as "the laughing philosopher" – no one knows why. He was certainly laughed at by some people for suggesting the existence of atoms. Here's his idea...



In those days, few people imagined that atoms really existed so people made fun of Democritus. But hundreds of years later he was proved right – so maybe he got the last laugh.

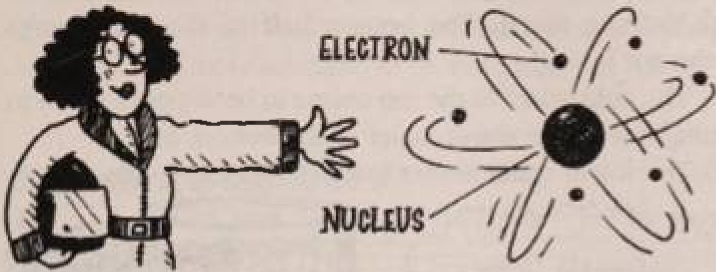
Bet you never knew!

Nowadays scientists can see atoms and even photograph them using a scanning tunnelling microscope. This brilliant bit of gizmo measures the electrical force between atoms at a single point. It produces amazing images that look strangely like table tennis balls!

Inside an awesome atom

Here's an interesting thought: imagine your incredible shrinking teacher ventures inside an atom. Here's what she sees.

1 An atom is a blob of matter called a nucleus surrounded by electrons. The electrons are tiny bits of electrical energy.



2 Electrons zoom chaotically so that by the time you've spotted where they are they've moved somewhere else.

3 Mind you, the electrons can't go just anywhere. They're found in layers known as orbits.

Dare you discover .... how to watch atoms in action?

You will need:

some water cooled in the fridge for two hours

food coloring

a large glass

All you do is:

1 Fill the glass half full with hot water.

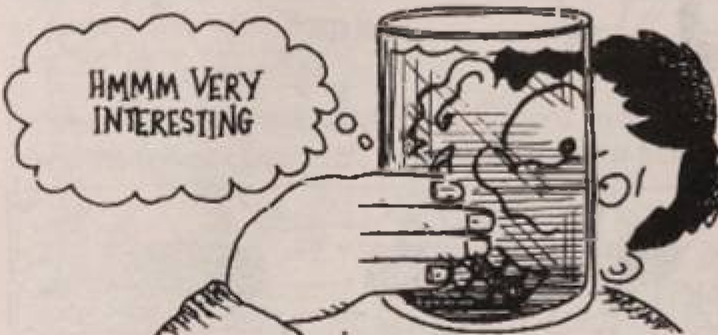
2 Add a few drops of food coloring and mix it up.

3 Fill the rest of the glass with the cold water. What happens?

a) Nothing at all. The bottom half of the water stays where it is.

b) The cold water at the top seems to be slipping down to mingle with the warm water in the bottom half.

c) The warm water seems to be moving upwards.



Answer: c) The warm water molecules are moving faster than the colder molecules. As they move apart they rise upwards. So you're seeing billions of atoms on the move.

The first problem for a chemist studying atoms is to work out how the atoms in a substance fit together. Now, the usual answer to this is to do lots of careful scientific experiments and then repeat them just to make sure they got it right. But one man had a different approach...

Choatic Chemists' Hall of Fame:

Friedrich Kekulé (1829-1896) Nationality: German

At school Kekulé was good at drawing and he studied to be an architect. One day he happened to attend a murder trial. Young Kekulé was enthralled by the gruesome scientific evidence and surprised to find it wasn't laughed out of court. So Kekulé decided to train as a scientist so he could find out more about this scintillating subject. That's how he came to be in London in 1854.

A Dream Discovery

1. 1854. Kekulé was sleeping on a double-decker bus.

2. All of a sudden he saw atoms dancing about.

3. Then he woke up.

4. But the dream had given him a nifty idea.

5. He decided to make model atoms using little balls joined by sticks.

That's how he figured out how some atoms can join together more easily than others to make new chemicals. It opened up a whole new field of chemistry. And all because of a dream!

It took years of patient experiments before Kekulé was certain his dream was correct. Benzene was indeed a ring of atoms. This dream discovery made it possible to develop new chemical dyes and thousands of other useful substances.

Elementary chaos

Atoms come in over one hundred varieties. These different varieties are known as elements. For years chemical knowledge was in chaos as confused chemists tried to classify these chemicals. The idea of elements was invented by a boring British scientist – John Dalton.

Chaotic chemists' hall of fame

John Dalton (1766-1844) Nationality: British

John Dalton wasn't exactly a laugh-a-minute kind of guy. He would drone on nonstop for hours about science, science and more science. And if that reminds you of a science teacher you know, you won't be too amazed to learn that John was a science teacher, too. They really did start young in those days. John was only twelve when he started teaching.

Like most other scientists, John knew that water could be broken down into hydrogen and oxygen. But those chemicals couldn't be broken down further. So he called them "elements" and said that each was a type of atom. People made fun of John. But they weren't laughing for long. Scientists found that their experiments proved John right. He became famous and now there's even a statue of him.

Chaotic chemical elements

There are about 94 elements on Earth. Scientists have also created new elements out of tiny bits of matter. But these have the rather irritating habit of falling apart after a second. Here's your very own chaotic guide to elements that don't do this.

CHAOTIC ELEMENTS SPOTTER'S GUIDE

Name of chemical: ALUMINIUM

Where found: in soil and rocks

Crucial characteristics: a light and useful metal. It's used to make tank armor, saucepans, kitchen foil and folding chairs. You can even make clothes out of it!

Name of chemical: CARBON

Where found: in diamonds, benzene, coal and the "lead" in your pencil.

Crucial characteristics: the most common atom in the human body, which is a bit weird, because people don't look anything like lumps of coal.

Name of chemical:
LEAD

Where found: This isn't the lead in your pencil. Real lead is a grey metal often found on old church roofs.

Crucial characteristics: it's quite a nasty poison if you happened to eat it by mistake. It's also very heavy so don't go dropping it on your teacher's toe.

Name of chemical:
CALCIUM

Where found: milk, chalk and marble and also in bones and the plaster used to set broken bones

Crucial characteristics: if you burn calcium it gives off a lovely red flame. But that's no excuse for setting fire to your teacher's plastered toe!

Name of chemical:
CHLORINE

Where found: chlorine is the stuff they put in swimming pools

Crucial characteristics: it's very good for killing germs, but not very nice if it gets up your nose.

Name of chemical:
COPPER

Where found: in rocks under the ground.

Crucial characteristics: lots of uses including electrical wires and the rivets that hold your jeans together. Air pollution caused by cars and industry causes a chemical reaction that turns copper green. That's why the copper plated Statue of Liberty in New York looks a bit sea-sick.

Name of chemical:
GOLD

Where found: in rocks under the ground.

Crucial characteristics: gold is good to make into jewelry – that's why people drape it around their necks. It's also worth lots of money.

Name of chemical:
HELIUM

Where found: in the air

Crucial characteristics: used to fill balloons. It's lighter than air so the balloons float skywards. Breathing helium makes your voice sound like Mickey Mouse. This happens because your voice passes faster through helium than ordinary air. So it sounds higher and squeakier!

Name of chemical:
HYDROGEN

Where found: it's the most common element. Stars such as the sun are made of hydrogen. So is 97 per cent of the known universe.

Crucial characteristics: hydrogen is also the lightest element so it floats upward. This was why hydrogen gas was once used in balloons. It's also burned as a rocket fuel. Hydrogen sulphide is a gas that stinks of rotten eggs. But don't confuse it with a stink bomb - it's poisonous.

Name of chemical:
IRON

Where found: much of the earth is made of iron. You find it in rocks and the soil.

Crucial characteristics: you can use iron to make railings. It's also found in the chemical that gives blood its tasteful red color.

Name of chemical:
OXYGEN

Where found: it's the most common element on Planet Earth

Crucial characteristics: it's really lucky that over one fifth of the atoms in the air are oxygen. Without them we'd be more than a little bit dead. Some people think that if they breathe pure oxygen they'll live longer. They must be confused because scientists believe that breathing too much oxygen is bad for you. They say it increases the pressure of the blood to dangerous levels.

Name of chemical:
PLUTONIUM

Where found: it's found in nuclear reactors but nowhere else in nature.

Crucial characteristics: Plutonium is incredibly poisonous. It looks like metal but it turns green in the air. And damp air makes it catch fire! The man who discovered plutonium in 1940 kept a lump of it in a matchbox. Weird.

Name of chemical:
SILVER

Where found: in underground rocks

Crucial characteristics: a really useful shiny metal much prized for dangling around the neck, making the shiny backs of mirrors and really fancy cutlery. In the last 50 years people have lost 100,000 tons of silver coins. Where have they all gone to? That's what I'd like to know.

Name of chemical:
SULPHUR

Where found: sulphur is a smelly yellow chemical spat out of volcanoes in choking clouds.

Crucial characteristics: at one time it was known as brimstone and mixed with treacle. It was used as a medicine for children. The medicine tasted disgusting so it was probably spat out by the choking children too.

Odd elements quiz

Some of the more obscure elements are ever so odd. Which of these are too strange to be true?

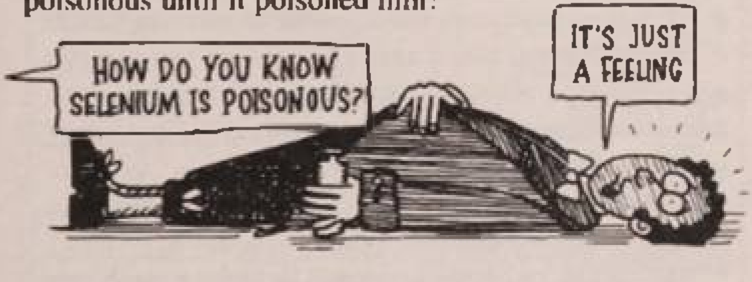
TRUE or FALSE

1 The element phosphorous was discovered by an alchemist while he was examining the contents of his own urine.

2 The elements yttrium, erbium, terbium and ytterbium are all named after a quarry in Sweden.

3 The element dysprosium was discovered in 1886. The Greek name means "really smelly."

4 The element selenium was discovered by the Swedish scientist Berzelius. Sadly, he didn't realize it was poisonous until it poisoned him!



5 The element cadmium was discovered when it accidentally got into a bottle of medicine.

6 The element krypton was named after the planet that Superman comes from.

7 The scientist who discovered beryllium named it after his wife – Beryl.

8 The element Astatine is so rare that if you searched the entire world you'd only find .006 ounces of it.
9 Technetium was first found in caterpillar droppings.
10 Lutetium is named after the ancient Roman name for Paris.

Answers: 1 Disgusting but TRUE. The alchemist was Hening Brand (1630?-1692?, but nobody's really sure) and he made his discovery in 1669. It must have given him quite a shock – phosphorous glows in the dark. **2** TRUE. The place is called Ytterby and several elements were discovered there. **3** FALSE. It actually means "hard to get at." **4** TRUE. And unfortunately Berzelius died. **5** TRUE. In 1817 German chemist Friedrich Strohmeyer was analysing the chemicals in a bottle of medicine. **6** FALSE. But Krypton has been found floating around in space! The name means "secret" in Greek. **7** FALSE. **8** TRUE. It's the rarest of all the elements. **9** FALSE. **10** TRUE.

Bet you never knew!

You can find all the different elements in the clever Periodic Table invented by Russian chemist Dmitri Mendeleyev (1834-1907). Here's how it works:

1 Elements are grouped according to the number of electrons in their outer orbits.

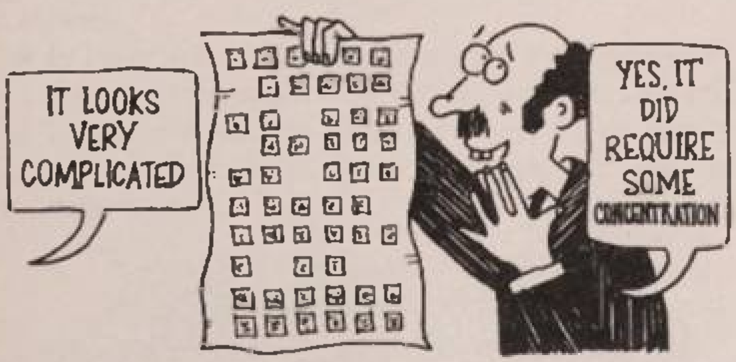
2 The elements in each group behave in similar ways when mixed with other chemicals.

Chaotic chemists' hall of fame:

Dmitri Mendeleyev (1834-1907) Nationality: Russian

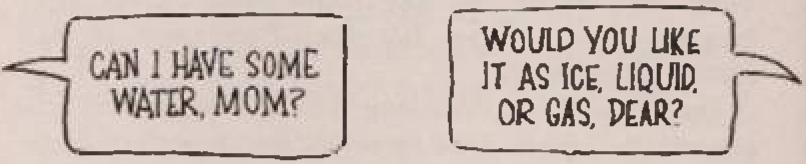
Other scientists had difficulties. But Mendeleyev lived a real-life soap opera. His father was a teacher who went blind. His mother ran the family glass factory and brought up 14 children. But when Dmitri was 14 the factory burned down.

Dmitri went to St. Petersburg to study chemistry. He discovered the Periodic Table by writing the elements on cards and arranging them as in his favorite card game – Concentration. In 1955 element 101 was named mendelevium in his honor. So Dmitri ended up in his own table!



The complicated bit

So that's it. All you need to know is the Periodic Table and which elements join together. Simple, really? Er – no. Just to add a little chaos – chemicals are always changing and getting mixed up. Confused? You soon will be. See you in the next chapter!



Chaotic chemical changes

Everything changes – this fact is so well known it's a cliché. But WHY exactly do things change? Well, with chemicals it's mainly due to the effects of heat or cold. This can result in a few chaotic chemical mix-ups.

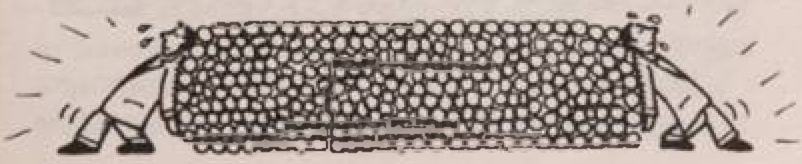
Bet you never knew!

You might think that water is runny, iron is solid, and oxygen is a gas. Wrong, wrong and WRONG again! In fact ANY chemical can be a solid, a liquid or a gas. It just depends on how hot the chemical is at the time. Below 32°F water is the solid object we call ice. Above that temperature water turns into ... well ... water, and above 212°F water boils and turns into a gas – you'd probably call it steam.

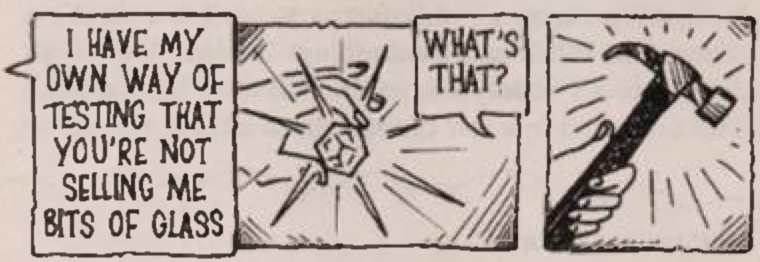
Solid secrets

Have you ever wondered why some solid objects are bendable and others are very tough? Well, have you ever wondered why your aunt's best china is always breaking and why her muffins are ... just like rocks? Here's the answer.

- In every solid object the atoms are bonded together. But what's important is the way the atoms are arranged.
- If they're in stretchy strings the object will be stretchy like an elastic band. You can squash them together quite easily.

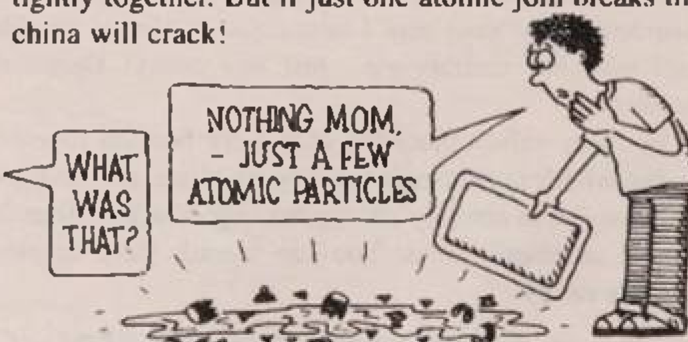


• In very hard materials such as diamonds the atoms are arranged in a very tight and very strong framework.

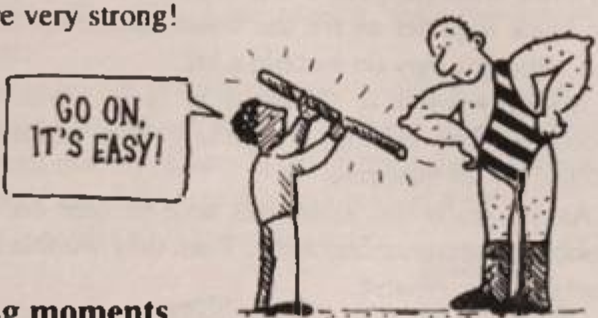


• In softer materials such as graphite – pencil lead – the atoms are arranged in loose layers that rub off easily when you write.

• In china the atoms are closely packed and joined tightly together. But if just one atomic join breaks the china will crack!



• In a metal the atoms are surrounded by a crowd of jostling electrons. (They're a bit like teachers in a playground at break-time.) The electrical force of the electrons keeps the atoms in place. But each atom can move a bit and that's why you can bend metal – if you're very strong!



Melting moments

Here are some impressive facts about melting and freezing water.

1 In Northern Canada some lakes freeze solid. The freezing starts with a single ice-crystal that grows and grows. So each frozen lake becomes a giant ice-crystal.

2 As water freezes it expands and crushes anything it traps with a force of 588 pounds per square inch. That's enough to sink a ship or crush a man to death!
to death!

3 You get snow and hail when water molecules join and freeze in the sky. Hailstones occur when lumps of ice swirl around in a cold cloud getting larger and larger. The largest hailstone ever was 7½ inches across and fell on Kansas in 1970.

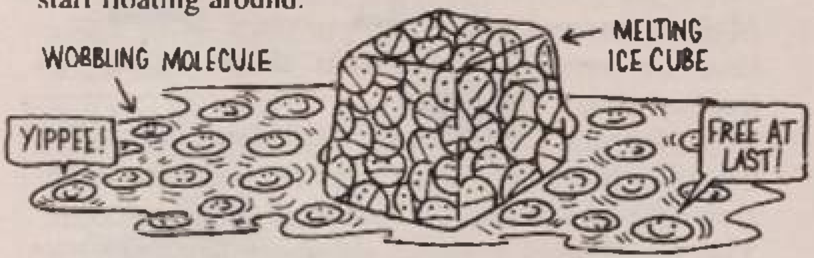
4 You can make snowballs because snow is partly melted ice and slushy so you can squash the snow together. If it's really cold as in the Antarctic, the snow is hard and powdery.

So you can't have a snowball fight at the South Pole.

5 Here's what happens when you melt ice... When they are stuck together as ice the water molecules are fairly still although they do wobble a bit.

6 It's only when a chemical is really cold that the molecules stop moving completely. This temperature is -459.67°F, absolute zero.

7 As ice melts the molecules take in heat energy and wobble about more and more. Then they wobble free and start floating around.



8 As they heat up even more, they move faster and faster until they take a flying leap into the air and become a gas.

Bet you never knew!

1 Different chemicals melt and turn into gases at different temperatures. It's all to do with the bonds between atoms in the chemical. If these bonds are strong you need loads of heat energy to break them apart. So their melting point is higher.

2 All gases need to be very cold before they become liquids. To make liquid oxygen you need to cool it to -306.74°F. And to make solid oxygen it needs to be a very chilly -361.83°F! Luckily, our weather isn't that cold or we'd have nothing to breathe. And that would cause chaos!

Test your teacher

Of course, anything can be a liquid – if it's the right temperature. Terrorize your teacher with this terribly tricky test.

1 Over hundreds of years glass sinks slowly to the bottom of a window frame. Does that make glass a liquid or solid?

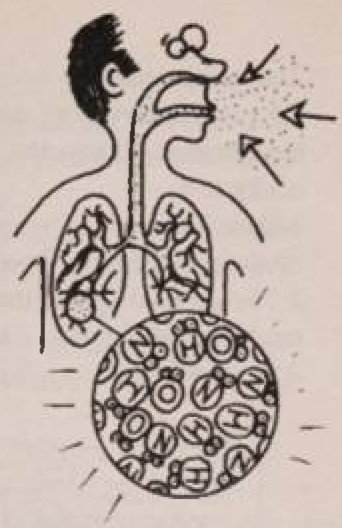
2 The green displays that you get in some calculators are made out of crystals – are they a liquid or solid?

3 Is school pudding a liquid or a solid?

4 If you cool helium gas to -455°F it can be poured and it even climbs up the sides of a beaker. Is it liquid or solid?

Answers: 1 It's a liquid! **2** Trick question. They're somewhere in-between. These are special crystals that don't melt when heated so they're solid even when they should be a liquid! **3** It's a liquid called a colloid – that's a liquid with lots of little oily drops in it. Yuck! One mark for colloid, half a mark for liquid and an upset tummy if it's solid. **4** Another trick question. It's a supercool liquid, which explains why it acts rather oddly.

Mixed-up mixtures



Much of our planet is made up of mixed-up chemicals. Take a breath of air. In one gulp you'll get a chaotic combination of oxygen, nitrogen and hydrogen and a few other gases thrown in for good measure. All these atoms are completely mixed up, but guess what? The funny thing is that nothing happens, there's no reaction between them, so you don't notice them all.

When you mix two gases or two liquids, the atoms of each chemical often spread out until they are thoroughly mixed. But some mixtures don't mix properly.

If a liquid is heavier than water it may sink to the bottom of a glass of water and not mix with it at all. Try out this chaotic chemical cocktail...

You will need:

a tall glass
water (adding a few drops of food coloring might make it more interesting)
oil
syrup (in roughly equal amounts)
umbrella (optional)
straw (optional)

All you do is:

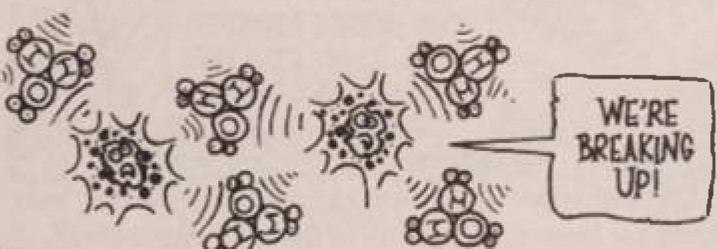
1 Pour a similar amount of each of the three liquids into the glass.
2 Sit around and wait for something to happen.
3 Check your answer against these three possibles...

a) the liquids all mix together.
b) the water stays at the top, the oil sinks to the middle and the syrup to the bottom.
c) the oil rises to the top, the water stays in the middle and the syrup sinks to the bottom.

Answer: c) Unless you've gone chaotically wrong somewhere.

Bet you never knew!

If you mix up a solid substance with lots of water, the solid sometimes dissolves. But why does this happen? A water molecule is two hydrogen atoms joined to an oxygen atom. Funnily enough, the electrons of the hydrogen atoms have been stolen by the oxygen atom. This gives the hydrogen atoms a positive electrical force and the oxygen atom a negative force. Molecules innocently floating about in the water are caught between the forces and RIPPED APART! Sounds painful.



Un-mixing mixtures

Not only can you mix up chemicals, much of the time you can un-mix them too. For example, if a substance is mixed with water you can boil off the water and you're left with the original chemical. Talking about un-mixing things from water – one scientist had a very funny idea about this. He was Germany's Fritz Haber and here's his story...

Chaotic chemists' hall of fame:

Fritz Haber (1868-1934) Nationality: German

Fritz Haber was a short and sharp-looking man with a short, sharp beard to match. In photographs he is always immaculately dressed. Born a merchant's son he dedicated his life to chemistry and the service of his country. Yes – Fritz was Germany's secret weapon.

Before the First World War (1914-1918) Fritz invented a new way to make a chemical called ammonia. This had good and bad results.

• The good news: the ammonia was used to make cheap fertilizers. Very handy for helping plants to grow.

• The bad news: it was used to make explosives. Very handy for blowing people up in the First World War.

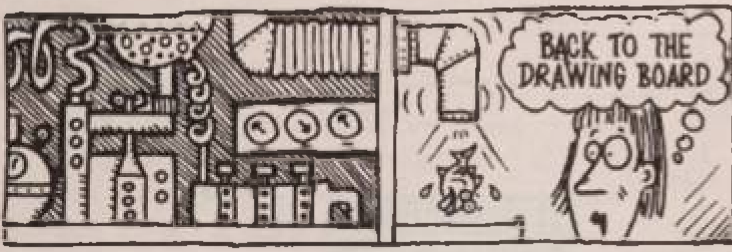
Eventually the Germans lost the war. The country was in a mess and nearly penniless. And that's when Fritz had his funny idea.

Fritz goes gold hunting

If you really want to raise a few billion dollars don't wash your dad's car on a Sunday afternoon. Go prospecting for gold instead! There's gold in that there sea – millions of tons of clinky-clanky yellow stuff! Think about it ... 71 percent of the Earth is covered by oceans with 97 percent of all the world's water. Imagine millions of streams scouring gold from rocks and crevices and rivers washing it down to the sea!

But there's one teeny little problem. The gold is in tiny little atoms and grains. They're mixed up with trillions of tonnes of water, salts and all the seventy or so other chemicals you get dissolved in the sea.

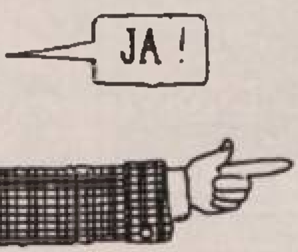
In the previous fifty years no fewer than fifty scientists had come up with inventions for removing the gold. And they ALL failed!



But Fritz and his fellow scientists were all keen to have a go. So they chartered a luxury ocean liner called the *Hansa* and set sail in search of gold-rich seawater. The plan was to boil off the water and use other chemicals to separate the gold from the solid dregs.

But after three voyages and eight years they gave up. Here's the cause of their chaos. If you searched a billion buckets of seawater you'd find traces of gold in only 40 – if you were LUCKY! There's loads of gold in the sea but there's even more seawater. And getting the gold ain't worth the effort.

But that's not the last we'll hear of Fritz. He pops up rather nastily in the next chapter.



It's a gas!

Without gases there'd be chaos. We'd have nothing to breathe and balloons would fall out of the sky. Gases can be chaotic – especially when they poison people or explode! But they're interesting, too. Sometimes they're even funny – take nitrous oxide, for example, better known to you as laughing gas.

Gases fact file

Name: Gases

The basic facts: Gases are atoms or clumps of atoms that whiz about like tiny balls. You can feel the gas atoms in the air every time you go out in the wind.

Horrible details: Some gases are poisonous (See next few pages for details)

Bet you never knew!

A very hot gas turns into a plasma. This is a burning cloud hot enough to rip electrons away from atoms. Phew! Our sun is a plasma of hydrogen and helium gases 27,000,032°F in its center. You can also find plasma inside the fluorescent lights in your school. But luckily they're not so hot!

Stink bombs

Some chemists don't smell too good. This must be true otherwise they wouldn't produce such stinky substances. Any smell is caused by gas molecules which we sniff in the air. Now *you* can kick up a bit of a stink using...

There are 17,000 smells known to science but the worst are ethyl-mercaptan (e-thile-mare-cap-tan) and butyl seleno-mercaptan (bu-tile see-le-no-mare-cap-tan). Both gases smell like rotten cabbage, garlic, onions, burned toast and sewer gas. ALL MIXED TOGETHER! Phew!

But if you really want more whiff for your money there's always vanillaldehyde (van-nill-aldy-hyde). This chemical is made in a laboratory and it smells of vanilla. In fact, it's so smelly that just three ten-thousandths of a gram is enough to stink up an indoor sports stadium. Hope your vanilla-flavored ice cream is more delicately fragranced.

Dare you discover ... gas experiments?

1 Want to grab a bit of gas?

You will need:

a balloon

All you do is:

1 Blow up the balloon and pinch the end with your fingers.

2 Squeeze the balloon.

What happens?

a) As you squash more the balloon gets harder to squeeze.

b) As you squash more the balloon gets softer.

c) The balloon stays the same.

2 Make your own gas

You will need:

a narrow-necked bottle half-filled with water

a balloon (use the same one!)

2 alka-seltzer tablets.

All you do is:

1 Blow the balloon up and release the air a few times to make it softer.

2 Tilt the bottle on its side and place the tablets in the neck of the bottle.

3 Stretch the balloon over the neck of the bottle.

4 Allow the tablets to fall in the water.

What happens?

a) The balloon is sucked into the bottle.
b) There is a small explosion.
c) The balloon inflates slightly.

3 Bubble trouble

You will need:
a bottle of fizzy mineral water, lemonade or cola.

All you do is:
Give the bottle a really good shake for two minutes. *Slowly* open the top and notice what happens.
a) Nothing
b) Loads of bubbles form and gas escapes.
c) Bubbles appear then sink to the bottom.

Answers: 1 a) Billions of gas atoms are squashed together. The harder you squeeze, the harder those atoms push back! **2 c)** The tablets react with water to make carbon dioxide gas. The molecules of this gas are made from one carbon and two oxygen atoms joined together. **3 b)** The fizz comes from carbon dioxide bubbles. The gas is dissolved in water under pressure. Removing the top reduces pressure and allows bubbles to form.

Bet you never knew!
Just as in experiment 3 gas bubbles form in the blood of deep sea divers as they surface. The "bends" as they are called can have fatal results! To prevent this, divers spend time in a pressurized chamber so their bodies get used to the change in pressure.

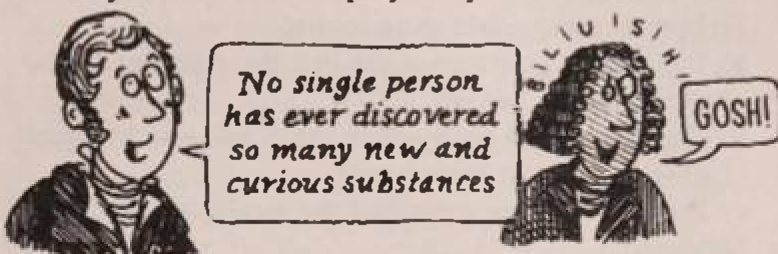
What a gas!

The air is mainly made of nitrogen. Some plants use this to help them grow though it doesn't do much for us. But the oxygen and carbon dioxide in the air are worth gassing about.

Chaotic chemists' hall of fame:

Joseph Priestly (1733-1804) Nationality: British

Priestly's friend Sir Humphry Davy said:



(Not since the first scientific analysis of school lunches anyway.) Joe could speak nine languages but he was useless at math. In the 1790s Priestly disagreed with the government and his political enemies sent a mob to smash up his lab. The shaken scientist fled to the USA. Could you think like Priestly? Try explaining the results of one of his famous experiments.

A load of hot air

1 In 1674 scientist John Mayow put a mouse in a jar with a candle.

2 The mouse fainted as the candle burned out.
3 In 1771 Priestly burned a candle in a jar until the flame went out. Then he added a piece of mint to the jar.
4 The plant stayed healthy.
5 A few months later Priestly added a mouse. This time the mouse stayed awake.
6 Finally the scientist added a candle in the jar again. The candle burned normally, the plant stayed healthy and the mouse stayed awake.

So how do you explain these results?

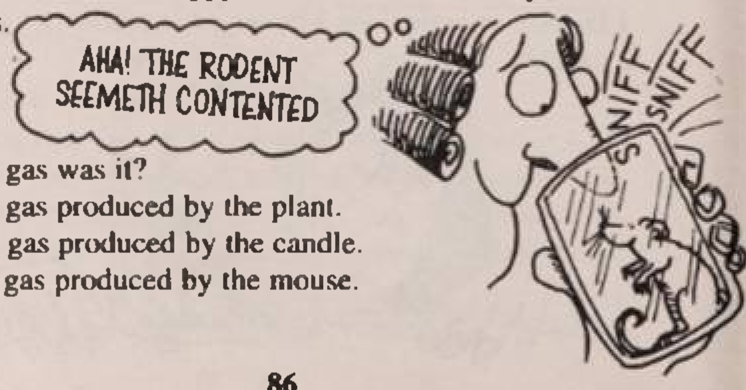
a) The mouse produced a gas that the plant used. The candle also used this gas.

b) The plant used a gas made by the candle and produced another gas that the mouse used.

c) The candle made a gas that the mouse and the plant both used.

Answer: b) Yes – the plant used the carbon dioxide to make food and produced oxygen so that the mouse could breathe.

In 1774 Priestly heated mercuric oxide to make a colorless non-smelly gas. He put this gas in a jar and added a mouse. The mouse seemed happy and relaxed. So Priestly sniffed the gas.



Which gas was it?

a) The gas produced by the plant.

b) The gas produced by the candle.

c) The gas produced by the mouse.

Answer: a) In 1783 Priestly's friend Lavoisier (later to lose his head) found that the gas from the candle was the same gas breathed out by the mouse. Its name is carbon dioxide. Lavoisier called Priestly's other gas – the one made from mercuric oxide – "oxygen".

Bet you never knew!

Joseph Priestly invented fizzy drinks. He put together a home-made machine from a washing tub and a few wine glasses and bubbled carbon dioxide through water. The water tasted fizzy and you could flavor it with fruit juices. But Priestly stored the gas in a pig's bladder and funnily enough some people complained that the drink had a "piggy" flavor.

Trick question for your teacher.

Who discovered oxygen – Priestly or Lavoisier?

Answer: Neither. Oxygen had been discovered some years before by Swedish scientist Karl Scheele.

Chaotic chemists' hall of fame:

Karl Scheele (1746-1786) Nationality: Swedish

Karl Scheele discovered new chemicals such as oxygen, chlorine and nitrogen. But life wasn't much of a gas for this sad scientist. Owing to a publishing mix-up the book describing his discoveries wasn't printed for 28 years! Meanwhile, other chemists had discovered the same chemicals. And to make matters even worse, Scheele died after being poisoned by a chemical he discovered but never got the credit for!

A mad machine

Meanwhile Lavoisier investigated hydrogen gas. This lighter than air chemical was ideal for filling balloons so they floated upwards. But there was one problem – hydrogen burns easily. In 1783 French balloon pioneer Pilâtre de Roziers tried to fly this chaotic machine. Can you guess what happened?

Answer: The hydrogen balloon caught fire and exploded. The crazy balloonist was killed.

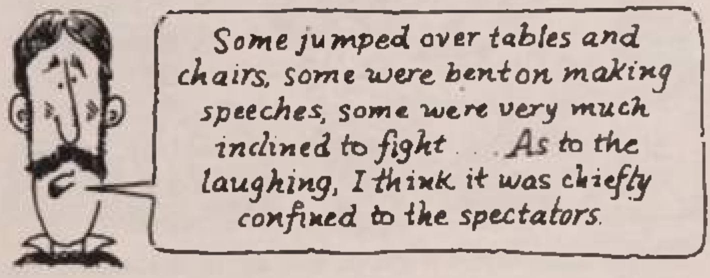
Bet you never knew!

Oxygen can't burn on its own, but when mixed with other gases it can burn horribly well. In 1996 a hospital patient removed an oxygen mask under the sheets to smoke a cigarette. His bed filled with oxygen and exploded! And that wasn't the nastiest gas disaster.

The last laugh

Sir Humphry Davy (1778-1829) was 19 when he discovered laughing gas, or nitrous oxide as the chemists call it. He thought there was something funny about the gas when he sniffed it. And he felt so good that he burst into roars of laughter.

Laughing gas shows became a popular form of entertainment. You could see people sniffing the gas and making fools of themselves. In 1839 a chemist described how people breathed the gas out of pigs' bladders:



And the funny thing was that people under the influence of the gas didn't seem to feel any pain.

The dabbling dentist

Ambitious American dentist Horace Wells (1815-1848) experimented unsuccessfully with laughing gas as a way of knocking people out for operations. Later he went mad and killed himself. Meanwhile his former partner William T. Morton the proud owner of a false teeth factory, was experimenting with another chemical – ether.

Following the advice of a professor called Charles Jackson, Morton tested the gas on his pet dog and then on himself. Mind you, I don't suppose he noticed that he'd knocked himself out. Next he tried it on a patient. Success! Sadly, this story has a painful ending. Ether is quite cheap and easy to make. So to make money Morton said he'd invented a brand new substance.

He colored the ether pink and added perfumes to it so no one would recognize it. Then he sold the bottles to doctors at ludicrous prices. He thought he'd be laughing all the way to the bank. But when the doctors found out they'd been cheated, they lost all confidence in Morton.

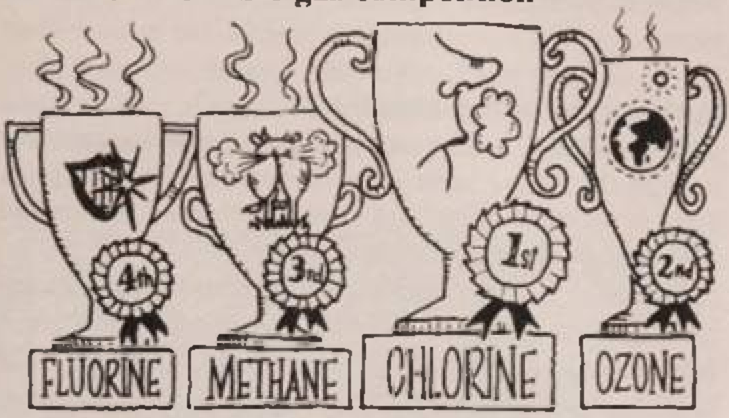
Morton exchanged a lot of hot air in his arguments with Charles Jackson over who had discovered ether. One day the inventor read a magazine article crediting Jackson with the discovery. He was so cross he had a fit and died. Meanwhile, Jackson had been acting rather oddly. After a visit to Morton's grave he went mad and had to be locked up.

In the last fifty years laughing gas has come back into fashion. It has been extensively used to knock people out before operations.

So I suppose Horace Wells got the last laugh.

And if you think this story sounds chaotic, wait until you get wind of these nasty niffs...

The most horrible gas competition



Fourth prize

Fluorine Five scientists tried to make this gas – all were poisoned. Eventually French scientist Henri Moissan (1852-1907) succeeded using platinum equipment. Platinum is one of the few materials fluorine doesn't dissolve.

Nowadays, tiny safe amounts of fluorine atoms are found in the chemicals called fluorides in toothpaste that help protect teeth from decay. That's OK, but too much fluoride actually discolors teeth.

Third prize

Methane gas bubbling from marshes catches fire to make the ghostly lights called jack-o'-lanterns. You'll also find methane in cows' gas (and humans') – *and* the gas that people use for cooking. It's true!

Second prize – runner up
Ozone gas molecules are formed by three oxygen atoms joined together. They smell of newly mowed hay and were discovered when a scientist noticed a funny smell in his lab.

Ozone kills germs. It also kills people if they breathe too much of it. Luckily most ozone is 16 miles up in the air where it forms a useful barrier against the sun's harmful rays.

Winner (just nosing ahead)
Chlorine Pollution by gases containing chlorine caused a hole in the ozone layer over Antarctica. The gap is as deep as Mount Everest and as big as North America and it's getting bigger all the time.

But this horrible yellow-green gas has been causing problems for centuries. Over 600 years ago an alchemist bubbled chlorine though water and said it was good for salad dressings. WRONG. Chlorine is horribly poisonous.

In the First World War German scientist Fritz Haber developed chlorine gas as a horrible weapon of war...

A breath of air
"Tell me about it," Billy pleaded.

Arthur McAllsop hunched his shoulders against the cold drizzle and shook his head. "I've told you son – it's not a nice story."

"You said you'd look after me."

"Yeah, I did. Listen son, just keep your head down and you'll be alright."

"Well, I need to know about it. Can't have been too bad – you're still here aren't you?"

A flare cut through the night. Billy blinked in the sudden blaze of light. He looked so young – just sixteen and his first time away from home. Must have lied about his age.

Arthur sighed. It was useless. The boy would find out soon enough.

"We were near Ypres. I expect you've heard of the fights there in 1915. Well, it was a quiet sort of day – warm for April. Nothing much to bother us all day. We were having a nice cup of tea when it happened."

"What happened?" asked Billy.

"Gas," said Arthur. "The gas attack. It was like a yellow fog rolling down. Well, luckily the wind blew the worst of it away. We didn't have gas masks then."

"Did you get gassed?"

"Only a bit. It was like a horrible sore throat and I couldn't stop coughing. But I was lucky – I was still alive."

"That night it poured with rain. The shelling didn't let up. Not for one moment. Chaos. You couldn't hear yourself talk. We had nothing to eat, no sleep. After we came out of the line everything was a mess. The gas had turned all the grass yellow. And there were no birds in the trees."

There was a long silence. It was a quiet night and if you listened hard you could hear voices from the enemy trenches. Orders in a foreign language. Then came a crack of rifle fire and the whine of a stray bullet.

"Arthur, you don't think they'd use gas on us?"

Both men sniffed the air. The trench smelled of moldy earth. Muddy water squelched on the duckboards beneath their army boots.

"No Billy – we'll be alright. They put the gas in shells now. They don't blow up but they do go plop! So if one plops you'd better put your gas mask on double-quick!"

It was getting lighter and a chill dawn breeze set the barbed wire twanging. Soon it would be time to stand to – then they could eat breakfast.

The soldiers heard the approaching shell. It whistled through the air like a train getting louder and louder. They both crouched, instinctively ducking their heads.

Waiting for the bang that never came. Instead the shell fell in the mud of No Man's Land with a gentle plop.

Billy turned white.

"Gas," he cried in a choking voice. "GAS!"

In seconds the word was passed down the line. Half-awakened soldiers groaned and cursed – fumbling with the clumsy gas masks they wore around their necks.

Only one man did nothing. A man who had already seen the worst of gas warfare and knew what to expect.

"Don't be silly, Billy!" cried Arthur McAllsop. "It's a dud shell. Gas shells don't whistle like that!"

Bet you never knew!

1 *By the end of the First World War more than 123,025 tons of gas had been released by both the British and the Germans.*

2 *The first gas masks were rifle cleaning cloths soaked in urine (the water in the urine was supposed to absorb the gas). Yuck!*

3 *Eventually the soldiers were given gas masks that absorbed the gas in layers of charcoal.*

4 *In 1975 Dr. Buddy Lapidus used this idea to invent odor-eating insoles. The charcoal eats up nasty smelly foot odor like a little gas mask!*

But gases aren't the only deadly chemicals. Metals make murderous weapons, too.

Marvellous murderous metals

What's hard, shiny and doesn't bounce when it hits the floor? No, it's not your teacher's bald head, although it could be – it's a metal! Where would we be without metals? Think of the chaos it would cause. We'd have no coins, cars or computers for a start. But then we'd also have less in the way of murderous weapons. Let's face the facts...

Metals fact file

Name: Metals

The basic facts: In a metal the atoms aren't actually joined together – they're surrounded by a crowd of electrons. This allows you to bend metals and stretch them into wires.

Horrible details: Some metals have horrible habits. Two called rubidium and caesium must be kept away from water to stop them from exploding!

But metals have many amazing secrets too!

Marvellous metal facts

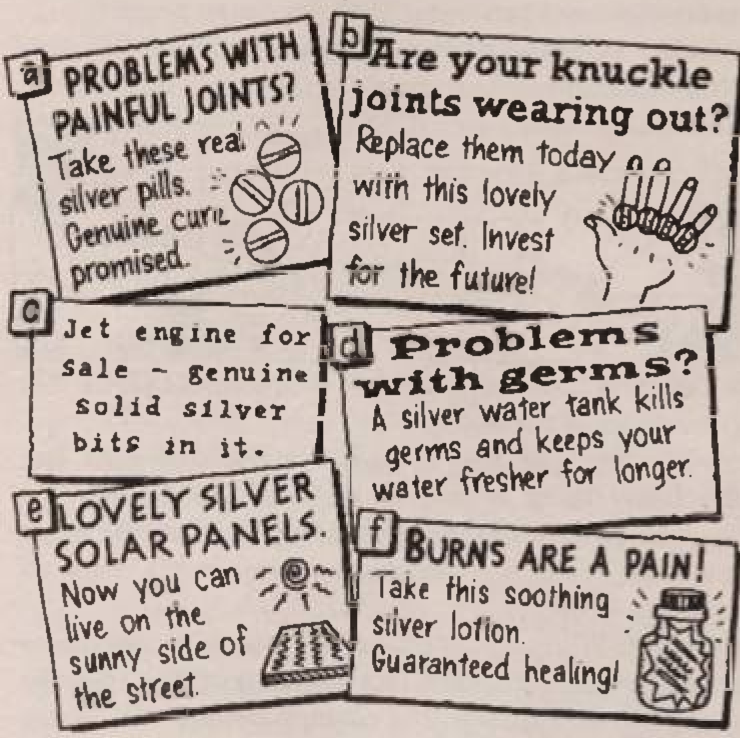
1 Some metals can float on water – for example, sodium does until it reacts with the water to make hydrogen gas.

2 Mercury is a metal that is actually a liquid at room temperature. You can see it in your thermometer. As the mercury heats up, it expands up the scale. Mind you – one Russian winter the thermometers all froze at -36.4°F. If your school ever gets that cold it's time to go home!
3 Gallium melts so easily that if you put some in your hand it collapses into a greasy puddle!

4 Tantalum is a rare grey metal used to make plates that cover holes in the skull.
5 Nowadays, platinum is more valuable than gold. But the funny thing is that in the sixteenth century the Spanish government thought the metal could be made into fake coins. So they dumped their entire stock of platinum in the sea!
6 In 1800 William H. Wollaston (1766-1828) invented a way to re-shape platinum into long threads so it could be made into new shapes. The cunning chemist was raking in cash like crazy from his invention and made sure no one else found out. The secret was revealed after he died. Well – he didn't need the money any more!
7 Titanium is a metal that doesn't melt easily. This is good for making fast aircraft because their wings get very hot due to air molecules rubbing over them at high speed.
8 Scientists have suggested making artificial legs out of titanium. At least they won't buckle under in the heat of the sun!

Sensational silver

Silver is so widely used it's difficult to believe that anything could be so useful. Which of these silver advertisements are too stupid to be true?



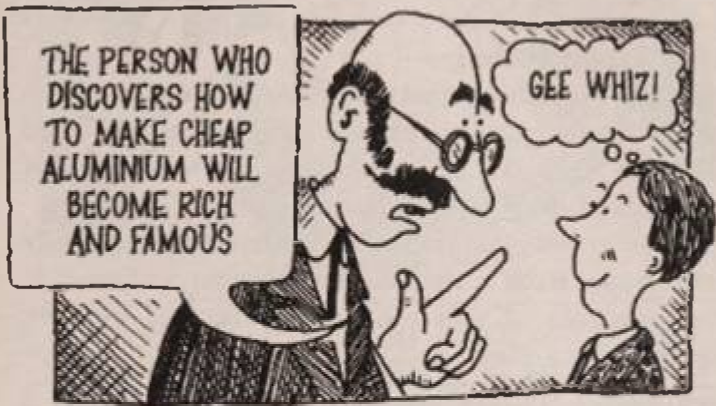
Answers: All are TRUE except b)!

Amazing aluminium

Apart from silver, aluminium is one of the most useful metals known to man. But aluminium was once amazingly difficult and expensive to make. The French Emperor Napoleon III had his cutlery and baby's rattle made out of aluminium just to show how wealthy he was!

Chaotic chemists' hall of fame:

Charles M. Hall (1863-1914) Nationality: American
Paul L.T. Héroult (1863-1914) Nationality: French
One day Charlie heard his teacher say,



So the go-getting young American decided to have a go. Soon he was hard at work on his main piece of equipment ... a dirty old gas stove in a woodshed.

Against all the odds – Charlie succeeded! The trick is to dissolve aluminium-rich bauxite in a chemical called cryolite. Amazingly this discovery was made at the same time by Frenchman Paul Héroult. Both inventors were exactly the same age and both worked in similarly chaotic chemistry labs! And here's the really bizarre bit. They were born and died in the same year too! Aluminium may be amazing, but it's not...

As good as gold

Yes – GOLD. It's the stuff that dreams are made of. Royal crowns, pirate treasure, ancient coins. For thousands of years men have fought, struggled and died to get their hands on this magical metal. And sometimes they've made complete fools of themselves...

Fool's Gold

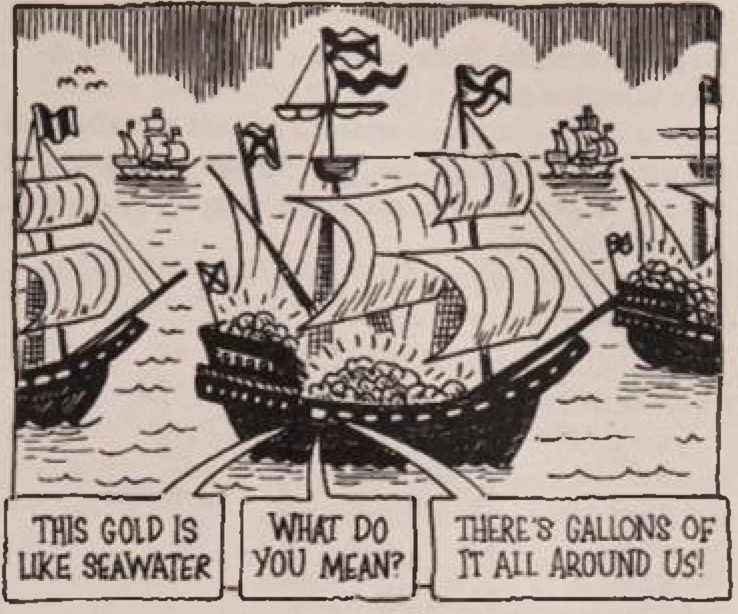
Sir Martin Frobisher (1537?-1596) was nobody's fool. The tough-talking Yorkshireman was everyone's idea of an explorer – brave, weather-beaten and determined.

In 1576 Frobisher sailed off in search of a sea route to Asia across the north of Canada. Sir Martin didn't find the fabled route but he did visit the icy wilderness of Baffin Island. And there he made a stunning discovery.

It was a lump of rock that glittered in the chilly northern sun! Back in England an alchemist confirmed it, "Yep – it's gold." Chaos soon ensued because everyone wanted to grab a share.

The next year, Frobisher returned to the island with a larger expedition. It was no picnic – they braved icebergs and gales that could tear a ship to pieces. On land there were polar bears strong enough to kill a man with a single blow. But it was worth the danger. Working with picks in the freezing cold, they hacked away 180 tons of the golden rock.

The following year Frobisher headed an armada full of excited adventurers. This time the ships returned laden with an incredible 1,180 tons of the glittering prize. It was worth a fortune – enough to make them rich beyond their wildest dreams. Or so they reckoned...



Then the bubble burst. There was no gold on Baffin Island. It was just iron pyrite – a common-as-muck mixture of iron ore and sulphur that you can find anywhere. Some unkind people called it "fool's gold." Sir Martin and his crew became a laughingstock.

Would you have been fooled by iron pyrite? Here are a few tips to make sure you get the right stuff.

Become a Gold Prospector

1 Panning for gold

Swirl a load of sand and water in a pan. Carefully swill the water and floating sand from the pan. Any gold will settle to the bottom of the pan as golden grains or nuggets.

2 Testing for gold

Scrape your golden nugget on a dark rock called a touchstone. If it leaves a streak of gold it's genuine.

3 Dig a gold mine

It takes time to dig your own mine. Some mines are thousands of meters deep so don't dig into your garden unless you're sure there's real gold lurking in the rocks beneath. You do have real gold in the rocks beneath your garden? Okay, then, here's how to get at it.

Getting the gold . . .

1 You'll need to spend a lot of money on machines, etc. Six hundred thousand dollars should cover it.

2 Smash thousands of tons of rock with heavy machines. Check every bit of rock to make sure you don't chuck away the golden nuggets by mistake. (You wouldn't see the funny side of this.)

3 Then smash them up in a giant cylinder filled with ball-bearings. (It's much quicker than using a potato masher.)

4 Mix the rock powder with the deadly poison cyanide plus water to make a slimy mess. (Don't try this in the living room.)

5 Leave the slime to settle in a tank. Then remove any bits of rock. Check for gold.

6 Add zinc dust to the slime. This separates out the cyanide from any gold there.

7 Melt the gold with a chemical called borax. The borax sticks to any unwanted chemicals and floats to the top of the mixture. Carefully skim this off.

8 A bit of further processing and you end up with a bar of 99.6% gold. It's as simple as that! (NOT)

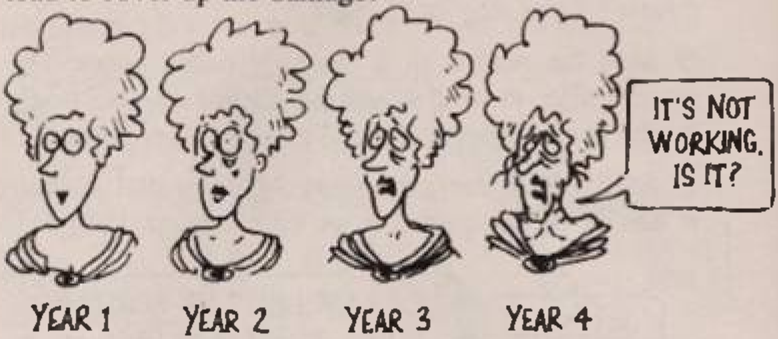
Now you've gone to all this trouble to get gold, what do you do with it? Oddly enough, you might put it back underground – in a bank vault. That's where half the world's gold ends up!

Bet you never knew!

Gold was used in medicines to kill off the lung disease, tuberculosis, but it poisoned the patients too. Yes, there's a mean side to metals. In fact, you could call them murderous.

Murderous metal poisons

Lead is dangerous. Sixteenth-century ladies used white lead face powder to improve their complexions. After a few years the poison ruined their skin – it absorbed the lead and gave them blood poisoning. But the ladies didn't know why their skin was ruined so they used extra lead to cover up the damage!



But the most poisonous metal in the world is arsenic. Many years ago this substance was used to make fly papers. Flies stuck to the paper and came to a sticky end once the arsenic got to work. Unfortunately a few humans went the same way too.

Mind you, poison isn't the only way that metals can murder people. Metals make lethal weapons too.

Murderous metal weapons

And that wasn't all. There followed iron guns and iron cannon firing iron cannon balls. This led to more chaos on the battlefield and buckets of blood being spilt. And oddly enough, there's iron in blood too.

Bet you never knew!

There's metal in your blood! Italian scientist ***Vincenzo Menghini*** *(1704-1759) discovered this vital fact. He added iron filings to the food he fed dogs. The aim was to find where the iron would go. It turned up in the dog's blood. Iron in the red blood cells attracts oxygen atoms allowing blood to carry oxygen round the body. Some spiders have copper instead of iron in their blood. As a result they have blue blood.*

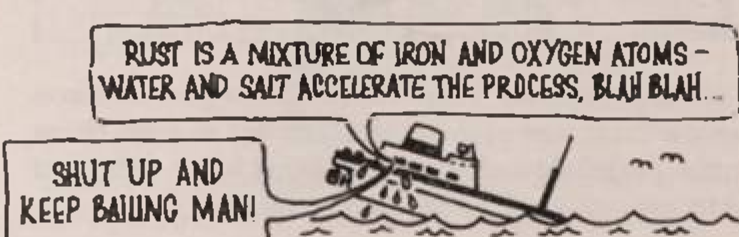
Chaotic chemical expressions

Answer: No. Her car's got a spot of rust.

A rotten reaction

One big problem with iron is that it joins up with oxygen atoms to make rust. That's right – rust is a compound of iron and oxygen atoms. And rusting is speeded up by water and salt. This is why rusty old ships sail the salty seas.

And rusting is just one of many rotten reactions.



Rotten reactions

What have rusting and rotting got in common with photography? Give up? They're all based on chemical reactions. But what exactly is a chemical reaction?

Reactions fact file

Name: Chemical Reactions

The basic facts: A chemical reaction is when atoms join together – or joined-up atoms split apart so new chemicals appear.

Horrible details: Rusting isn't the only rotten reaction caused by oxygen. Oxygen mixed with butter or margarine over time makes them revoltingly rancid! It's enough to wipe the smile off anyone's face.

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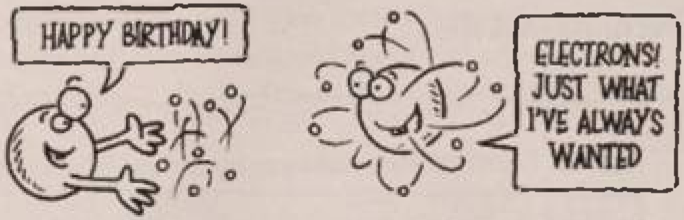
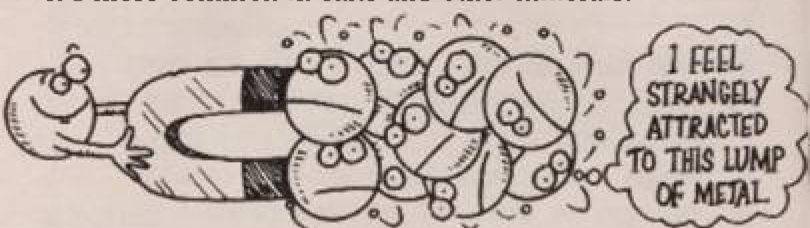
Quick reactions

Normally, when atoms bump into one another they bounce apart again. But if they're moving fast they can stick together before they have a chance to rebound. The outer groups of electrons decide what happens next... Sometimes atom kindly gives the other its electrons.



When this happens an electrical force sticks the atoms together like metal to a magnet. This is an ionic bond and it's more common in salts and other minerals.



Sometimes, the atoms share electrons. The electrons whiz around both atoms. When atoms join together like this it's called a covalent bond.

These bonds tend to form between non-metals – often gases or liquids. With both types of bond a new chemical is created.

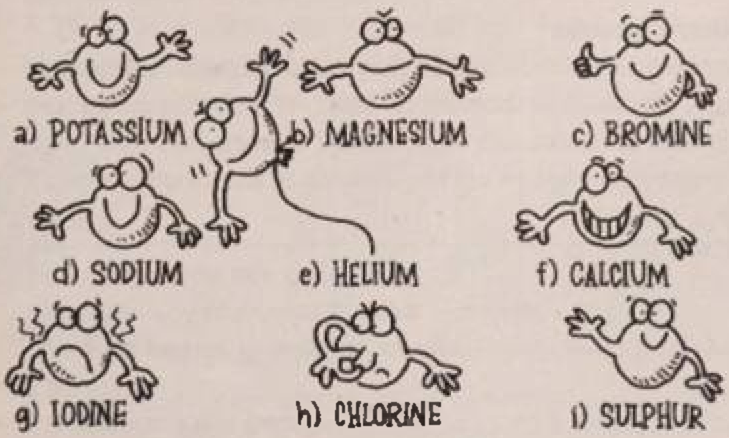
Bet you never knew!
You can do this by joining up atoms together to make what's called a compound. In 1930 there were one million known compounds – today there are well over ten million! Nowadays, chemists use computer programs that show how a chemical will look once the atoms are assembled.

Predictable reactions

So atoms bump together and decide to join up. It sounds hit or miss doesn't it? But it isn't. Do you remember Mendeleyev playing Concentration in the chapter, "Elementary chaos?" Thanks to Mendeleyev's Periodic Table, scientists can predict what happens. It's so simple. It just depends on the number of outer electrons an atom has. If you have an adverse reaction to this, you shouldn't try this puzzle.

Rotten reaction puzzle

Here are the atoms you'll be using to work out the puzzles.



First puzzle

How many outer electrons does each atom have? Read the clues below then work it out for all the atoms above.

Clues:

1 Sulphur has six electrons – that's three times more electrons than calcium. But between them they've enough to make a new chemical.

2 Helium has the same number of electrons as sulphur and calcium combined.

3 Magnesium has twice as many electrons as sodium and potassium.

4 Sodium and chlorine have enough electrons to make a chemical called sodium chloride. That's salt to you.

5 But sodium has only half as many electrons as calcium.

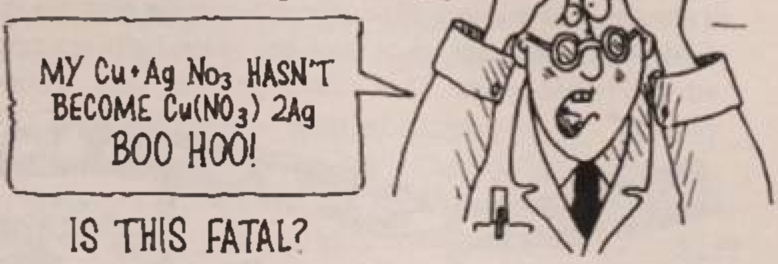
6 All the other atoms have one less electron than helium.

Second puzzle

For two chemicals to join they need a combined total of eight electrons in their outer orbits. Which atoms can join together to make new chemicals? Remember, they need a combined total of eight electrons in their outer orbits.

Answers: First puzzle a) 1 **b)** 2 **c)** 7 **d)** 1 **e)** 8 **f)** 2 **g)** 7 **h)** 7 **i)** 6
Second puzzle Potassium/sodium + bromine/iodine/chlorine • Magnesium/calcium + sulphur • Helium can't join with any other atom.

Chaotic chemical expressions



Answer: No. His photos haven't come out.

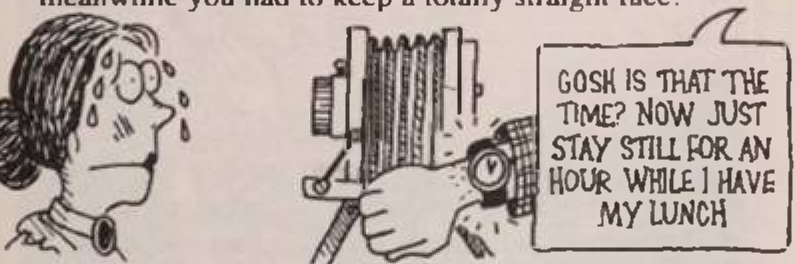
Get the picture!

You might think these chemical reactions are a bit remote from everyday life. Surely you'd never normally have a hand in a reaction? But if you take a photograph you'll need a chemical reaction to get the picture!

1 The first photographers used light-sensitive silver chloride paper. Energy from light causes a reaction that turns the silver chloride black.

2 Light showed up as dark on the photograph. Dark patches showed up as white.

3 To be in a photo you had to sit still and wait for the chemical action to work. This could take hours and meanwhile you had to keep a totally straight face!



4 Unfortunately the chemicals continued to react to light so you had to look at your photographs in the dark!

5 This problem was overcome when inventors discovered a chemical that removes silver chloride from the photograph.
6 Modern black and white film has quick light-reacting silver bromide salts. This means you can take action-photos.

7 Some of these salts are so sensitive to light you could take a photo from Earth of a candle flame on the Moon!

Electrifying reactions

One incredibly useful type of reaction is electrolysis. It was developed by scientific superstar Michael Faraday.

Chaotic chemists' hall of fame:

Michael Faraday (1791-1867) Nationality: British

Michael had a tough childhood. His family was so poor that one day he was given a loaf of bread...

He couldn't afford books but he got interested in science after reading books that he was supposed to be binding for a bookseller. He asked Sir Humphry Davy to take him on as an assistant. As luck would have it, Davy was temporarily blinded during a particularly dangerous experiment. So Faraday got the job.

Faraday investigated the process of electrolysis using different chemicals. Basically, you mix compounds with ionic bonds with water and run electricity through the solution. The atoms are pulled towards one or other of the two electrical terminals. The chemical gets torn apart!

Bet you never knew!
One use for electrolysis is in electroplating. You electrolyse a compound containing metal and a thin layer of the metal forms over an object. It's used to make silver-plated jewellery, for example. In 1891 sinister French surgeon, Dr Varlot, used the technique to cover a dead body in metal. The result of this revolting process was to wrap the body in a .04 inch layer of copper. He then put the gruesome object on display. I bet he got a few shocked reactions.

Quicker and slower reactions

Some reactions take a second – but others take millions of years. Luckily for chemists, many reactions are speeded up by heat. This makes atoms move a lot faster so they bump together more often. But you can slow down reactions by cooling. That's why food (and dead bodies) can be kept cold to prevent the reactions that make things go rotten.

Dare you discover ... how to stop a reaction using another reaction?

You will need:
an apple chopped into pieces
some lemon juice

All you do is:

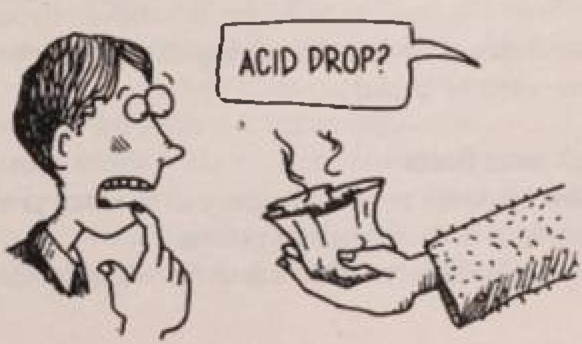
1 Leave a piece of apple uncovered for a few hours and it goes brown. It's a reaction between chemicals in the apple and oxygen in the air just like rusting. It's starting to rot.

2 Try sprinkling some lemon juice over another piece of apple. What happens?

a) The apple goes black.
b) The apple stays the same.
c) The apple dissolves.

Answer: b) The acid in the lemon juice reacts with metal atoms in the apple that would normally help to speed up the other reaction.

But acids have their gruesome side too. See the next chapter for the grisly details.



Appalling acids

They lurk in lemons and vinegar and tea leaves and even car batteries. Some of them have killer molecules that rip apart other nicer chemicals. It's appalling what they can get up to. Can you face the facts. . .?

Acids fact file

Name: Acids

The basic facts: When you put an acid in water it splits to produce hydrogen atoms. These atoms have a powerful electrical charge that rip other molecules to bits!

Horrible details: Acids taste sour and sometimes stink. You wouldn't want to go near some of them. They're strong enough to dissolve a human body!

But not every acid is quite so appalling. Sometimes they can even be useful...

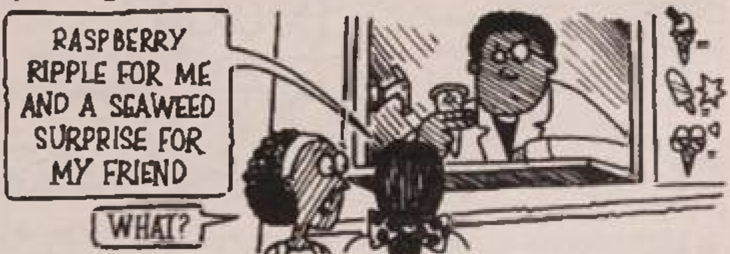
Useful acid facts

1 Amino acids are molecules that join to make proteins. Most of your body is made of proteins.

2 Ascorbic acid is another name for Vitamin C. This

useful chemical is found in fresh fruit and prevents the deadly disease, scurvy. The vital vitamin was discovered by two different chemists and they spent the rest of their lives arguing over who was first!

3 Do you like the flavor of orange or lemon juice? Well, that's acid. Yes, citric acid helps make the taste of the juice.
4 Alginic (al-jin-ick) acid is found in seaweed. It's useful for keeping cakes moist and when added to bandages helps to stop bleeding! It's even used in ice-cream to stop the ingredients separating. You can amuse your friends by telling them their ice-cream started off as seaweed!



5 Salicylic (sallis-sill-ick) acid is used to make aspirin. Yes – the miracle pain-killer is an acid. It was first found in willow bark. People once chewed the wood to reduce fevers. Don't try this – it tastes disgusting.
6 Horribly useful acids were once used to produce leather. These tannic acids from acorns or poisonous hemlock bark killed the germs that made leather rot. The acids are also found in many other substances including tree bark

or even a cup of tea, but luckily they don't harm people. But other acids are completely useless.

Appalling acid rain

What do these places have in common – the Acropolis, Athens, St. Paul's Cathedral, London and the Lincoln Memorial, Washington? Give up? They're all being dissolved ... by RAIN! Industry and traffic produce sulphur dioxide gas. This makes rain more acid. In 1974 rain fell on Scotland that was as acid as lemon juice. That must have left people feeling rather sour.
Volcanoes make the problem worse. In 1982, the volcano El Chichin in Mexico belched out thousands of tons of acid gas!

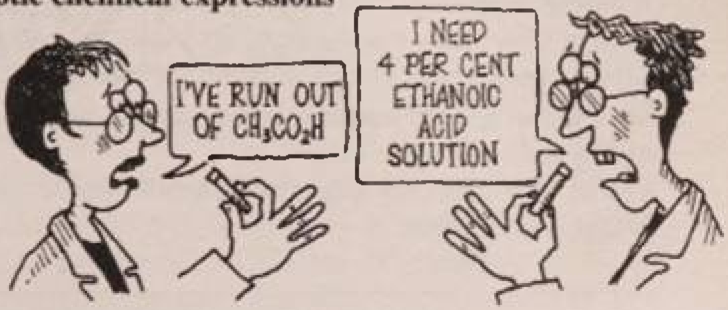
Acid rain eats away at buildings old and new. Even your school is in danger! Oh well, every cloud has a silver lining.

It kills trees by the million.

It does terrible things to fish. They don't grow and the acid dissolves their bones!

Acid rain doesn't dissolve people. But funnily enough, it can turn your hair green. It reacts with copper in water pipes to form copper sulphate, which causes the interesting color change.

Chaotic chemical expressions



What's their problem?

Answer: No vinegar for their fries.

Dare you discover ... some simple solutions?

Dissolving a bone

You will need:

a stiff bone with no cracks in it. No need to go to too much trouble – a chicken bone will do.

vinegar

All you do is:

Cover the bone in vinegar and leave it for 12 hours.

What do you notice about the bone?

a) It's gone green.
b) It bends easily.
c) It's only half its original size.

Answer: b) The calcium in the bone has been dissolved by the acid.

Sour secrets

You will need:
15 drops of lemon juice
A cup of milk

All you do is:
Stir the ingredients together. What happens next?
a) The milk goes pale blue.
b) The milk gives off a disgusting smell.
c) The milk curdles.

Answer: c) The milk curdles because its molecules are broken down by the acid in the lemon juice.

Bottled egg

You will need:
a fresh egg
some vinegar
a glass
a bottle with a wide neck

All you do is:
1 Soak the egg in the vinegar for two days. The egg will look the same but the shell will be thinner and softer.

2 You can carefully squeeze the egg into a bottle. Ask your friends to guess how you did it.

Answer: The acid in the vinegar has dissolved some of the calcium in the egg shell.

Bet you never knew!

You've got acid in your stomach. This fact was discovered by William Prout (1785-1850) in 1823. The hydrochloric acid kills germs and dissolves your food. So why doesn't it dissolve people too? Well the funny thing is – sometimes it does – that's when people get ulcers. The slimy stomach wall usually stops this from happening but too much acid can cause indigestion.

Sinister sulphuric acid

It's oily, colorless and turns things to sludge, but it's got nothing to do with school lunches. It's sulphuric acid – a chemical so powerful that it has to be watered down before it can be used safely.

So why bother making sulphuric acid? Well, it does have its uses. For example, you can use it to make fertilizers for plants. If you add acid to paper it becomes see-through. It's often added to toilet paper. Fortunately the acid is washed off later otherwise it could be appallingly uncomfortable. But that's not the only thing sulphuric acid can do...

The acid test

An acid test is when you use a specially-treated paper called litmus to detect acid. The paper goes red if there's acid around. But in 1949 the acid test was one of lies versus truth and the issue was murder!

In 1949 businessman John Haigh was charged with murder. He had disposed of his victim's body in an appallingly horrible way by dumping it in sulphuric acid. Haigh had boasted to police that there would be nothing left. As he said at the time:

But Haigh was wrong. The acid had not destroyed the evidence. There were a few grisly tell-tale bits remaining – and a complete set of plastic false teeth. These were promptly identified by the dentist of the murdered woman.

Haigh then admitted getting rid of five more bodies using the same method. He went on trial at Lewes Assizes. The jury took eighteen minutes to reach their verdict and John Haigh was executed.

Appalling acid poisons

1 Rhubarb leaves contain poisonous dicarboxylic (di-car-box-sill-ic) acid. It's there to poison any hungry caterpillar that likes nibbling it. Luckily, it's not in the stalk and that's the part we eat.

2 Bee stings contain acid and that's why they hurt. You can neutralize a bee sting with bicarbonate of soda because this is alkaline.

3 But put alkali on a wasp sting and it hurts more than ever. Wasp sting poison is alkaline not acid! And if you want to know more about alkalis you'll need some basic base facts.

Bases fact file

Name: Bases

The basic facts: Bases capture those nasty hydrogen atoms made by acids. So they turn an acid mixture back to normal. You can tell if something's a base because it turns indicator paper blue.

Horrible details: But bases can be nasty too. Some of them have a horrible bitter taste, burn the skin and dissolve things.

Bet you never knew!

1 You can make a base into a clock. When you heat up the base ammonia the nitrogen atom inside the molecule vibrates at a regular rate. Funnily enough, in 1948 scientists used this regular "ticking" to tell the time!

2 You can use flowers to detect acids and bases. Hydrangea plants produce pink and white flowers when soil is alkaline and blue flowers when it's acidic.

Dare you discover ... the secret of sherbet?

You will need:

2 ounces citric acid crystals (You can buy them from a pharmacy.)

1 ounce bicarbonate of soda

7 ounces confectioner's sugar

All you do is:

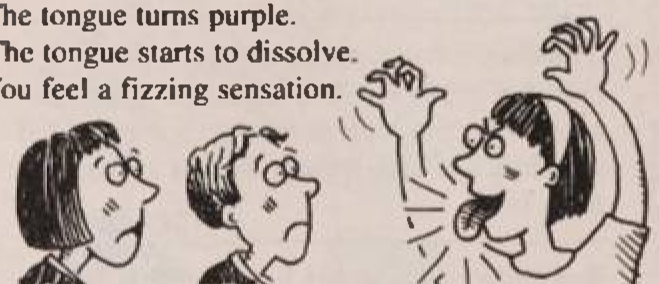
Mix all the ingredients thoroughly.

Try putting a bit in your mouth. What do you notice?

a) The tongue turns purple.

b) The tongue starts to dissolve.

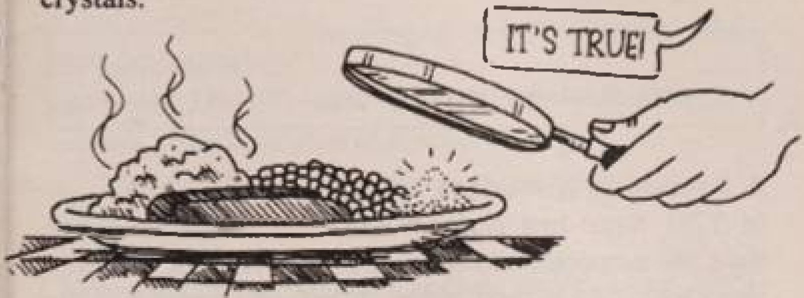
c) You feel a fizzing sensation.



Answer: c) The acid lemon juice and the alkaline bicarbonate of soda react together to produce carbon dioxide gas. If you add sherbet to a drink you can make it taste fizzy.

Salty secrets

When you mix an acid and a base they react to make ... a salt. A salt isn't simply the stuff you put on your french fries. If you look closely at a salt you'll see an arrangement of tiny shapes. It's a collection of crucial crystals.



Crucial crystals

Here's a question to mystify your teacher. What do metals, gems, bones and computer chips have in common?

Answer: They all contain crystals. Some of them are crucially important.

A smashing discovery

In 1781 René-Just Haüy was having a rather chaotic time. He dropped a calcite stone on the floor. It shattered into identically shaped pieces. Intrigued he smashed the broken bits even more with a hammer. This produced smaller fragments that were still of the same intricate shape. He was looking at crystals!

Crystals fact file

Name: Crystals

The basic facts: Crystals are groups of atoms arranged in little piles of boxes. The boxes fit together to make larger boxes of the same shape.

Horrible details: Disease-causing viruses can be made into crystals. The funny thing is, they come alive as soon as they get into a living creature.

A sick discovery

This discovery was made by Wendell M. Stanley (1904-1971). He infected some leaves with the tobacco mosaic virus. He mashed up the dried leaves and found that the virus had turned into nasty needle-like crystals.

Bet you never knew!

Salt is made up of crystals. If you look at salt through a microscope you'll see them as a pile of little boxes.

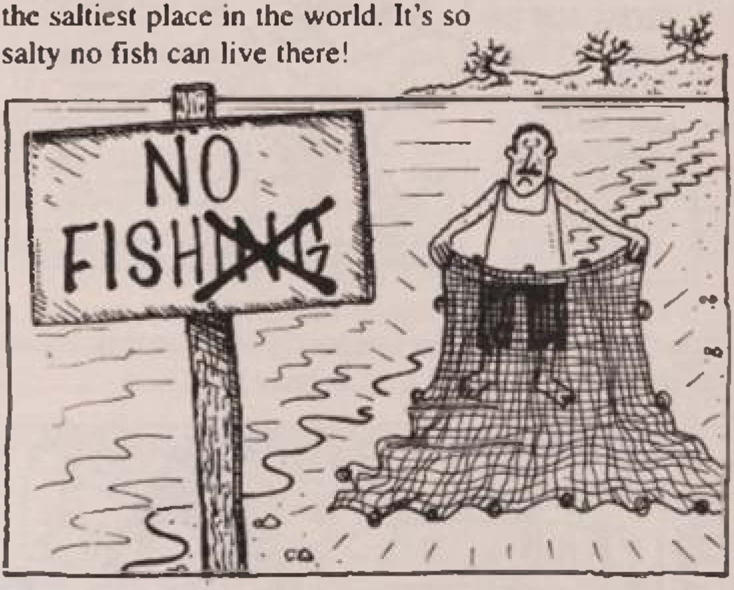
Salty secrets

1 Salt contains the elements sodium and chlorine. Both chemicals are poisonous but strangely a little salt is vital for your health!

2 In the Middle Ages people used to baptize their babies in salt water. It was thought to bring good luck.

3 In France an unpopular tax on salt helped to trigger the French Revolution and the execution of thousands of people.

4 Salt is a major problem in parts of Asia. As swampy land dries out salt is left in the soil and kills the plants.
5 But that's nothing to the Dead Sea. This inland lake is the saltiest place in the world. It's so salty no fish can live there!



Crucial crystals quiz

Crystals can be used for loads of crucial jobs but some of their uses you wouldn't believe. Which of these is too incredible to be true?

1 Diamonds were used to make spacecraft windows for a trip to Venus.

2 Diamonds are used to make lenses for protective goggles.

3 Rubies have been used to make lasers.

4 Crystals are used in some hospitals to kill germs.

5 Scientists are investigating using energy locked up in the atoms of crystals to power space craft.

6 Crystals were used in early radio sets.

Answers: 1 TRUE. The diamonds didn't heat up in the planet's fiery atmosphere. **2** FALSE **3** TRUE. The atoms in the crystals take in energy and let it out in one intense beam of light. **4 and 5** FALSE **6** TRUE. The crystals were used to control electrical currents inside the radio.

Bet you never knew!

The colors in gems are due to tiny amounts of other chemicals. For example, a bit of chromium turns a crystal pink. A bit more chromium makes a ruby red. Most diamonds don't contain other chemicals and that's why they're clear.

Crucial diamond facts

1 Diamonds are made from carbon atoms. 155 miles below-ground intense heat and pressure force the atoms into a cage-like shape.

2 Diamonds are so hard the only thing that cuts them is ...

another diamond. Their strength makes diamonds ideal for cutting all kinds of metals. You'll also find diamonds on the end of dentists' drills (that's if you dare look)!

3 The gems are sometimes spat out by volcanoes. This is why diamond mines are dug into volcanic rock.

4 It was Lavoisier who discovered that diamonds are made of carbon. He used a giant magnifying glass that focused the rays of a hot sun onto a diamond. Suddenly it disappeared in a puff of carbon-dioxide gas. The carbon in the gas came from the diamond.

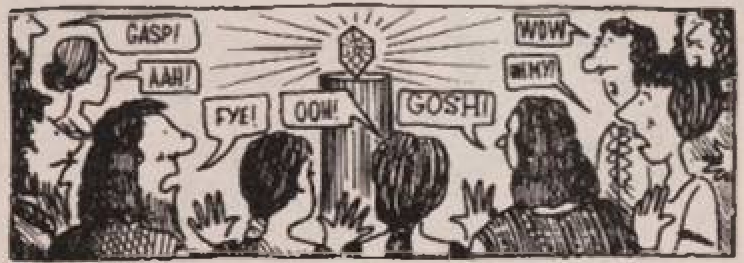
5 Scientists believe that up to 15 per cent of the planets Uranus and Neptune could be made up of diamonds. If you could find a way to get your hands on them you

could become the richest person in the Solar System.

6 Diamonds are so mysterious that it's not surprising that there are many diamond myths. But BEWARE – some diamonds are cursed with deadly misfortune. Here's the sinister story of just one famous gem.

A deadly diamond

It was a large blue diamond – unmatched in its beauty and rarity.



No one knew its origin. Some whispered that it was the eye of an Indian goddess – stolen from a temple. And perhaps it was cursed too.

It was sold to the French King and was worn by Queen Marie Antoinette. In 1793 she was executed and her priceless stone was stolen!

In 1830 the gem was sold in a London auction. It was bought by a banker – Henry Hope. But Hope died penniless with his business empire in ruins.

A young Prince bought the diamond for his girlfriend. He later shot her.

A Turkish Sultan bought the stone. A few weeks afterwards he was forced to give up his throne.

A wealthy Greek bought the diamond but he was killed when he drove his car off a cliff.

The next owner was an American millionairess who wore the diamond in a necklace. Her husband went mad and two of her children died in tragic accidents.

The next owner of the necklace wisely gave it to a museum. And that's when the story should have ended.

But in 1962 a museum curator took the diamond to Paris for an exhibition ... in his pocket! His plane landed four hours late and the man's car was involved in an accident. The curator wasn't hurt but he never took the stone anywhere again.

Mind you, diamonds can threaten disaster for other reasons too.

A cut above the rest

Premier Diamond Mine, South Africa, January 26, 1905
Frederick Wells couldn't believe his eyes. Embedded in the wall of the freshly dug pit was a prize worth dying for. A huge diamond weighing perhaps 1 pound, 2 ounces – that's

as big as a man's fist. In a few moments the dazed mine boss was frantically digging out the diamond with his penknife.

It was the largest diamond ever found and it was fit for a king. So the government bought it for $750,000 to give to King Edward VII of Britain as a birthday present.

Now came the tricky bit. The diamond was a rough stone. For its true beauty to shine, the stone had to be split in pieces and each piece carefully cut and polished.

So it was sent to Mr J. Asscher – the most famous diamond cutter in Amsterdam. For months Asscher studied the gem trying to guess how it would split. If he was right, the diamonds would be objects of priceless value. But if he was wrong the gem would shatter into fragments. The King would lose everything – but then so would Asscher. His business would be ruined because no one would ever trust him with their diamonds again. He would be a laughing stock and a famous failure.

With shaking hands Asscher set the gem against a wedge. He made a tiny notch in what he hoped was the right spot. He took a chisel and slowly and painstakingly placed it at the precise angle in the notch. His mouth was dry and there were tiny beads of sweat running down his forehead. His hand trembled violently as he picked up a mallet. This was the moment of truth...

Would the diamond shatter? Would it split to perfection? Asscher would never forget the next few moments...

He hit the chisel with all his strength.

The steel chisel shattered.

The diamond was too hard.

Asscher was led away to hospital. He was laughing like a madman and his nerves were shattered – even if the diamond wasn't.

Meanwhile, just thinking about the priceless gem made his skin crawl. But he was determined to try again.

After weeks of treatment Asscher felt well enough to return to work. At last the dreaded day dawned. This time a doctor was on hand to provide first aid.

Asscher closed his eyes and clenched his teeth. He gripped the chisel in one sweaty hand.

Then he struck...

The diamond split cleanly in just the right place. But Asscher was lying on the floor. He had fainted!

The Cullinan diamond was cut into 105 beautifully polished diamonds – each one worth thousands of dollars. Two of these are in the English crown jewels. The finest and largest diamond is the Star of Africa, which holds pride of place in the royal scepter.

DIY diamonds

Not surprisingly, many chemists have tried to make their own diamonds. But chaos often ensued. For example, Scotsman J.B. Hannay blew up his laboratory in 1880 after heating carbon in an iron tube.

Henri Moissan, the discoverer of fluoride, knew that diamonds are sometimes found in meteorites. So he decided to make his own shooting star. He melted a lump of iron with carbon in the middle. But he didn't find any diamonds.

Eventually, scientists learned how to make diamonds. You've got to heat graphite to 2732°F under massive pressure. Thousands of tiny crystals appear. But it takes a week of this treatment to make even a small diamond.

Dare you discover ... how to make your own crystals?

You will need:
a beaker
salt and warm water
food color

All you do is:
1 Mix the salt and water in the beaker so that the salt dissolves.
2 Add the food color.
3 Leave the mixture in a warm, sunny place for about two days. Sit back and wait for a reaction.
So what happens?
a) You return to find priceless gems have formed in your beaker.

b) The mixture evaporates down and colored crystals appear.
c) You can fish some shiny lumps out of the beaker with a spoon.

Answer: b) The water molecules float away and the salt molecules join up to make crystals, which gain color from the food coloring.

Bet you never knew!

Buckminsterfullerene is the name given to a form of carbon discovered in 1985. It forms hollow crystals in the shape of footballs. They're named after Richard Buckminster-Fuller (1895-1983) an American architect who designed domes of this shape for factories and exhibition buildings. Buckminsterfullerene is a bit of a mouthful, so scientists call the shapes "bucky balls" for short. They sound very rare and exotic – but they're not. You'll find them in boring old soot.

Mind you – there's a lot of soot wafting about in the next chapter. It's made by combustion (that's the posh word for burning) and fiery explosions!

Bangs and burning

Burning and explosions are nothing out of the ordinary. They're just chemical reactions that get ... a bit out of hand. For centuries people have found bangs and burning useful. Read on for an explosive story.

A burning issue

Thousands of years ago one of your ancestors made the greatest discovery of all. Fire. Without it school lunches would be even worse – just raw veggies and very tough meat. There'd be no heat and no electricity because this form of power depends on burning coal or oil. There'd be no metals because there would be no metal smelting (apart from gold, that is!). And your school would be built of mud because without fire you can't make bricks and glass.

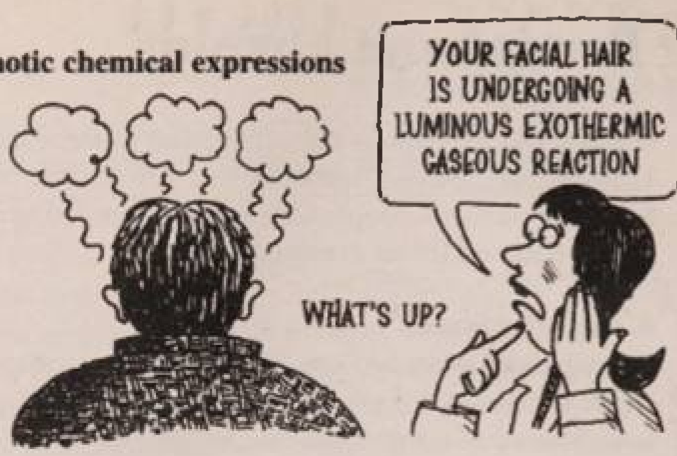
Burning fact file

Name: Burning/Combustion

The basic facts: Burning is a reaction in which oxygen combines with the chemicals in the substance to make heat and light.

Horrible details: The human body can burn to ashes but it takes a huge heat hundreds of degrees centigrade.

Chaotic chemical expressions



Answer: His beard's on fire.

Bet you never knew!

1 Fire sucks in air to make light and heat.

2 A flame gives off heat and light energy. The yellow bit of a candle flame consists of unburned carbon from the candle.

3 Gas can burn with a clear flame if there's enough oxygen to burn all the gas. There are no messy bits of leftover carbon.

Dare you discover ... lemon's burning secret?

You will need:

half a lemon
a cup
paper
an empty fountain pen

All you do is:

1 Squeeze the lemon juice into the cup.
2 Wash and dry the pen tip.

3 Dip the pen in the lemon juice and write a few words on the paper.

4 Hold the paper in front of a warm radiator. The writing appears on the page. Why?

a) The heat makes the paper whiter so you can see the writing.

b) The heat makes the paper darker so that the writing shows up.

c) The heat makes the lemon juice darker so you can see it.

Answer: c) Lemon juice burns at a lower temperature than paper. This fact is very useful for sending your own secret messages.

Fearsome phosphorous

One chemical that burns easily is phosphorous. For centuries doctors prescribed this poisonous chemical as a medicine. The doctors thought that it must be good for you because it glows in the dark! Then an inventor discovered phosphorous matches.

HORRIBLE SCIENCE HEALTH WARNING

Matches are useful for starting fires. Luckily, none of the experiments in this book involves burning down your school. So to avoid scenes of chaos and other dire consequences leave the matches safely in their box.

Strike a light

In 1826 John Walker, a chemist from Stockton-on-Tees, England was stirring potassium carbonate and antimony with a stick. When he scraped the stick on a stone floor to get rid of the chemical blob on its end, the stick caught fire. John Walker had met his match.

John decided to sell his new inventions and strike it rich. At that time people carried tinder boxes containing flint and steel to make sparks and a bit of dried fungus to burn. Now everyone had money to burn on the new matches!

But the new matches were deadly. If the air got warm and moist, the matches burst into flames. They sometimes set fire to people's pockets and made poisonous fumes. A few customers got more than their fingers burned.

And there was an even more terrible price to pay. Phosphorous slowly poisoned the girls who made matches. Entering the body through rotten teeth it caused a ghastly bone disease nicknamed "phossy jaw."

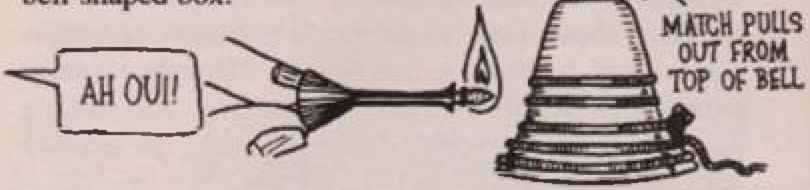
When these facts came to light social reformers campaigned to ban the matches. In 1888 the workers went on strike (that means not working, not striking matches, silly). But people didn't stop using the matches until they were banned in 1912.

Nowadays we use "safety matches." They were developed as early as the 1840s. Basically you've got two reactive chemicals – potassium chlorate on the match head and a phosphorous-based chemical on the striking surface. Since the chemicals don't mix until the match is struck they should be safe enough. But the early safety matches didn't quite get it right. They sometimes had the habit of exploding all by themselves.

Nowadays in Britain alone people use 100,000,000,000 (one hundred thousand million) matches every year! That's enough wood for 70,000 trees.

Mad machines – the self-igniting match

Here's a marvellous match-saving (and tree-saving) invention. A nineteenth-century French scientist made this bell-shaped box.



As you pull out the match, a spark sets fire to the chemical inside the box. Return the match to its hole and the flame goes out. Brilliant!
JUST WATCH WHERE YOU USE IT!

Explosions fact file

Name: Explosions

The basic facts: Explosions are just a type of burning.
1. "Low" explosives produce rapid burning and lots of gas. The gas blasts outwards causing the explosion.
2. "High" explosives use chemical reactions to do this faster.

Horrible details:
Explosives blow people up. Oddly enough though, most explosion injuries are caused by flying objects rather than the blast itself!

Bet you never knew!

Methane gas caused explosions in coal mines. Miners used candles to see in the dark but this led to disasters that claimed hundreds of victims. These explosions are rare now – thanks to our old friend Sir Humphry Davy.

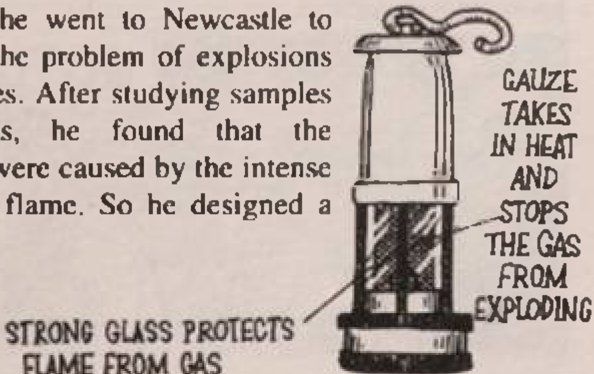
Chaotic chemists' hall of fame:

Sir Humphry Davy (1778-1829) Nationality: British

Sir Humphry on schooling...

Now let that be a lesson to teachers everywhere. In fact, Davy taught himself science and he must have done a good job. Within five years of reading his first chemistry book he was a Professor of Chemistry at the Royal Institution!

In 1815 he went to Newcastle to investigate the problem of explosions in coal mines. After studying samples of the gas, he found that the explosions were caused by the intense heat of the flame. So he designed a lamp:



But as mines were getting safer, a soldier's life was getting more dangerous.

A potted history of gunpowder

1 A seventh-century Chinese alchemist described how to make gunpowder from sulphur, saltpetre and charcoal.

2 Saltpetre is found in rotting pig manure. Early gunpowder makers boiled the disgusting mess and then cooled it to make saltpetre crystals.

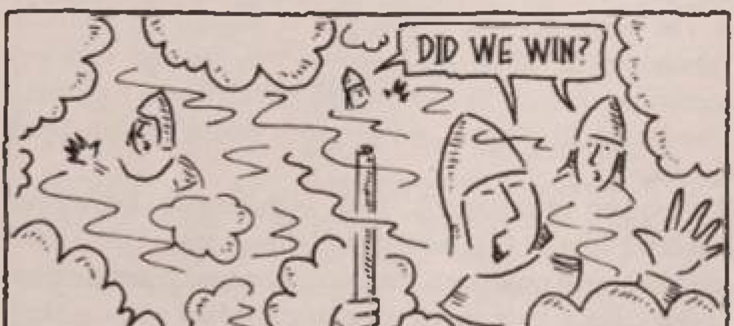
3 Licking the mixture checked the crystals for unwanted salt. Eurk!

4 For six centuries the Chinese guarded their secret. Then Europeans somehow managed to steal the recipe and invented cannon.

And muskets that could fire through armour...

And bombs to put under city walls...

5 Wars would never be the same again. The problem with gunpowder was that it filled battlefields with thick smoke. So you couldn't see anything...



6 Nowadays gunpowder is found in fireworks and a similar chemical is used to preserve tinned meat.

Bet you never knew!

One type of explosive was invented after another bit of chemical chaos. Christian Schönbein (1799-1868) was experimenting in his kitchen when he spilt a mixture of nitric and sulphuric acid. So he snatched his wife's apron to mop it up. Keen to avoid an explosive situation with his wife the chaotic chemist left the apron to dry. It dried ... and exploded! Schönbein had discovered nitro-cellulose – the world's first exploding fabric. Oddly enough, in the First World War nitro-cellulose was used to stiffen plane wings.

Bangs and blasts!

1 The bang in your firecracker is caused by mercuric fulminate. In 1800, its inventor was injured during a lecture as he tried to show it off. Luckily, you only get a tiny bit in a firecracker or your party would go with a very loud bang!

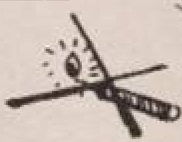
2 Another explosive is TNT – otherwise known as trinitrotolulene (try-nite-tro-toll-you-lene). One TNT molecule will produce a blast one thousand times its size. It just takes a little shock to set it off. Mind you – a blast like that will give you more than a little shock.

3 Amazingly, about half a pound of butter stores as much energy in the bonds between its atoms as the same quantity of TNT! But butter tastes nicer on toast and it doesn't blow up either.

The man who made a bomb

Dynamite was discovered by Swedish inventor Alfred Nobel. The blasting power comes from nitroglycerine which is an oily mix of glycerine and acids used by Schönbein. Although he became one of the world's richest men, Alfred Nobel wasn't a bundle of laughs. He was tormented by a guilty conscience. Here's what his diary might have looked like.

1865



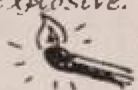
Dear Diary

It's all got out of hand. Explosives are fantastic and fascinating and fun, and I've never been afraid of them . . . but today I've discovered just how dangerous, dreadful . . . and deadly they can be. There was this explosion in the factory.

All my work's destroyed. And most terrible of all, my brother is dead. That's what explosives really do. They kill people. It's horrible. And now I'll never see my brother or speak to him again.

I'll never touch explosives again, either! If only Dad hadn't got me started, what with his underwater mines, I'd never have thought about playing around with that nasty nitroglycerine stuff.

No, that's it, finished. No more loud bangs for me, not even so much as a pop. I'm going to forget all about the amazing effects of playing with chemicals, loud bangs, fireworks, sparks flying . . . It's just too dangerous. But it's so fascinating, too, maybe I could just play around a little, from time to time. I could try and do something good with explosives. Maybe I could invent one that didn't do anyone any harm. I could invent a safe explosive. Yes, that's it, that's what I'll do!



1866

I'm brilliant! I've cracked it. I've invented a safe explosive that will definitely make the world a better place. They'll use it in mines and, well, anywhere, really. And the brilliant thing about it is that it won't blow up if you accidentally drop it. It's so simple to make. I just mixed that nasty nitroglycerine with kieselguhr (made from the ground-up

skeletons of tiny sea creatures). That was all! The kieselguhr absorbs the chemicals in the nitroglycerine. Then you fire an explosive cap to set it all off. I'm going to call my new invention "dynamite".

~1895~

Disaster! My wonderful life-saving invention has gone horribly wrong. It's out of control. It's made me rich beyond my wildest dreams, but what good is the money when they use my invention for weapons of war? I wish I'd never discovered it. I want to be remembered for good deeds, not bad.

But if I can't get it right, maybe someone else can. I'm going to use my fortune to fund a really special prize. It will be presented every year, and given to people whose inventions do truly great things for science, the arts . . . and peace. That should make the world a better place . . . shouldn't it?

But can chemicals really make the world a better place?

Chemical chaos?

Chemicals cause chaos – if we don't look after them properly, if they explode at the wrong moment, or if we let them loose without knowing what they'll do to the environment. So are we cooking up a chaotic chemical catastrophe? Or is it just the chaos of invention ?

As ever, it's always the bad news that hits the headlines first. (You don't hear so much about the exciting new discoveries that happen all the time.)

A DEADLY DISASTER!

December 11,1979 Just before midnight, 106 train wagons of dangerous chemicals jumped the tracks in Mississauga, Ontario, Canada.

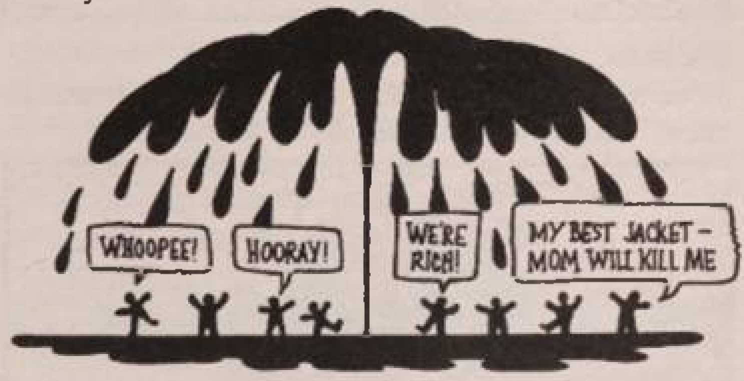
One wagon contained 89 tons of chlorine, 11 others were full of easy-to-burn propane gas. Witnesses report scenes of chaos with massive fires raging out of control. One carriage exploded at once and another was blasted 820 yards away.

A quarter of a million people were forced to flee their homes as the chlorine wagon began leaking deadly fumes. Firefighters on the scene are working round the clock in a desperate bid to plug the leak. Their first attempts have failed to make the area safe. Meanwhile the evacuees wait anxiously for news of when they can return to their homes . . .

Luckily, the first explosion had thrown the chlorine high into the air and away from nearby cities. The locals were not in any danger, but it was days before the experts could confirm the air was safe. Others haven't been so lucky. Although the chemical industry has strict safety standards, horrible accidents can happen. In Bhopal, India, in 1984 two thousand people were killed by a poison gas cloud following an explosion at a chemical factory. And there's more bad news...

A sticky situation

Imagine crude oil – it began as the rotten bodies of plants and animals squashed under the ground millions of years ago. It's thick, black, sticky and very messy and people risk their lives to get at it. They drill holes in the beds of stormy oceans and venture into barren deserts.



And why? Because oil is horribly useful. You can make it into substances such as gasoline to power cars, asphalt to surface roads and the raw ingredients of plastics.

Trouble is – like many chemicals, oil causes chaos when it gets out of human control. Oil spills wipe out wildlife and turn golden sandy beaches into black, slimy wastelands. And car exhausts cause problems too.

How's this for progress...?

The 1900s...

Smog made from coal smoke and fog caused pollution in cities. In Britain smoky coal fires were banned in the 1950s.

The 1990s...

Smog made from car exhaust fumes caused pollution in cities. What do you think should be done about it?

The good news

Although chemistry seems horribly chaotic at times, chemistry is also incredibly creative. The creative ideas of chemists can make most people's wildest dreams look rather tame. Just imagine a spacecraft made from a material that resists temperatures of 18,032°F without melting.

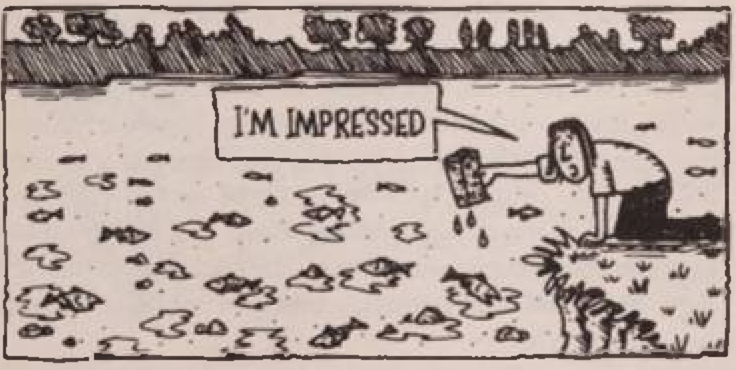
If your reaction is to say, "What will those science fiction writers think of next?" you'll be amazed to know that this substance already exists. It was invented in 1993. And here are a few more substances that seem too good to be true.

Fantastic facts

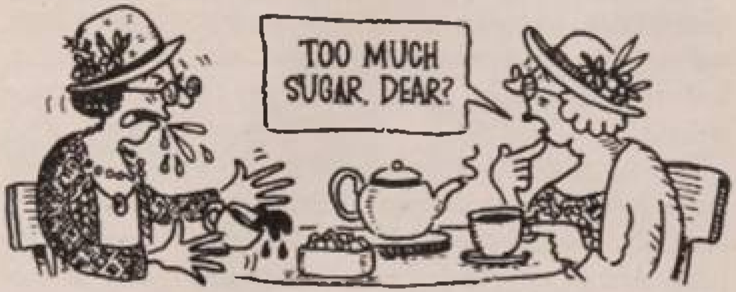
Chemists have invented...

1 A superacid called fluoro-antimonic (flewer-ro-anti-mon-ic) acid with twenty thousand trillion (20,000,000,000,000,000,000) times the dissolving power of the most powerful concentrated sulphuric acid. Keep your fingers clear of that!

2 A sponge called H-spon invented in 1974. It's so good at mopping up spills that it can hold up to 1,300 times its own weight in moisture.



3 A new type of sugar cube 650 times sweeter than ordinary sugar. It's called talin and is made from seeds of the West African Katemfe plant.



4 Crystals called zeolites in the shape of tiny sieves that separate individual atoms in a chemical. They're a compound of aluminium, silicon, water and metals.

And there's more good news...
Chemists can actually use their chemical knowledge to tackle the chaos of chemical pollution.

1 Many of the world's cars contain catalytic (cat-a-lit-ic) converters. The metal honeycomb shape is coated with platinum. This traps the nasty chemicals produced by the car's engine and breaks them down into harmless chemicals such as water.

2 Ordinary petrol contains lead – added to stop the car engine making knocking sounds. Unfortunately lead in car exhaust fumes is enough to take your breath away. Don't forget lead is poisonous! So chemists have developed lead-free petrol and you can use it in your catalytic converter.

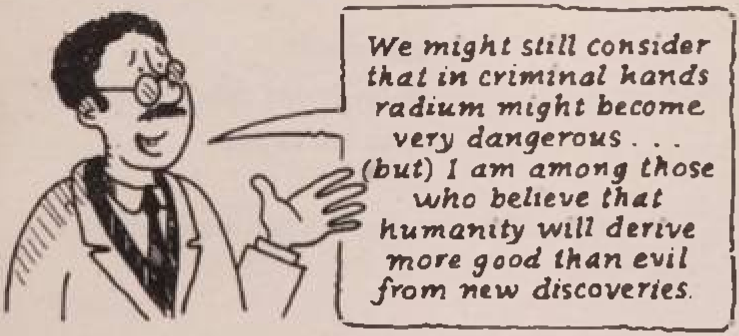
3 Every year people chuck thousands of tons of plastics in deep holes in the ground. What a waste. But in 1993 a factory opened in Britain that turns plastic back into the oils that they were made of originally. So now you can make old plastic into new plastic.

4 You remember that hole in the ozone layer caused by chlorine-based gases? They were used to put the squirting power into aerosol cans. But they've been banned and chemists have developed safer gases to use instead. So now you can spray on deodorant without causing a stink for the environment.

The chaotic truth

It's not chemicals that cause chaos – it's *humans*. We make chemicals. We store them, we use them – ultimately we are responsible for what they do.

We can use them for good or allow them to cause chaos and destruction. The decision is ours. Here's what one chemist had to say on the subject. Pierre Curie (1859-1906) and his wife Marie (1867-1934) discovered the element radium. Pierre said:



We hardly know what lies in the future. Except that out of the chaos of chemistry will emerge even more amazing and incredible inventions. And the future will be more fantastic and hopefully brighter than ever before. And that's the chaotic truth!

HORRIBLE SCIENCE

Science with the squishy bits left in!

Also available:

Ugly Bugs
Why do flies throw up on your tea?
Take a magnifying glass to the insect world.

Blood, bones and body bits
Are you dying to find out which animals live on your eyelashes? The human body goes under the scalpel.

Look out for:

Nasty Nature
Why do vultures have bald heads? Explore the nasty side of the animal world.

Science has never been so horrible!

HORRIBLE SCIENCE

Science with the squishy bits left in!

Chemical Chaos could make your brain explode! Are you burning to find out:

- why glass eyes aren't really made of glass?
- what would make the worst stink bomb ever?
- how to make your own toothpaste?

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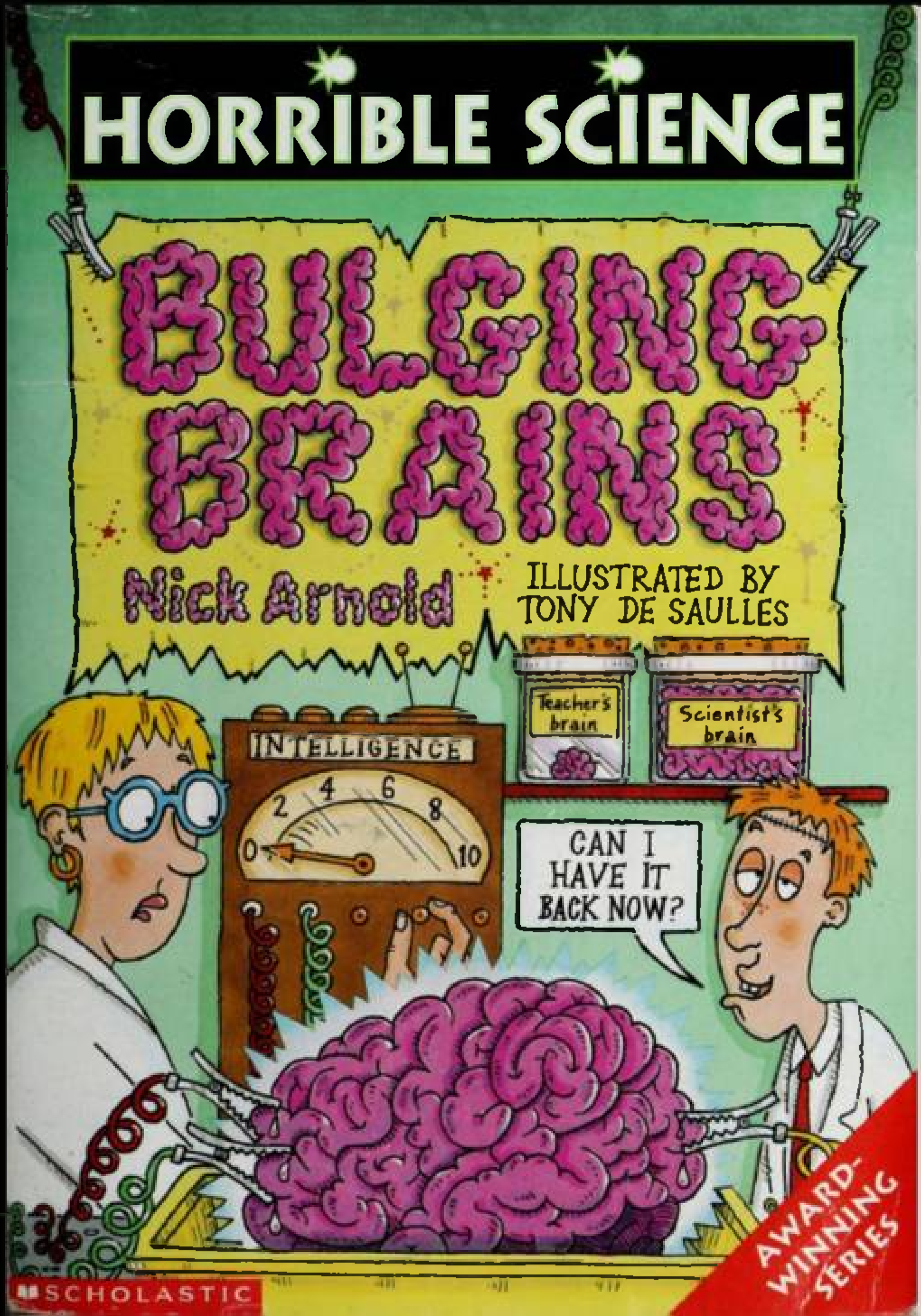
HORRIBLE SCIENCE
BULGING BRAINS
Nick Arnold
ILLUSTRATED BY TONY DE SAULLES
Teacher's brain
Scientist's brain
INTELLIGENCE
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HORRIBLE SCIENCE

BULGING BRAINS

Nick Arnold

Illustrated by

Tony De Saulles

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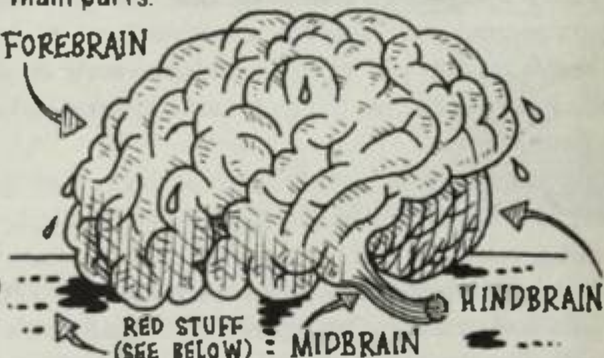
Inside the bulging brain

Still want to be a brain surgeon? Excellent. Now that you've found out a bit about what the bulging brain does, you're ready to check out how it works . . .

Bulging fact file

NAME: The brain

BASIC FACTS: The brain is made up of three main parts:



Each area is made up of smaller parts with different jobs. (For more details see page 32-35.)

DISGUSTING DETAILS: The brain needs energy from the sugar and oxygen carried in the blood. So it sucks in about one pint (750 ml) of the red stuff every minute. All this hot blood gives out lots of heat – that's why your brain is the hottest part of your body.

Bet you never knew!

Your brain weighs less than 2.8 pounds (1.3 kg) – that's a little less than the weight of a large box of sugar or the weight of all the germs swarming in your guts. In fact, the brain is only one-fiftieth the weight of a grown-up man, and it's far lighter than your guts, your blood, your skin, or your bones.

Have you got a bulging brain?

So just how smart is your brain? Well, if you're going to be a brain surgeon you'll need to know all the answers to this brain-teasing quiz:

1. What happens if half your brain is damaged?

a) It doesn't half hurt, ha-ha. No, seriously, you can't remember anything.

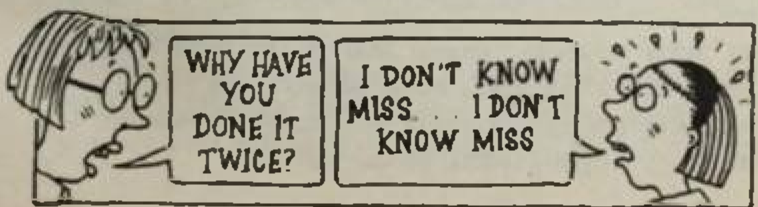
b) You die. No one could survive such a terrible injury.

c) You can live normally although you have to relearn vital skills such as talking.

2. What happens if someone cuts your brain in two?

a) Your brain becomes twice as smart.

b) Your brain functions normally but you may find yourself doing your science homework twice.



c) Each side of your brain behaves like a separate person.

3. Imagine you were born without 97 percent of your cortex (cor-tex) – that's the wrinkly part of your brain at the top where you do your thinking. You're left with a tiny slice of brain in this area. What would happen to you?

a) You'd be left with the brains of a half-witted stick insect.

b) You'd be as brainy as anyone else . . . but only for five minutes a day. The rest of the time you'd blunder around like a zombie in a horror movie.

c) Your brain would work normally and you could be as brainy as your science teacher. (Yes, teachers are believed to be intelligent.)

4. What would you feel if someone stuck a finger into your brain and wiggled it around?

a) Unbearable agony – the worst pain in the world.

b) You'd feel hot and cold shivers all over your body.

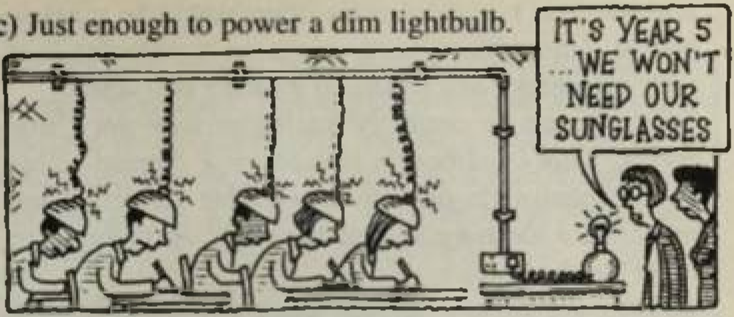
c) Nothing, because the brain cannot feel touch.

5. How much energy does your brain use in a science test?

a) Such a small amount that it can't be measured (especially if you don't know the answers).

b) Enough to light up the classroom. No wonder the test makes you light-headed, ha-ha.

c) Just enough to power a dim lightbulb.



6. Why do you feel tired after the test?

a) All that mental effort strains the brain.

b) During the test your brain drew extra energy in the form of sugar in your blood. After the test your body feels tired because it lacks this vital blood sugar.

c) You were so tense your muscles bunched up and used up energy. And your muscles feel tired – not your brain.

7. How much of your brain is water?

a) About 5 percent

b) 32 percent

c) About 80 percent

Answers:

All the answers are **c)**, so you can check them without taxing your brain too much. And here are a few more details to get you thinking.

1. A bump on the head can injure the brain (see pages 129–139 for the grisly details). Yet the brain can survive dreadful injuries. If one half of the brain is injured, the half that's left learns how to do the work of the damaged half.

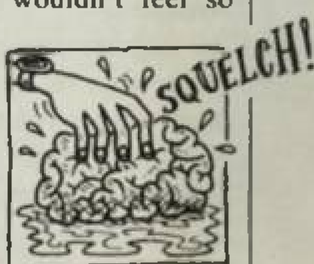
2. This operation was performed in the 1960s on patients suffering from violent fits. The operation stopped the fits from spreading through the brain. But afterward the two sides of the brain acted like separate people. One woman tried to put on a different shirt with each hand. She ended up wearing two shirts.

3. People can be perfectly intelligent with very little cortex. This condition is caused by a disease called hydrocephalus (hi-dro-cef-al-us). This results in too much fluid sloshing around the skull, so there's less room for the brain.

4. Your nerves take signals from elsewhere in your body to your brain. This means you actually experience pain, touch, taste, smell, sound, and vision in your brain. But oddly enough, there are no touch sensors on the brain itself. (You'll find the lowdown on senses on pages 45–64.)

5. Yes, in lightbulb terms we're all rather dim. Scientist Louis Sokoloff of the US National Institute of Mental Health has found the brain uses the same amount of energy gazing dreamily at a sunset as it does in a tough science test. So what would you rather do?

6. If the questions were really easy and you managed to relax in the science test, you wouldn't feel so beat.



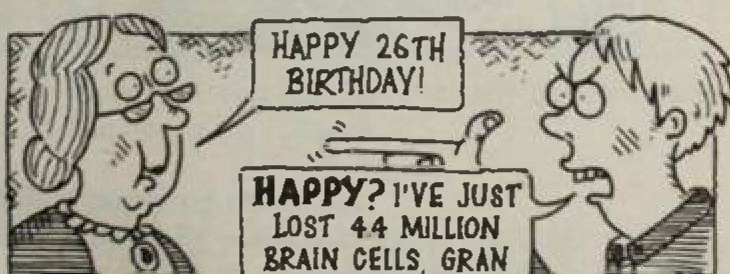
7. That's why when you become a brain surgeon and get to touch a brain it'll feel like pudding or a soft-boiled egg. The brain needs water for vital chemical reactions such as sending nerve signals. Without water, a brain begins to overheat and starts to see things that aren't there. Ultimately it will die.

Bulging brain secrets

Psst – wanna know a brain secret? There's more to your brain than water. For example, your brain's made up of millions of cells and each one is so small you need a microscope to see it. (No, these aren't cells that people get locked up in.) Read on, your brain might learn something . . .

Bulging brain cells

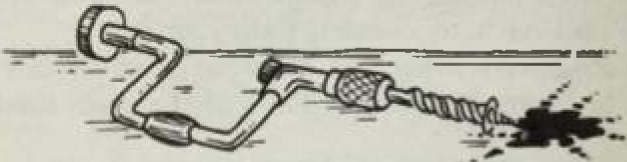
1. Your brain is bulging with 100,000,000,000 – that's 100 *billion* – nerve cells or neurons. These are special cells used for sending signals inside the brain. If you don't believe it, try counting them yourself.
2. Each cell is a living blob, and some are so tiny that you can fit 25 onto this period. (You'll need a steady hand for this.)
3. If you laid the cells from just one brain in a line they would stretch 621 miles (1000 km) – a quarter of the way across the USA.
4. Unborn babies grow new brain cells at the rate of 2,000 every *second.* And all your brain cells were already in place when you were born. But after you get to age 25, about 12,000 cells die each day (that's 4.4 million a year).



Don't worry! You can lose cells at this rate for a lifetime and still have 98 percent of them left.

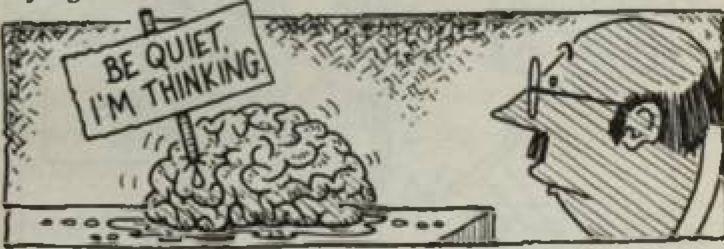
5. Your brain cells are desperate for oxygen. Starve a brain of blood for just seven seconds and it goes on strike and switches itself off. You might call this fainting. Scientists aren't quite sure how this fascinating process takes place.

Yep – even now scientists are baffled by the mysterious brain. But not quite as baffled as the people who first probed the brain's grisly secrets. Check out the next page and prepare to be baffled, bewildered, bemused, and . . . ***horrified.***

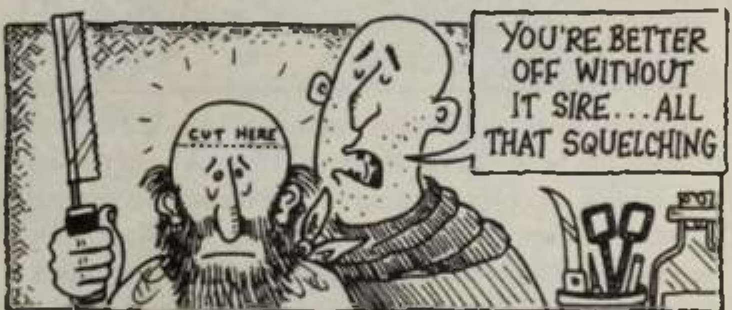


BULGING BRAIN EXPERTS

The first brain surgeons had a problem. The bulging brain is mysterious because you get no clues to tell you what's going on inside it. I mean, there's no helpful sign saying . . .



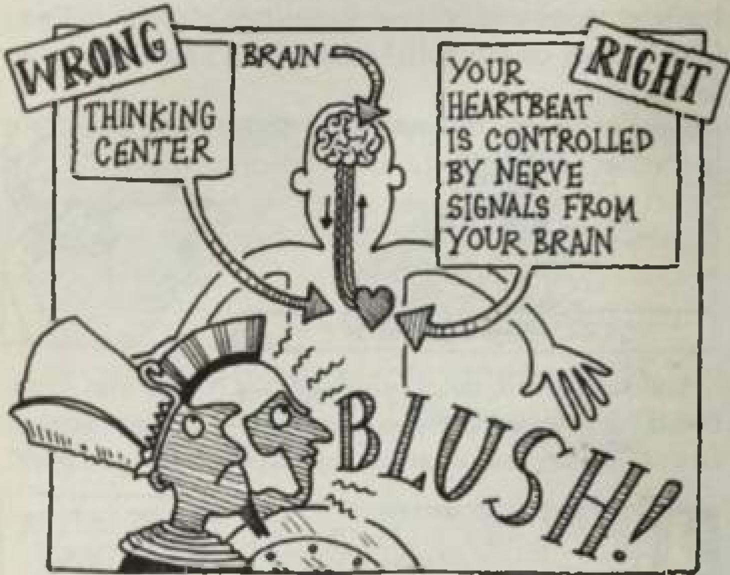
Unlike certain other parts of the body, the brain doesn't do interesting things like digest food, burp, or even fart. The brain just sits around all day squelching to itself.



So it's not so surprising that these early pioneers made some mind-boggling mistakes.

Mind-boggling mistakes

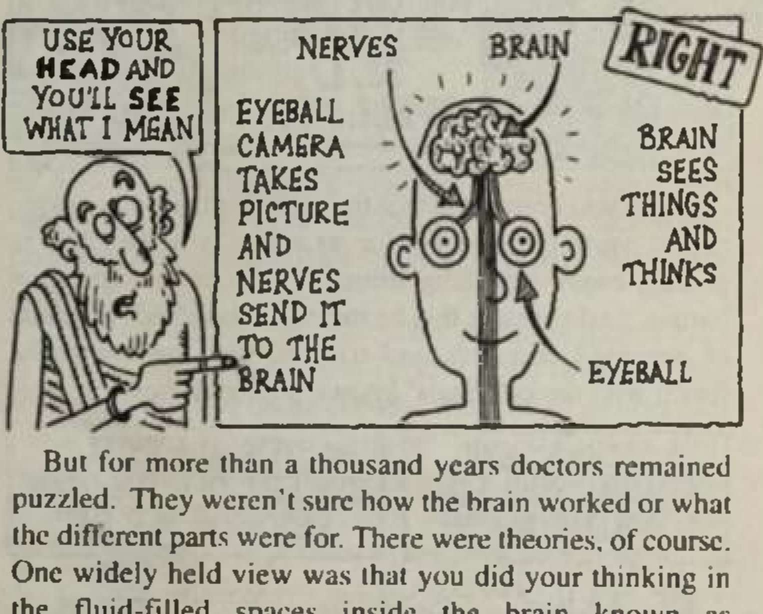
The ancient Egyptians and Greeks thought that the thinking part of the body was the heart. This seemed right because your heart beats faster when you're upset or excited. Is that why your teacher (who could be as old as the pyramids) makes you learn boring facts "by heart"? Well, anyway, the ancient Greeks and Egyptians were *wrong*.



Brainy Greek philosopher Aristotle (384–322 B.C.) also thought the heart did the thinking. He reckoned the brain was simply a cooling system for the blood. According to Aristotle, when you get a cold your cooling system overflows. (That's why snot dribbles out of your nose.)

But he was *wrong*, too. Snot is made in the lining of the nose to catch germs and dust. Your nose is runny in a cold because your body is trying to flush out the germs that cause the illness.

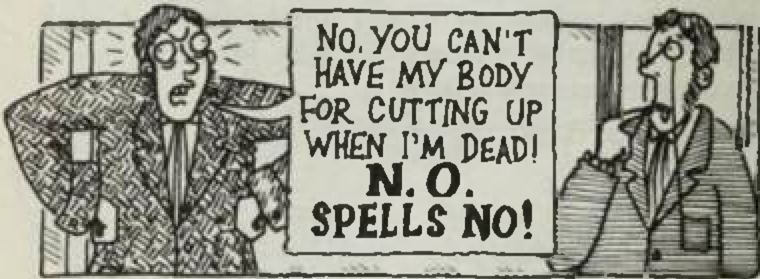
Actually, Greek doctor Alcmaeon of Croton (6th century B.C.) had already figured out what the brain was up to. He cut up dead bodies and noticed that there were nerves running from the eyeballs to the brain. He also noted that patients with head injuries couldn't think clearly. "Clearly," thought Al, "the brain has to be involved in seeing and thinking."



But for more than a thousand years doctors remained puzzled. They weren't sure how the brain worked or what the different parts were for. There were theories, of course. One widely held view was that you did your thinking in the fluid-filled spaces inside the brain known as ventricles (ven-trick-als). The rest of the brain was a squelchy bubble-wrap to cushion the vital holes. But by the 18th century, scientists were looking at the brain in a more scientific way. And making strange and grisly discoveries . . .

Bulging brain secrets: Franz Gall (1758–1828)

As a child, Franz noticed that one of his school friends had bulging eyes. This boy was good at spelling, and Franz wondered if everyone who is good at spelling has bulging eyes. After he became a doctor in Vienna he cut up dead bodies and came to the conclusion that the eyes bulged because the brain behind them was also bulging. Franz reckoned this bulging area dealt with spelling.



Franz was convinced that the size of other brain bulges reflect your personality, for example, whether you're greedy, enjoy smashing things up, or have a sense of humor. And to prove this he measured hundreds of skulls of executed criminals and tried to link the bumps he found with the criminals' known personal traits.

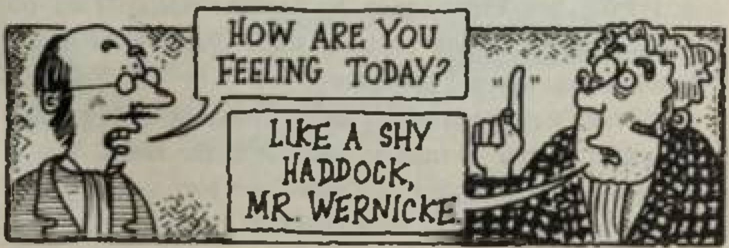
Despite his many skulls, er, I mean skills, Franz was on the wrong track. There is no link between the shape of your brain and your personal qualities. But up to the 1850s many people believed Franz had found a way to measure personality. And when Franz's own brain was examined after his death it was found to be smaller than average. Now, I wonder what that could mean?

The talking brain: Paul Broca (1824–1880)

Paul was working as a surgeon in Paris when he met a patient named Tan. "Tan" was his nickname because the poor man had suffered a brain injury that left him unable to speak any word except "tan." Tan was already ill when he saw Broca. Broca could do nothing to help his patient, and a few days later he died.

Tan's misfortune was a great opportunity for science. Broca cut open Tan's brain and found that the injury was in what's now imaginatively known as Broca's area (surely it ought to be called Tan's area?). Broca realized that this area of the brain helps you pronounce words properly.

This was a major discovery, but as far as speech goes it wasn't the last word – geddit? In 1874 German scientist **Carl Wernicke (1848–1905)** found another part (now known – surprise, surprise – as Wernicke's area) that helps you *choose* the right words. People with brain damage in this area often talk utter nonsense but with perfect grammar. (For more details, see page 75.)



The twitching brain: Julius Eduard Hitzig (1838–1907)

If Mrs. Hitzig had walked into the bedroom unexpectedly one day in 1870 she would have received a horrible shock. Her husband and his pal Gustav Fritsch were experimenting on a dog's brain using her dressing table as a workbench.

At the time, Hitzig was working as a doctor in Switzerland, but he didn't have a lab of his own. (By the way, it's a bad idea to use your mom's dressing table to practice your brain surgery. You could use the bathroom instead, but make sure you mop the floor afterward.)

Actually, the dog was getting quite a shock, too. An electric shock to the left side of its brain. Hitzig found that this made the dog's right legs twitch. This electrifying test proved that the left side of the brain controls the right side of the body and vice versa. Later in the year, war broke out between Germany and France, and Hitzig got the chance to try the same tests on wounded soldiers with parts of their brains shot away. The results confirmed his theory.

As a result of the work of these pioneers, new groups of scientists began to take an interest in the brain. You'll be coming across some of them later on in this book. Here's a handy guide to help you spot them . . .

Spot the scientist

1. Neurophysiologist

(new-ro-fizzy-olo-gist)

INTERESTED IN: finding out how the brain and nerves work.

WHAT THEY DO: study bits of chopped-up brain and analyze chemicals from the brain.

WHERE THEY WORK: University laboratories or large hospital labs.

2. Neurologists (new-rol-lo-gists)

INTERESTED IN: Studying the brain and nerves, too, but they're especially keen on horrible but fascinating brain and nerve diseases.

WHAT THEY DO: Treat patients with diseases of the nerves and brain. Some of them are also neurosurgeons, which is the fancy term for brain surgeons.

WHERE THEY WORK: Hospitals.

3. Psychiatrists (si-ki-a-trists)

INTERESTED IN: Diseases of the mind. Psychiatrists are trained as doctors rather than purely as scientists.

WHAT THEY DO: Talk to the patient and attempt to find the causes of their illness.

WHERE THEY WORK: general hospitals and psychiatric hospitals and clinics.

4. Psychologists (si-col-lo-gists)

INTERESTED IN:
Studying the brain by looking at the way it makes people behave.

WHAT THEY DO:
Set up experiments to find out how people react in certain situations. Some of these tests are a bit wacky. Some psychologists are interested in diseases of the mind, but unlike psychiatrists they are not trained as doctors.

WHERE THEY WORK: University labs and hospitals.

Peculiar psychologists

The psychologists take their lead from a very peculiar German scientist, and here's his story.

Horrible Science Hall of Fame

Gustav Fechner (1801–1887) Nationality: German

Fechner's brain was always bulging with ideas, but his interest in the mind began with a horrible accident. The physics professor was studying light when he blinded himself by looking at the sun. (Something you should never do.) So you could say poor old Gus got blinded by science – geddit? He became so miserable that he went mad for two years.

But one day he was sitting in the garden, and he felt a sudden impulse to tear off his bandages. Amazingly, he found he could see again! Incredible colors flooded his brain, and he was so excited he imagined he could see brains inside flowers. (Yes, you did read that last part correctly.) Gus wrote a peculiar book describing how plants have minds. (Believe this and you're a real cabbage brain.)

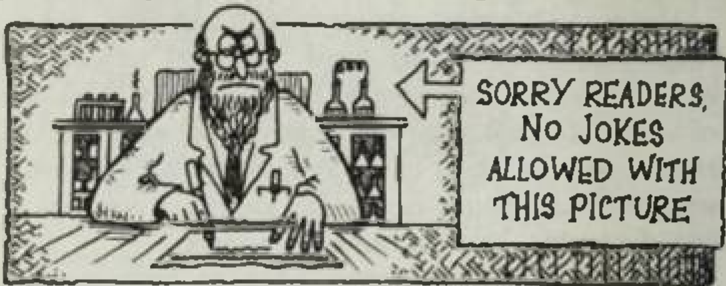
Two years later Gus was enjoying a nap. Well, maybe "enjoying" is the wrong word. Gus was racking his brains. And not about whether he'd find a toy in his box of breakfast cereal or how to make contact with a turnip. He was trying to think of a way to study the brain using scientific experiments rather than cutting it open on an operating table. Then he had a brainstorm.

All you had to do was measure how the brain reacts to different sensations. For example, in one test Gus shone a light in volunteers' eyes and slowly increased the brightness until they noticed the change. This allowed him to measure the brain's ability to notice changes in brightness.

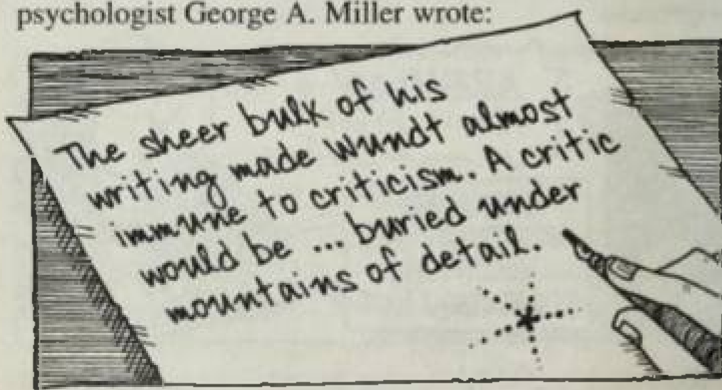
Gus had launched a new branch of science called psychology – the study of human behavior (although the name actually means "study of the mind" in Greek).

And this exciting new science owed its existence to the fact that the scientist wanted an extra snooze. (Tell your parents this story next time you want a nap. You never know – they might even fall for it.)

Fechner's work was continued by another German, **Wilhelm Wundt (1832–1920)**, who set up the world's first psychology lab. Wundt never laughed or smiled or joked and spent his entire life working.

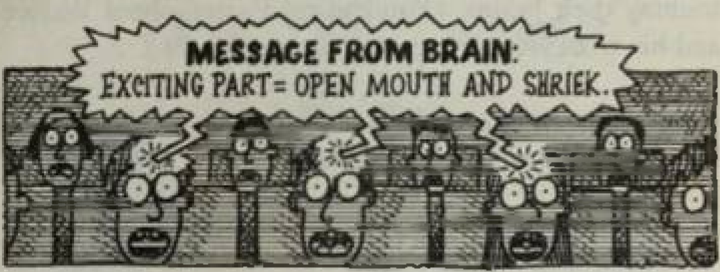


His books totaled 53,735 pages – that's equal to writing a 500-page book every year for 100 years. He wrote so much that critics complained that it was hard to discover what Wundt actually thought. American psychologist George A. Miller wrote:

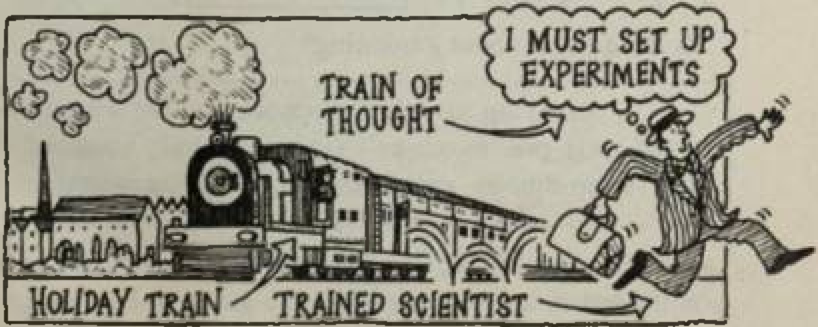


Brilliant, eh? So if you want to baffle your teacher, write a 500-page essay for your science homework. But this tactic didn't stop other psychologists from disagreeing with Wundt's approach to psychology. Increasingly they were finding that the brain did a lot more than simply respond to sensations.

Another German psychologist, **Max Wertheimer (1880–1943)**, wondered if the brain plays tricks to help make sense of a film. A film is made up of thousands of pictures that you see very quickly – about 24 pictures a second. The brain can't keep up with this rapid change, so it sees the pictures as a continuously moving scene. So your brain gets the whole picture – and you get the whole movie, including the exciting part *and* the happy ending.



Max dreamed up this idea on a train in 1910. He was supposed to be on vacation, but he excitedly leaped off the train (he waited for it to stop first – he wasn't that excited) and set up experiments to find out why.

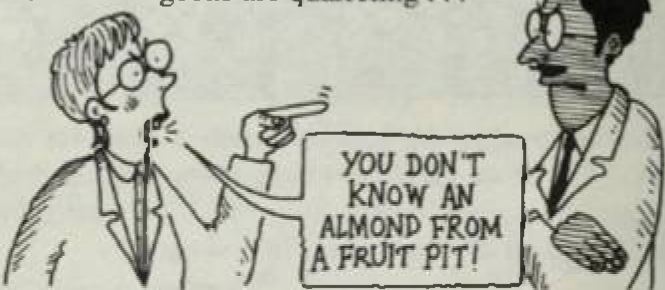


Max proved the brain sees the whole scene first and then figures out how the moving objects relate to one another. And he worked out a new theory of psychology called Gestalt (ges-stal-t) based on these ideas. Gestalt actually means "whole" in German, and the new theory underlined the importance of finding out how the brain makes sense of things like a film. This was a step forward from Wundt's work, which simply looked at how the brain responds to sensations.

Meanwhile, American psychologists such as **John B. Watson (1878–1958)** and, later, **Burrhus F. Skinner (1904–1990)** were changing the behavior of rats by training their brains. (You can read more about Watson and his wacky experiments on pages 86–89.)

Bulging brain expressions

Two brain surgeons are quarreling . . .

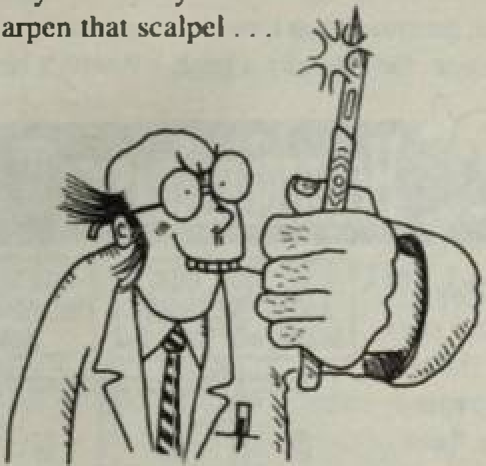


Is the quarrel about gardening?

Answer: No. The amygdala (a-mig-dal-a) and putumen (putt-you-men) – almond and fruit pit in Greek – are odd names for areas of the brain.

Confused yet? Well, there are lots more bits and pieces you'll need to know about if you're going to be a brain surgeon. Maybe things would be clearer if you could get your hands on a real, dripping brain. Like to be grossed out? Hope so, because if not, the next chapter's so nasty, it could drive you out of your mind.

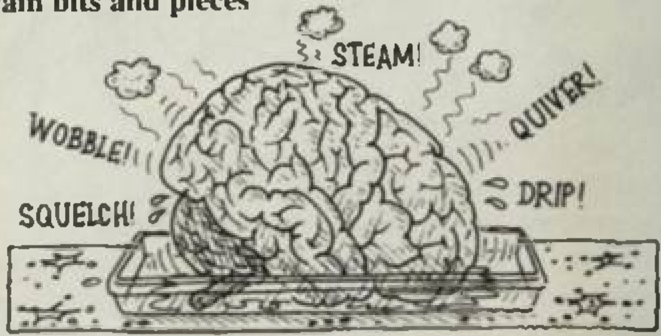
Better sharpen that scalpel . . .



BULGING BRAIN BITS'n PIECES

As a brain surgeon you need to know all about the main bits and pieces in the brain. Fortunately, we've got hold of a real, genuine brain from a real, genuinely dead person to help you. Go on, take a peek – it won't bite you.

Brain bits and pieces



The main area you can see is the cortex (that's the wrinkly, thinking part, remember?).

Dare you discover . . . why the cortex is wrinkly?

Ever wondered why brains are wrinkly? Now's your chance to discover the *real* answer . . .

All you need is:
Two sheets of letter-size paper. (Your school report might come in handy here.)

All you do is:
1. Crumple one sheet of paper into a tight little ball.

2. Open it up but don't flatten it.
3. Place it over the second sheet of letter-size paper.

What do you notice?
a) The crumpled-up paper seems to have shrunk.
b) The crumpled-up paper has got bigger.
c) Both sheets of paper are the same size.

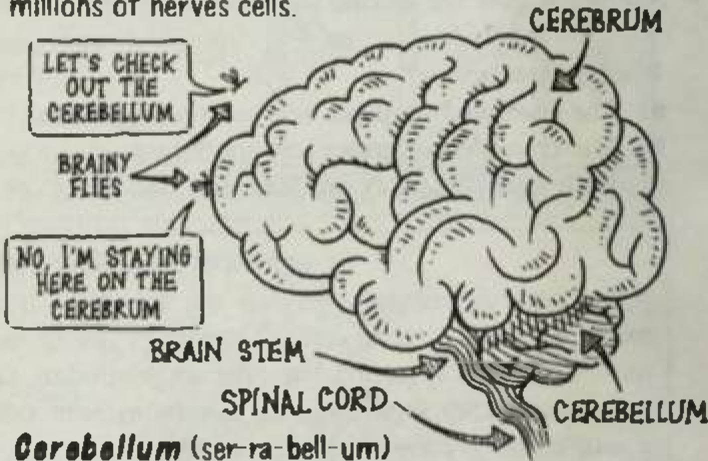
Answer:
a) The wrinkles and bumps on the paper make it take up less space. The wrinkles on your cortex allow a larger area to squash between your ears. And that's very important because the cortex is very thin – no more than 0.12 inches (3 mm) thick. If your brain was flat it would be the size of a pillowcase, and you'd need a huge head to contain it.

To find out more about some of the vital brain bits and pieces, let's have a peek at this gory but fascinating medical textbook.

BRAIN SURGERY FOR BEGINNERS

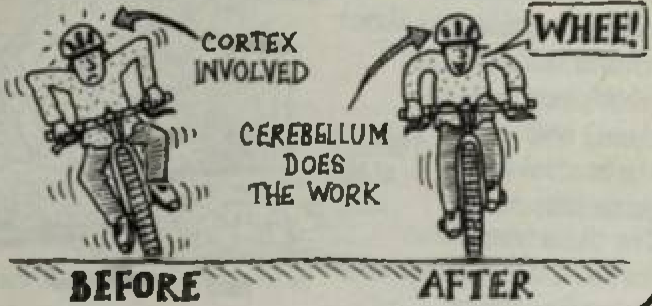
Chapter 1: Brain bits and pieces

Cerebrum (ser-ree-brum)
This is the largest part of the brain – it's so big it makes up 85 percent of the brain. This area is REALLY important because its wrinkly surface is the cortex, where thinking takes place. The cerebrum is divided into two halves (no one knows the reason for the split) The halves are linked by a bridge at the base made of millions of nerves cells.



Cerebellum (ser-ra-bell-um)
The name means "little brain" in Latin – because it looks a bit like a little brain. This pear-sized blob has two halves – one for each side of the brain. Both sides help the brain balance and control its body's movements.

Bet you never knew!
When you learn a skill such as riding a bike you think about what you're doing. Well, hopefully – otherwise you'd fall off. But after a while you happily pedal around without thinking. Oh, so you knew that? Well, when you stop thinking about what you're doing your cerebellum takes over from your thinking cortex and tells your body what to do. Scientists have found that with the cerebellum in charge you can move faster and less clumsily. (For more details on what the cerebellum can do check out pages 74 and 100.)

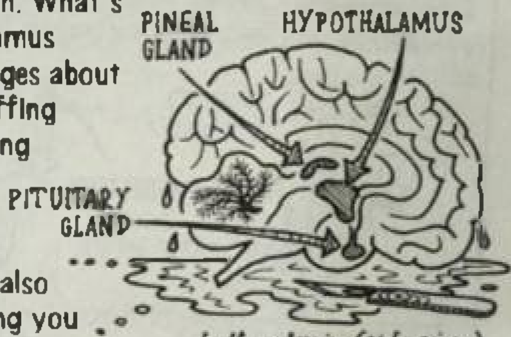


Spinal cord
This is a bundle of nerves 18 inches (45 cm) long and as thick as a thumb. Although it's not technically part of the brain, as a brain surgeon you need to know what it does. It actually takes signals to and from the brain.

Brain stem
This bit links the brain with the spinal cord. It's useful for helping the brain to go to sleep. And it's also useful for waking up the brain to danger or something interesting.

As a brain surgeon you'll need to know a bit more about the even smaller but still vital bits and pieces that lurk deep within the brain. We've cut some brains in half to help you . . .

Thalamus (thal-a-mus)
You've got two of these - one on either side of the brain. Each thalamus is full of nerve cells, and nerve signals reaching this area can be rerouted to other parts of the brain. What's more, each thalamus passes on messages about smell (that's sniffing whiffs not making them), and the control of some muscles. The thalamus is also involved in helping you remember things.

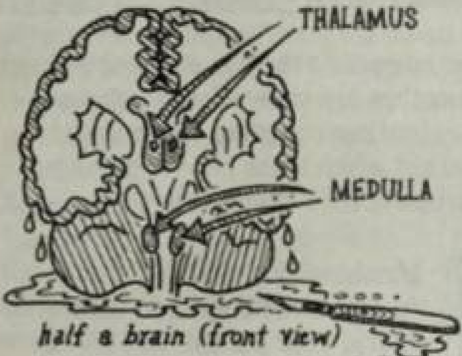


half a brain (side view)

Hypothalamus (hi-po-thal-a-mus)
A bossy little blob the size of one of your knuckles. It reckons *it's* the boss of the entire body. Controls the water content in the blood, its temperature, sweating, shivering, growing, when you sleep, etc.

The pituitary gland
Vital sidekick for the hypothalamus. Follows its orders and makes the chemicals that go round in the blood. These chemicals, or hormones as scientists call them, order the body to do what the hypothalamus wants.

The pineal (pi-nee-al) ***gland***
The name means "pine cone" because it looks a bit like a tiny one. It's sensitive to the amount of light in the day – and this may make you feel tired in the evening and wake you up in the morning. There's a type of fish called a lamprey that has a pineal like an extra eye on top of its head. The extra eye gives it all around vision. (Scientists have failed to prove the common belief that teachers have this eye in the back of their heads.)



half a brain (front view)

Medulla
Looks after the digestive and breathing jobs. It does this work automatically – which is kind of handy. Just imagine if you had to think how to do these things. You might end up breathing in your supper and then you'd be choking on your food and making a mess on the table.

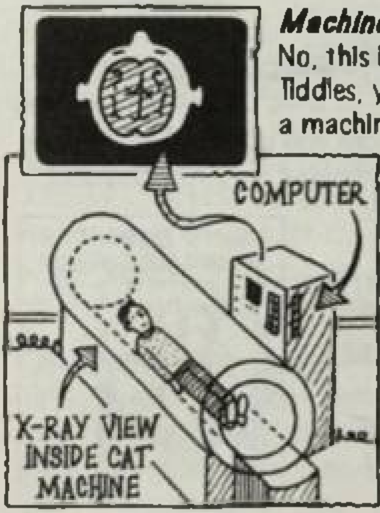
Limbic (*lim-bick*) ***system***
An odd mixture of bits and pieces including the amygdala (known in English as the "almond") deep in the brain. Shapes your feelings and is also involved in memory.

Brain Surgery for Beginners

Chapter 2: Vital brain tests

Of course, as a brain surgeon you'll be performing operations on living patients (hopefully they'll still be alive after the operation, too).

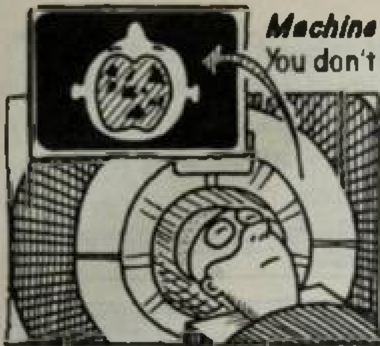
To help you plan your operations there is an amazing collection of machines that can show what's going on inside the brain before you start cutting. This is useful because you can find out which areas may be damaged or not functioning properly. Let's check them out . . .



Machine 1: a CAT

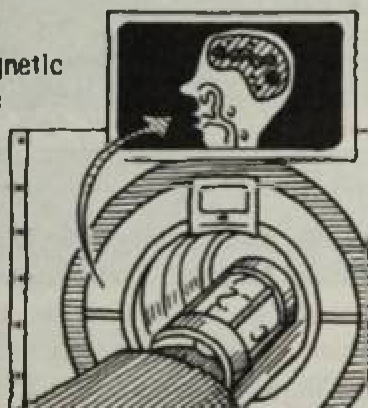
No, this is nothing to do with Tiddles, your pet cat. This CAT is a machine. CAT stands for Computerized Axial Tomography (ax-e-al toe-mog-graf-ee). As a brain expert you should be able to spout this kind of jargon effortlessly. The machine sends weak X-rays through the brain and shows the result on a computer screen.

Machine 2: a PET



You don't need cat food for this PET either. It's a Positron Emission Tomography (poz-it-tron e-miss-e-on toe-mog-graf-ee) machine. Your poor old patient has to be injected with a radioactive chemical. The scanner detects what happens when the blood takes the chemical into his brain. The blood flows to the parts of the brain that are most active. So you can see what's going on and spot any areas that don't seem to be working properly.

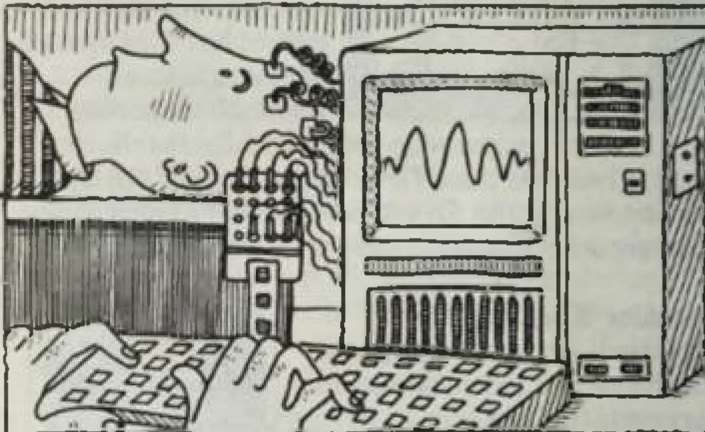
Machine 3: an NMR



This stands for Nuclear Magnetic Resonance. This nifty device surrounds the brain with a magnetic force and bombards the blood in the brain with radio waves. The atoms (tiny bits that make up chemicals) in the blood bounce back a special type of radio wave that can be detected by the machine. The NMR scan can also show where the blood is flowing inside the brain. More blood flows to the parts of the brain that are thinking, and this can be useful for discovering which areas of the brain are used for particular jobs such as solving math problems or talking.

Machine 4: an EEG

This stands for electroencephalograph (el-leck-tro-en-cef-falo-graf) machine. The metal electrodes pick up electrical signals given off as the brain thinks and the machine displays them as a print-out showing the signals as peaks.



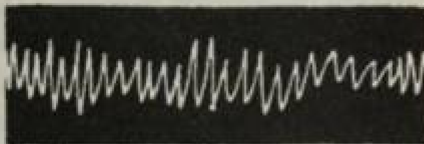
Important note to the reader:

Sorry to interrupt the book. Just a quick message to say that the EEG machine is an ultrasensitive piece of equipment. This was tested by an American doctor in the mid-1970s who wired up lime-flavored Jell-O to an EEG machine. (The flavor didn't actually affect the test.) According to the machine, the Jell-O was alive and thinking! In fact, it was reacting to people chatting in the next room. So make sure you read this book q-u-i-e-t-l-y.

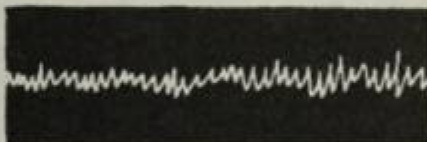
Checking the print out

Here's what your EEG print out might show.

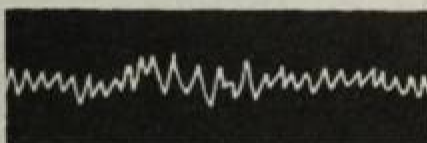
1 An alpha rhythm. This means the brain's thinking in a dreamy kind of way.



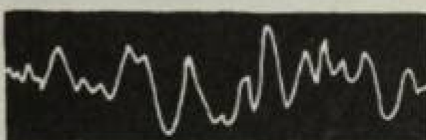
2 Beta rhythm (a bit faster). The brain is paying attention to what's going on.



3 Theta rhythm (a bit slower). The brain is feeling sleepy.



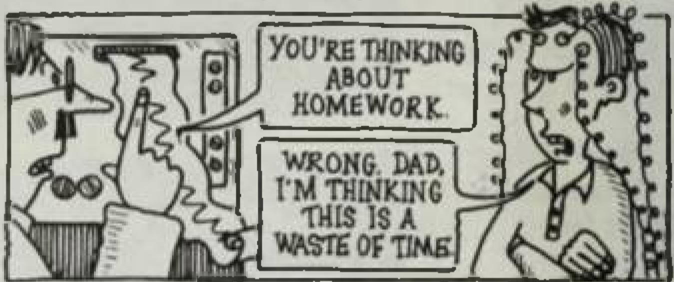
4 Delta rhythm (very slow). The brain has fallen into a deep sleep. (This has been found to be a common condition among children in science class.)



If the line is completely flat you should check that your patient is still alive. A flat line normally means the patient is dead!

Bet you never knew!

The EEG was invented by German Dr. Hans Berger (1873–1941), who spent five years sticking electrodes on people's heads to measure brain activity. He even tested his invention on his children. Hans reckoned he would be able to show what his children and the other patients were thinking. He couldn't do this, but he spent another five years writing up his experiments. And then . . . no one paid any attention.

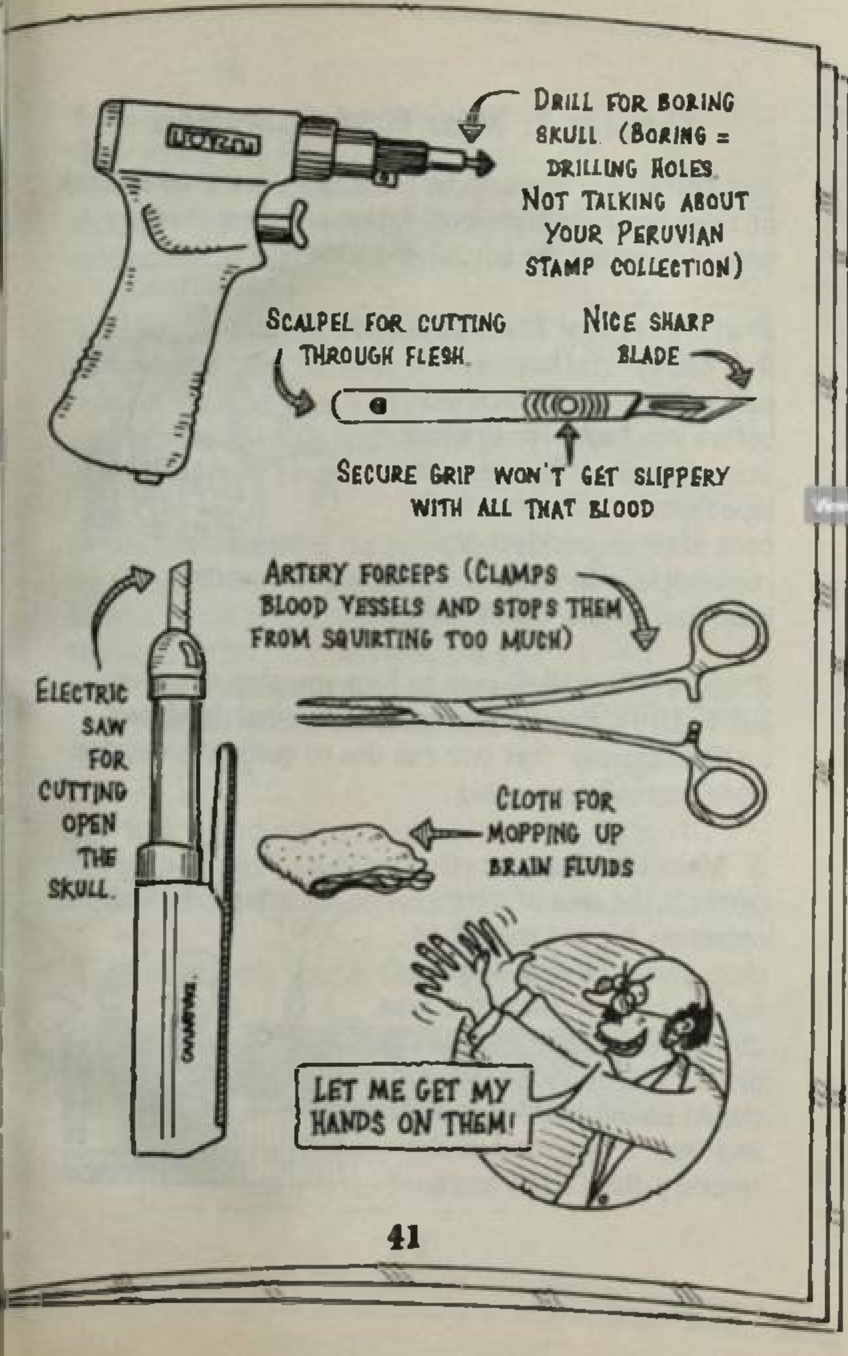


It wasn't until British scientist Edgar Adrian (1889–1977) showed that unusual wave patterns could be a sign of brain disease that EEG machines were used in hospitals.

BRAIN SURGERY FOR BEGINNERS

Chapter 3: Surgical tools

Congratulations, you're now almost ready for your first brain operation! First, though, you need to get familiar with a few brain surgeon's tools.



View Page 120

Chapter 4: Your first operation

Just before you move on to the surgery part, take a look at these handy instructions. Better still, keep them by your side during the actual operation.

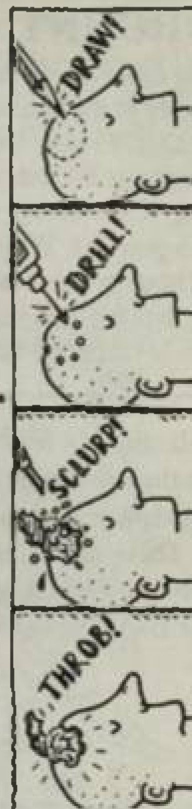
Brain surgery instructions

1 It helps if you have a particular operation in mind before you begin. For example you might want to remove a blood clot or a fragment of bone after an accident. No responsible brain surgeon would cut open someone's brain just to take a peek inside.

2 Use a PET or NMR scan to help you plan where to cut. In 1998, scientists at Toronto Hospital developed an NMR scanner that you can use to guide your scalpel while actually operating.

3 Make sure there are no germs in the area of your operation. It's not enough to clear away the dishes and put the cat out. The entire area should be scrubbed with strong disinfectant to kill germs. You should be thoroughly washed and wear a face mask and a specially disinfected gown.

4 Draw a line on the patient's head to show where you intend to cut. Oops! Nearly forgot. The patient's head should be shaved to prevent bits of hair getting mixed in with the brain.



5 To get at the brain you need to remove a bit of skull. First drill some holes in the skull. (You'll have to concentrate. One slip and you might drill through the brain.)

6 Next, saw between the holes and lift up a flap of skull and meninges (men-in-gees) – the protective layers under the skull. As you lift the meninges you may hear a *sclurping* noise as the clear fluid that surrounds the brain bubbles out.

7 If everything goes according to plan the brain should be pulsing as the blood squirts through its blood vessels.

8 Now to begin your brilliant brain operation...

HORRIBLE HEALTH WARNING!

Stop! Don't do anything until you've read the next page!

Important and very urgent announcement:

In order to do brain surgery properly you have to study in medical school for at least seven years. You didn't really think you'd be allowed to do brain surgery at your age did you? Sorry to disappoint you. You'd better stick everything back together and be grateful. Why? Because practicing brain surgery without proper training could land you in serious legal trouble and result in your allowance being stopped for 33,000,000 years. Sorry!

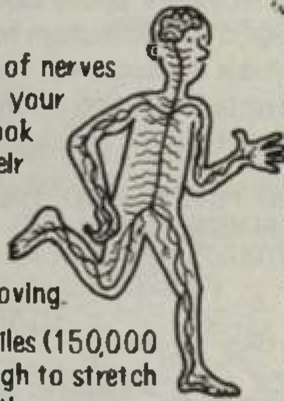
Still, there's lots more fascinating things to find out about the brain. For example, there are the amazing ways in which it manages to find out what's going on around you. These are called "senses." So here's a challenge for your brain – has it got the sense to read the next chapter? Better find out!

STARTLING SENSES

Without senses, life would be like sitting in a dark cupboard. Yep, even more boring than a science lesson. But thanks to your brain, you are bombarded with startling sights and sounds and smells. It's lucky you've got strong nerves to cope with it all. After all, your senses won't work without nerves.

Bulging fact file

NAME: Nerves



BASIC FACTS: **1** A network of nerves spreads from your brain and your spinal cord to reach every nook and cranny of your body. Their job is to carry signals from your senses to your brain and orders from your brain to get those lazy muscles moving.

2 In all you have 93,000 miles (150,000 km) of nerves. That's enough to stretch round the Earth nearly four times.

3 An average-sized nerve is made up of thousands of neurons.

DISGUSTING DETAILS: **1** Your nerves are always keyed up and ready for action. In fact, when they send a signal they actually stop working! (See next page for details.)

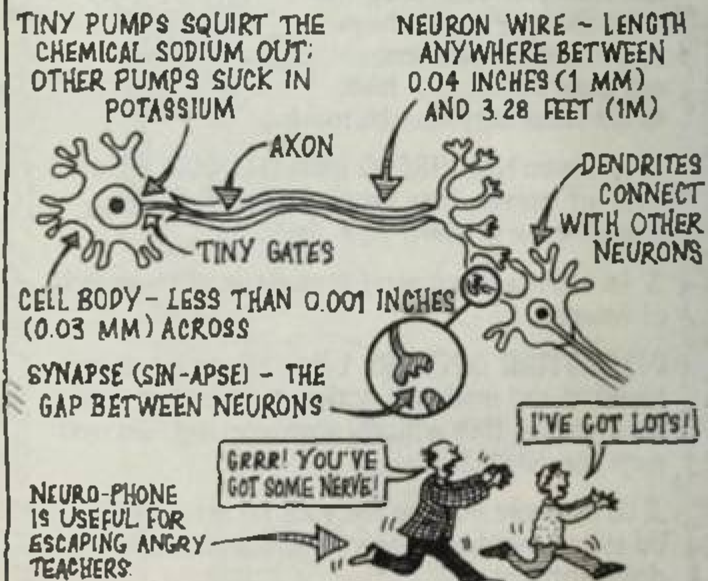
2 So it's more relaxing for your nerves when you do something than when you laze around all day doing nothing!

Your nerves are sort of like an amazing telephone system that takes messages all around your body. Just imagine they are a phone system – the manual would make fascinating reading . . .

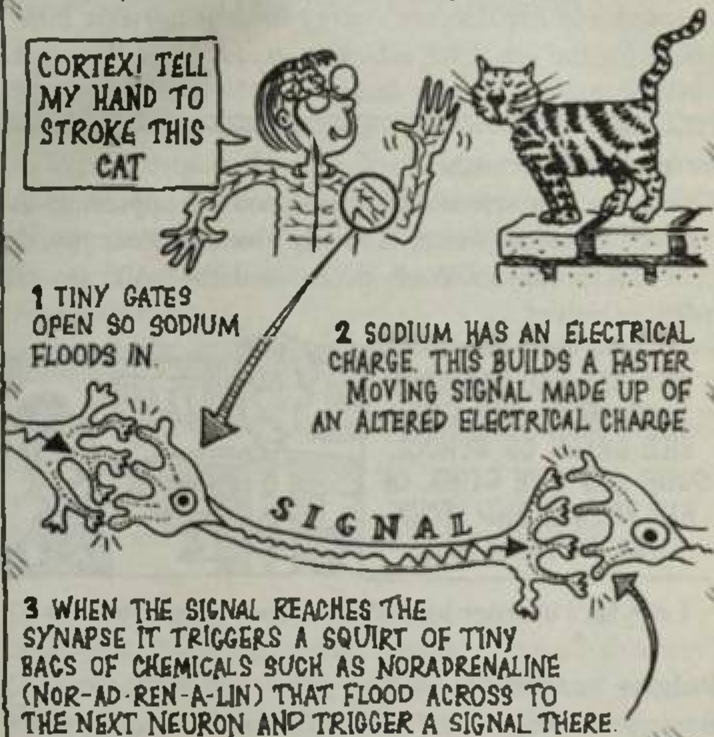
HOW TO USE NEURO-PHONE

You'll always get the message with Neuro-phone!

Congratulations on buying Neuro-phone, the high-tech intra-bodily communication network! Each neuron wire is custom built to send speedy and reliable messages ten times faster than a champion sprinter! Now you can move your body, waggle your ears, or slurp a milkshake! Just do what you feel like!



To activate your Neuro-phone system you don't need to worry about boring dialing codes or numbers. Simply ask your brain cortex to send a message anywhere you want in the body. Neuro-phone will do the rest for you. . . here's how.



Bet you never knew!

1. Nerve signals are F-A-S-T. Tests show a monkey can spot a banana, use its cortex to decide what to do, reach out, and grab the food – all inside one second. Could you move any faster if someone offered you a candy bar?

2. Remember that a science test only produces enough electrical activity in your brain to light a dim lightbulb? (See page 13 if you don't.) Well, what do you have to do to light up a Christmas tree? The answer is, even when you're doing nothing there's enough electrical nerve energy in your nervous little body for the job. After all, there are no fewer than 100 billion neurons in your body.

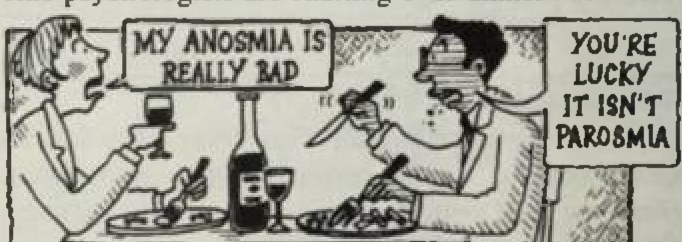
Sensational senses

Thanks to your sensational senses you can appreciate the true beauty of the world. A lovely blue cloudless sky, the delicious aroma of fresh pizza, and the soft, smooth touch of velvet.

Let's take a closer look at these marvelous abilities . . .

Bulging brain expressions

Some psychologists are chatting over dinner . . .



Are these weird types of food?

Answer: No. These are problems caused by blows on the head.
Anosmia = you can't smell anything.
Parosmia = all food tastes disgusting. Of course, the scientists might have been eating a school lunch. Then their food would have tasted *really* horrible!

Bet you never knew!
The sense of taste gets weaker as we grow older. At present scientists don't understand why this happens, but you can observe the effects during any lunchtime. Many children can't stand the vile flavor of school lunches but elderly teachers happily relish the revolting recipes.

Dare you discover . . . a touch of the ridiculous?

All you need is:
your body
clothes (don't forget to put some on your body)

All you do is:
1. Nothing. If only all science experiments were this easy!
2. Concentrate on trying to feel the clothes you are wearing against your skin. (Don't touch them with your hands.)

What do you notice?
a) I can't feel anything except my itchy socks.
b) I can feel the material against my skin. Funny, I never noticed it before.
c) This experiment has given me a headache.

Answer: b) If your nerves feel a constant sensation like your clothes they get used to it and stop firing. That's why you don't feel your clothes, and you may forget you're wearing any. Hopefully, you should notice if you're not wearing any.

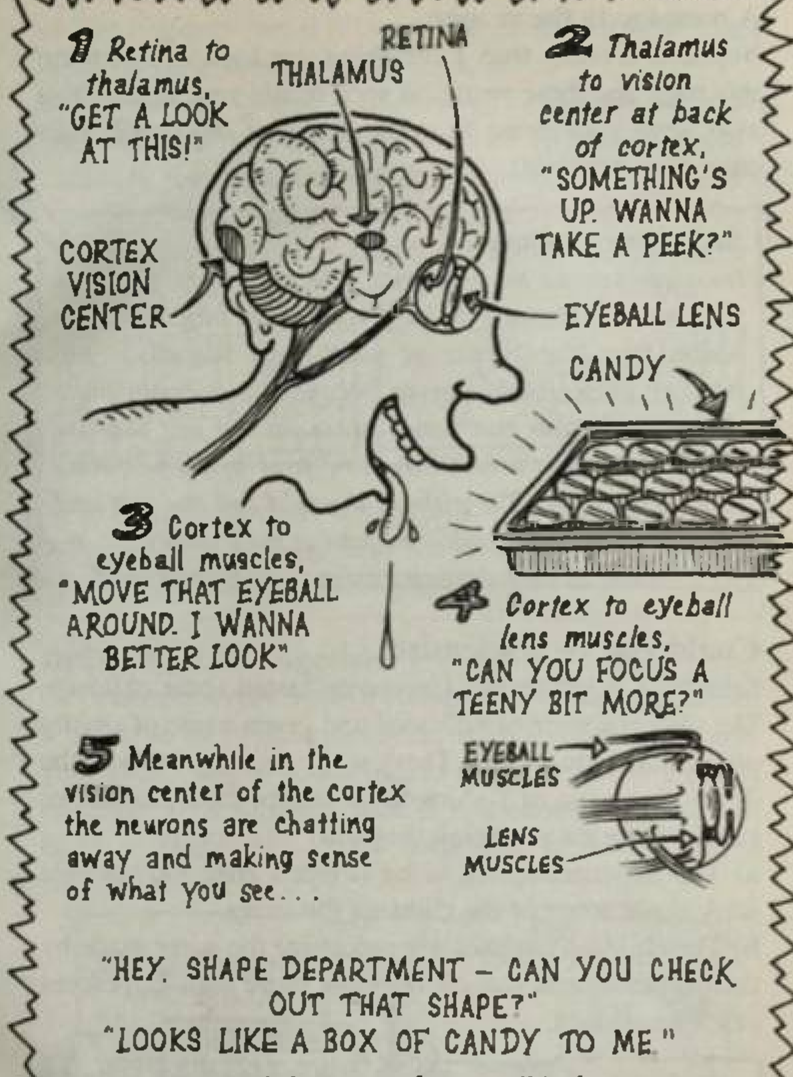
If you answered **c)**, stop concentrating so hard and if **a)**, consider the possibility that you're only wearing your socks. This could be a sight for sore eyes, and talking about vision . . .

Seeing is believing

You might think that you see with your eyes. But your eyeballs simply act like cameras and pick up light patterns from the outside world. It's the brain that makes sense of this information. Sounds complicated? Well, fortunately, the Neuro-phone people have logged the neuron calls involved so you can make sense of it all.

Take a look at this . . .

You see through your eyeballs. An image of the scene falls on the retina, and the one million neurons in your optic nerve take the image in the form of nerve pulses to your brain. Now read on . . .



1 Retina to thalamus, "GET A LOOK AT THIS!"
RETINA
THALAMUS
2 Thalamus to vision center at back of cortex, "SOMETHING'S UP. WANNA TAKE A PEEK?"
CORTEX VISION CENTER
EYEBALL LENS
CANDY
3 Cortex to eyeball muscles, "MOVE THAT EYEBALL AROUND. I WANNA BETTER LOOK"
4 Cortex to eyeball lens muscles, "CAN YOU FOCUS A TEENY BIT MORE?"
EYEBALL MUSCLES
LENS MUSCLES
5 Meanwhile in the vision center of the cortex the neurons are chatting away and making sense of what you see...
"HEY, SHAPE DEPARTMENT – CAN YOU CHECK OUT THAT SHAPE?"
"LOOKS LIKE A BOX OF CANDY TO ME."
"COLOR DEPARTMENT – ANY NEWS?"
"IT'S DEFINITELY PINK."
"MOVEMENT DEPARTMENT – ANY ACTION?"
"NOPE – IT'S JUST SITTING THERE."

A message to the reader:
Yep, this is really true. Everything you look at, including this page and these words, is seen *inside* your brain. You also need your brain to make sense of the words (see page 81 for details).

Bet you never knew!
Imagine you're in a science test. At times like this you're concentrating so hard your brain blots out your vision from the corner of your eyes. You also stop hearing background noises because your brain blots these out so you can concentrate on the job you are doing. Scientists aren't sure how your brain performs this useful trick. But without it you'd fail the test and there'd be a terrible blot on your school record.

Could you be a scientist?

Scientists at Vanderbilt University tested some children. The children were blindfolded and given a pile of smelly old T-shirts to sniff. They were asked to spot the distinctive scent of T-shirts belonging to their brothers or sisters. How do you think they did?

a) The experiment had to be stopped after the horrible stink made some of the children throw up.

b) The children could easily recognize the scent made by their brothers and sisters. They got more than 75 percent of the tests right.

c) The children found it impossible to identify the smell made by their brothers and sisters.

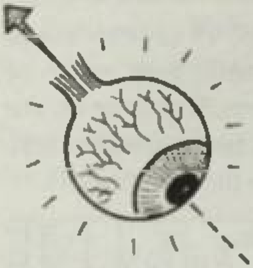
Answer: b) And in tests, 16 out of 18 parents could identify their children by their smell. Your sense of smell is better than you may imagine. If you lie on the floor you can actually detect the cheesy smell where someone in a dirty sock walked on the floorboards.

(No need to test this remarkable skill just now.) And you can identify more than 10,000 different whiffs and stinks. (Heaven nose how you do it.)

Bringing it all together

Of course, in everyday life your brain uses all your senses together to build up a picture of what's going on outside your head. Maybe you'd like to discover how it all slots together. Your mission, should you choose to accept it, is to . . . (BIG ROLL OF DRUMS HERE) . . . eat a chocolate.

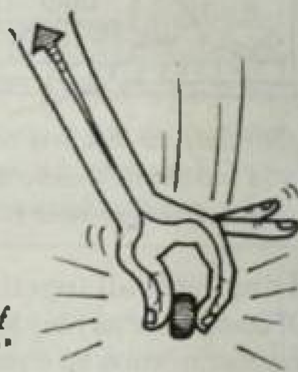
(Yep, but it's not as simple it sounds.) Before we start let's listen to those Neuro-phone messages and get an idea of what's involved.



Retina to vision center and brain stem, "I CAN'T TAKE MY EYES OFF THOSE CHOCOLATES."

Brain stem to cortex, "THERE'S SOMETHING INTERESTING AHEAD. WANNA CHECK IT OUT?"

Cortex to fingers and arms, "EXTEND FINGERS AND PICK UP A CHOCOLATE. HOW DOES IT FEEL?"



Finger-touch receptors to thalamus, "TELL THE CORTEX IT'S NICE AND COOL AND SMOOTH AND VELVETY."

Thalamus to sensory area of cortex, "YOU GOT ALL THAT?"

Ears to medulla, "HEY, LISTEN TO THAT NEAT RUSTLE IN THE BOX."

Medulla to thalamus, "PSST! TELL THE CORTEX TO GET A LOAD OF THIS."

Nose to thalamus, "WOW! WHAT A LOVELY CHOCOLATEY WHIFF – TELL THE CORTEX TO GET A SNIFF OF THIS."

Tongue to cortex, "I'M READY TO SWALLOW. THERE'S LOADS OF SPIT DOWN HERE!"

A note to the reader:
Drooling spit at the sight of candy is a reflex (see page 60) triggered by nerves leading from the brain to your gooey saliva glands. Are you starting to drool, too? If so, try not to dribble on the nice clean page.

Another note to the reader:
So would you like to try this mission for yourself? Chances are you've already had quite a bit of practice.

But if you feel like checking whether your brain can handle all these senses, it's worth asking your parents for chocolates. You could explain that you need an extra large box in order to get this vital science experiment absolutely right. And if your parents fall for that, you might as well ask for a day out at a theme park, too.

So how did you do?

a) I ate the chocolate so fast I didn't have a chance to follow the instructions.

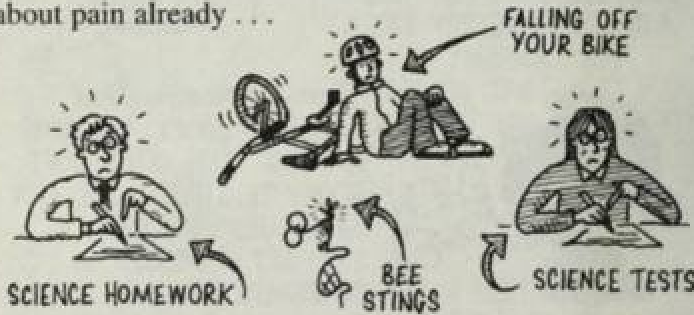
b) I got the instructions mixed up and bit my tongue by mistake. Ouch!

c) It was great and all my senses and brain parts worked perfectly.

(If you checked **a)**: oh my, that's tough, better practice on another piece of candy. If **b)**: you might as well go on to the next section. Because it's a bit of a PAIN, too.)

Putting up with pain

Pain is the worst thing you can sense. But you know all about pain already . . .



Dare you discover . . . how to put up with pain?

Note to the reader:

This experiment has been banned on the grounds that it's far too cruel. Here are a few facts instead.

A few painful facts

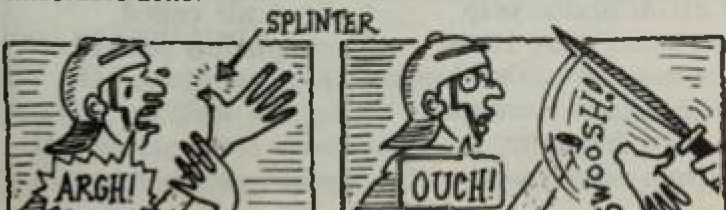
1. Pain is a big trick played by your bulging brain on the rest of your body. Imagine you stub your toe on a stone or even the cat.

You might think you feel the resulting pain in your big toe. But you actually experience the pain in your brain, because that's where the nerve signal goes.

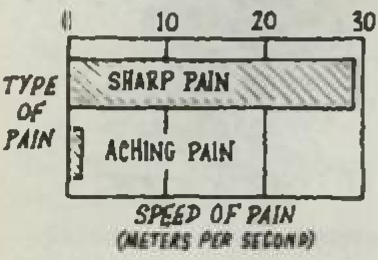
2. Your body is crowded with countless thousands of pain receptors. Obviously any damage to the body is red-hot urgent news for the brain. There may be more damage just about to occur, so the pain receptors try to let the brain know what's going on NOW.

3. The crushed pain receptors let in a chemical released from the injured areas. This kick starts a nerve signal that blasts up to your brain.

4. The deeper the pain receptors the less sensitive they are – that's why a really bad injury can hurt less than a little scratch. Pain deep in the body often feels like a dull, miserable ache.



5. Different pain signals move at different speeds. A sharp prick on your skin hits your brain at 98 feet (29.9 meters) a second. A longer pulse, like a burning or aching pain, moves through the neurons at a slightly more leisurely 6.5 feet (1.98 meters) a second.



But there's much more to pain than just a horrible feeling in the brain. Here, for a change, is a bit of good news . . .

THE DAILY BRAIN

The paper that makes you think! Issue 3,752 . 1975

What a relief!

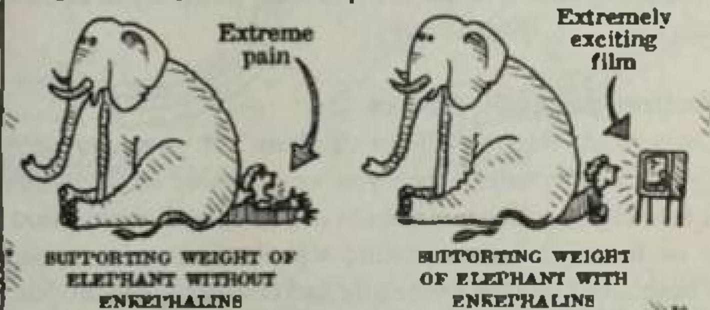
Scientists at Aberdeen University, Scotland, claim brains help deaden pain. Brain researchers John Hughes and Hans Kosterlitz were following a lead from neurophysiologists in Baltimore.

Now they reckon they've found what they were after. Previously unknown chemicals called enkephalins (en-kefa-lins) that block pain signals. Well, we at *The Daily Brain* salute this great new discovery.

If we didn't have these chemicals we're sure they'd be *sorely* missed.

Daily Brain Science Correspondent Dr. Alan de Mind writes:

The newly discovered chemicals may explain why working out or other distractions such as a white-knuckle ride or an exciting film takes your mind off pain. Presumably doing these things can trigger the brain to make the painkilling chemicals.



Bet you never knew!
Another way to deaden pain is to confuse your nerves by getting them to send other signals. So if you bang your shin you could try rubbing it with your hand or a lump of ice. This gets the nerves sending more signals that swamp the pain signals.

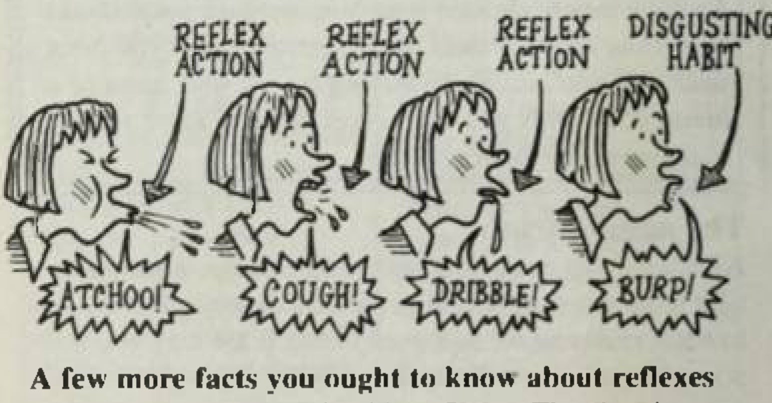
The painful truth

Afterward it's hard to remember exactly what pain is like. Your cruel, heartless brain wants every pain you feel to seem really awful and unexpected. That way you'll do something about it. The painful truth is that pain is there so your brain can teach you a painful lesson.

You might think it would be great to live in a world without pain. Life would be super, wouldn't it? You could wander around endlessly bumping into things and not worry about how much it was going to hurt. Until one day you noticed that your fingers had dropped off. Of course, if you'd felt pain in the first place you'd have escaped with a bad cut rather than no fingers on one hand. By the way, if the thought of all that blood makes you feel like throwing up at this point, feel free – being sick, or vomiting to use the technical term, is just another of your . . .

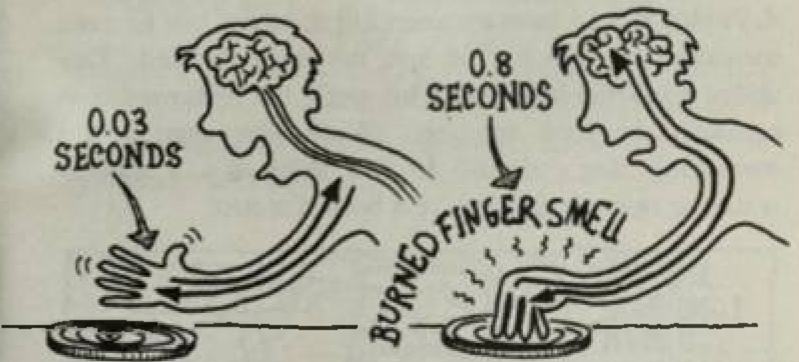
Action-packed reflexes

Do you do things without thinking? If your answer is "yeah, all the time," then you've probably been making a few reflex actions. Reflexes are actions that your body does in response to startling signals from your senses. These are things like sneezing and coughing and drooling that you can't stop once they start. (For this reason farting or burping are not reflexes, and you've got no excuse for doing them during mealtimes.)

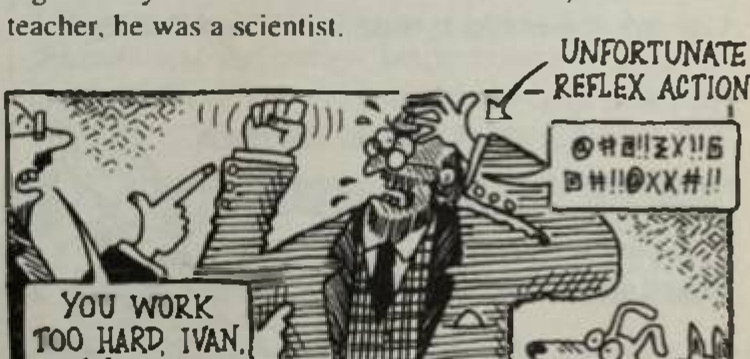


A few more facts you ought to know about reflexes

1. Your brain isn't involved in reflexes. The signals go to your spinal cord and out again in nerves that control your muscles. This saves time and means that you can whip your hand away from the hot plate of the cooker in 0.03 seconds instead of up to 0.8 seconds if your brain was consulted.

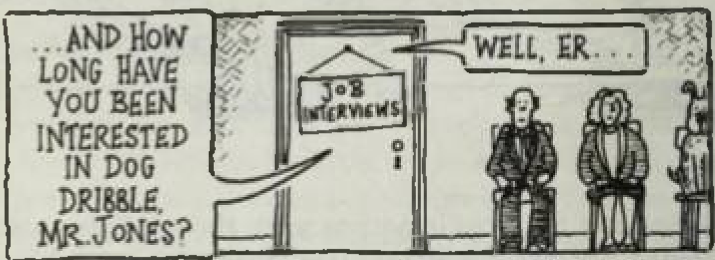


2. Some of the most important work about reflexes was carried out by a Russian, Ivan Pavlov (1849–1936). Pavlov was a cold, unfriendly man who flew into terrible rages if anyone dared criticize him. And no, he wasn't a teacher, he was a scientist.



3. His most famous experiment was to show that you could train dogs to make reflex actions. Dogs drool when they see food. Pavlov rang a bell every time the dogs were fed. After a while he stopped feeding the dogs, but they still drooled when he rang the bell.

4. Pavlov was so keen on scientific accuracy that he even measured the amount of spit the dogs drooled. This added no particular value to his work, but it showed how seriously he took his job. Would you want a job measuring dog's drool? If you think it's a mouth-watering opportunity, you're a born scientist.



Dare you discover ... a reflex action?

All you need is:

One dog (Count first to make sure it's got four legs.)

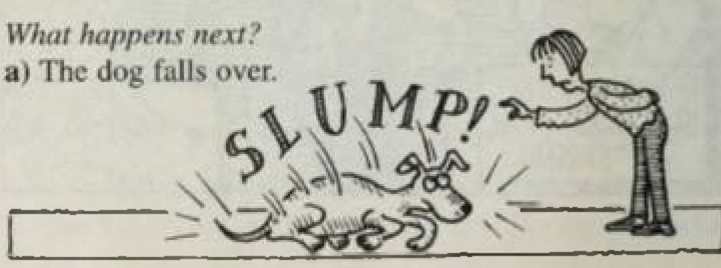
All you do is:

1. Rub the dog's back until the dog reacts.

2. Note what happens next.

What happens next?

a) The dog falls over.



b) The dog scratches its back with its hind legs. (It probably thinks your hand is an extra large flea.)

c) The dog wags its tail and sticks its tongue out and dribbles everywhere.

Answer: b) The dog often scratches its back without thinking in a reflex action – much like you sneezing. The nerves involved in the dog's reflex were discovered by British scientist Sir Charles Sherrington (1857–1952), who won the Nobel Prize for this breakthrough. I expect he was itching to tell his pals about it – ha-ha. If you said **a)**, your dog is probably missing a leg or two.

HORRIBLE HEALTH WARNING!

Don't try the above experiment with the neighbor's rottweiler or you may never tie your own shoelaces again.

CONGRATULATIONS! You've successfully read this chapter. Now for the bad news. So far you've been looking at the easy-peasy stuff your brain does. You might find the next chapter rather more mind-bending.

Yep – it's time to put your bulging brain to work.

ER...

BULGING BRAIN-WORK

Sometimes you need your bulging brain for something more intelligent than scarfing a piece of candy. Jobs like listening to music and thinking and talking and reading. Oh, so you don't think they sound too difficult? Well, they are. But don't worry, by the time you've read this chapter you'll have boosted your bulging brainpower. Well, maybe – just a bit.

First, sort your left from your right

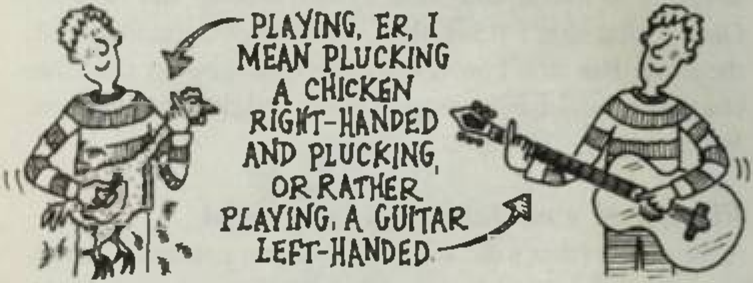
Your cortex (that's the wrinkly, thinking part of the brain, remember?) is split into two halves. To understand how you use your brain you first need to know how the two halves work together. Bear in mind that one side of the cortex is stronger than the other and takes over most of the work. But which side is that? Well, the diagram below will help you sort that out. But don't forget that the left side of the cortex looks after the right side of the body and vice versa. Got all that?

Anyway, here's the diagram.

(If the teacher was left-handed these arrangements would be reversed.)

Are you ambidextrous?

Ambidextrous means that you're able to write or draw or hold a tennis racket or play the guitar or pluck a chicken equally well with both hands.



This is because neither side of the cortex is stronger than the other. Famous ambidextrous people include English artist Sir Edwin Landseer (1802–1873), who often drew a horse with his right hand and a deer with his left hand at the same time. Try it for yourself – it's much harder than it sounds.

Test your teacher

Is your teacher left-handed, right-handed, or ambidextrous? Well, this teacher teasing test will certainly keep her brain fully occupied until the end of the class. By the way, if you're feeling kind you can give your teacher one clue before you start the test: all the answers are for right-handed people.

1. Are babies always

a) left-handed?

b) right-handed?

c) ambidextrous?

2. Which side of your brain do you use for working out hard math questions?

a) the left
b) the right
c) Neither, I use a calculator.

3. Which side of your brain do you use for having a chat with your friends?
a) the left
b) the right
c) the left for chatting with friends but the right when talking to important people like the principal.

4. Which part of your brain do you use for painting a watercolor?
a) the left
b) the right
c) Neither, it's the cerebellum that does the work.

5. How do Japanese people differ from the usual right-left division of work within the brain?
a) They use both sides of their brains for talking.
b) Annoying insect sounds trigger brain activity on the left side of their brains instead of the right for everyone else.
c) They can talk aloud without their brains showing unusual activity.

Answers

1. c) In babies, both halves of the cortex are equally strong. One side doesn't take over until the child is about two.

2. a) If you're right-handed you read, write, and work out math problems mostly using the left part of your brain. (If you're left-handed you are more likely to use the right side of your brain for these tasks.)

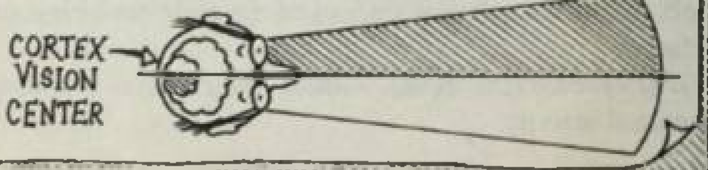
3. a) The left side also deals with talking aloud. The poor old right side has to spend its life listening to the left side talking.

4. b) At least the right side of the brain gets to deal with all the enjoyable artistic jobs like making a collage or drawing.

5. b) This finding was reported by Japanese scientist Tsunoda Tadanobu. Some Japanese words sound like insect or water sounds. So the scientist suggested Japanese people listen to these sounds with the left side of their brains that normally deals with language. (Award your teacher an extra credit if he or she managed to explain this theory.)

Bet you never knew!

For reasons that scientists don't quite understand . . . You see things at the back of your cortex (not at the front, which is where your eyes are). You see things to the left in the right side of your brain. Things to the right get seen in the left side.



Dare you discover . . . if you're left- or right-eyed?

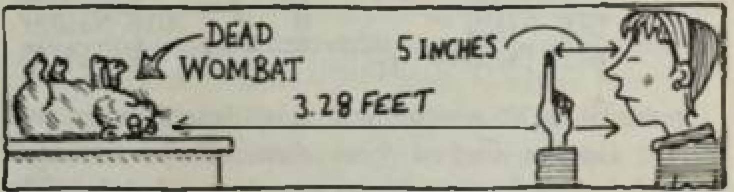
Your left eye is controlled by the right side of your brain and vice versa. But which side of your brain is stronger? Here's how to find out.

All you need is:

a finger (preferably one of your own)
two eyes (These should definitely be your own.)
a stationary object 3.28 feet (1 meter) away (It doesn't matter what this object is. It could be a picture, the wallpaper, or even a dead wombat.)
a ruler

All you do is:

1. Stick your finger 5 inches (12 cm) in front of your nose.
2. Focus your eyes on the stationary object. The finger should appear out of focus. Note the position of the finger.
3. Now wink each of your eyes in turn.



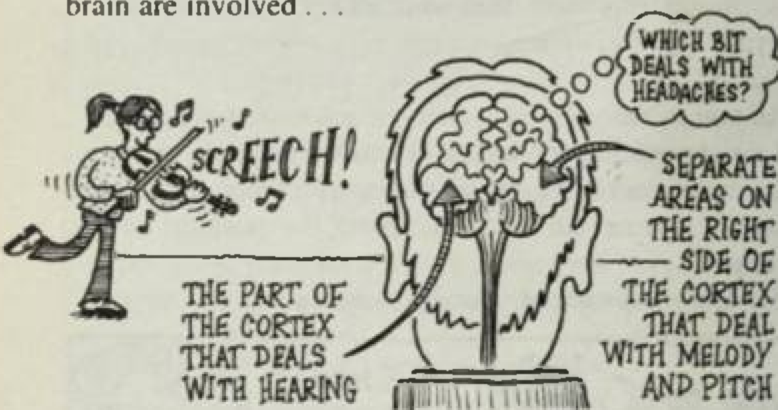
What do you notice?

a) Nothing, and people started asking me who I was winking at. It was really embarrassing.
b) Each time I winked an eye the finger seemed to jump sideways.
c) The finger seemed to stay where it was when I winked one eye and jump sideways when I winked the other.

Answer: c) The finger didn't appear to move when you looked at it through your dominant eye. This is because with both eyes open you see mostly through that eye. Right-handed people usually have a dominant right eye and so they do most of their seeing in the left-hand side of their brains. OK, got all that? Here's a chance to rest your eyes for a bit and listen to some music.

Could you be a scientist?

When you listen to music the following areas of your brain are involved . . .



In the 1970s US neurophysiologists Joseph Bogen and Harold Gordon studied these areas. They injected a powerful painkiller into blood vessels that fed the right side of their patients' brains. This put the right side of the brains to sleep for a while. When the patients tried to sing using only the left sides of their brain what did they sound like?

a) They sang beautifully, like trained opera singers.
b) They could open their mouths, but no sound came out.
c) They sounded like a calf bellowing.

Answer: c) Without the help of the right side of their cortex the singers couldn't produce a tune. Mind you, some people seem to have this problem with both sides of their brain in working order.

Teacher's teaser

A note to the reader:

You try this teaser at your own risk, OK? Don't blame me if you get expelled. To do it, all you have to do is sing loudly outside the teachers' lounge.

Answer: Words are controlled by the left side of your brain and tunes by the right. When you sing it's hard for your cortex to cope with two sets of information at the same time. I mean – just think, you have to access your memory centers to remember what the words and notes actually sound like. Very musical people actually grow extra neurons in the areas of the right cortex that deal with sound and hearing. OK, got all that? No? Why not ask your brain to chew it over . . .

Think for yourself (it's not that easy)

1. Thinking is the way that your brain makes sense of the world and organizes the information it gets from your senses. Scientists believe that thinking is a wave of brain activity that spreads as neurons fire signals at one another. Does that get you thinking?

2. Remember, the brain has different areas for different jobs like talking or sniffing things. But neurons all over the cortex are involved in thinking, and the active areas vary according to what you're doing. Your level of concentration or even your feelings can affect the pattern of brain activity.

3. Brain neurons fire most of the time, and scientists think that this could mean your brain is vaguely mulling over past memories. The increased activity caused by thinking might be due to your brain drawing on memories to build up a particular thought.

4. When you do two different things at once (see page 73), each half of your brain has separate thoughts. Is that a good thing? Well, maybe you're of two minds about it.

Bet you never knew!

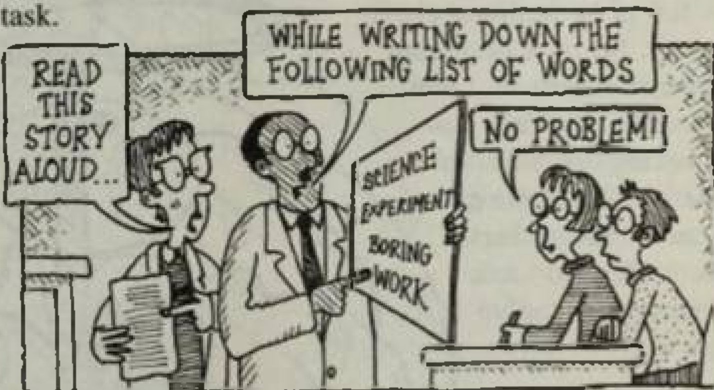
There is no limit to the number of thoughts you can have. You don't believe me? Well, read on. Your brain has billions of nerve cells, remember? If you look at a neuron magnified 10,000 times it appears like a tiny tree with more than 5,000 branches.

Scientists think there are more than 100,000,000,000 – that's ONE HUNDRED BILLION – brain synapses. (Remember, these are the gaps between neurons.) And scientists believe a thought can travel through these synapses in ANY order. So there may be more possible routes for a thought than atoms in the entire universe. And that means that there's NO LIMIT to the thinking power of your brain.

WOW! That really is something to think about. But oddly enough, although your brain is unbelievably powerful, it finds doing several things at once a bit of a strain.

Could you be a scientist?

Some psychologists gave two students a brain-teasing task.



How do you think the students did?

a) They were useless. The brain simply can't manage to read, talk, listen, and write all at the same time.

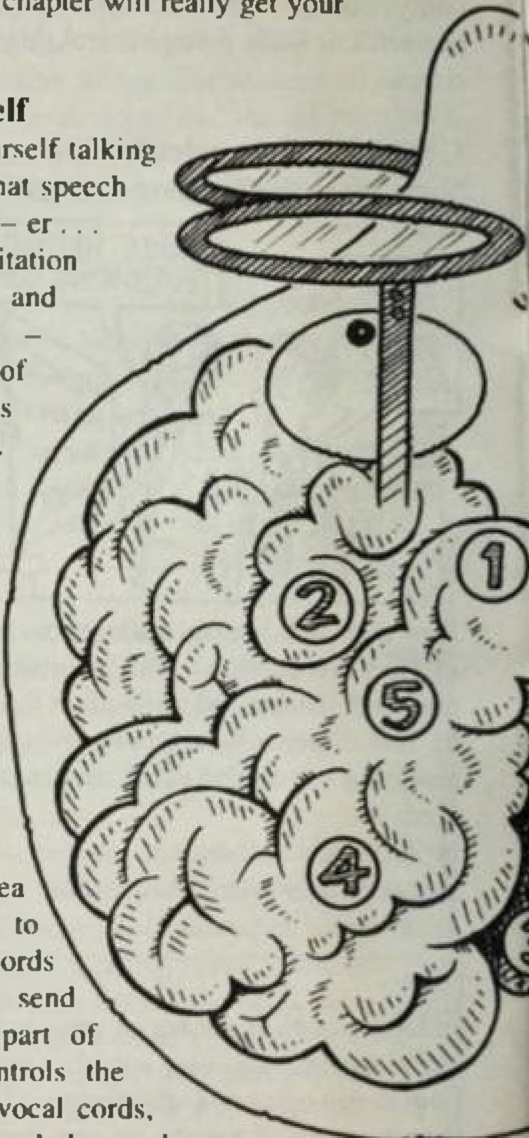
b) The students found themselves writing the story and repeating out loud the lists the scientists were reading to them.

c) Although the students started off slowly and made mistakes they soon learned how to do the tasks at the same time.

Answer: c) The brain can be trained to do different things at once. The part that helps you to do this is the cerebellum. And this explains how your hairdresser can cut your hair and chat at the same time without snipping your ears off.

And speaking of talking or talking about speaking, the next part of this chapter will really get your tongue wagging.

Speak for yourself



Try listening to yourself talking and you'll realize that speech is full of hesitation – er . . . (sorry, bit of a hesitation there), repetition, and mistakes. Yep – speaking is one of the hardest things your brain tackles. In order to talk correctly you've got to:

Access your memory (**1**) for the correct words and your memory of how to pronounce them.

Use the Broca's area (**2**) of your cortex to pronounce the words correctly. It should send a message to the part of the cortex that controls the movement of your vocal cords, tongue, and lips to speak the words.

You will need your cerebellum (3) to coordinate all these complex movements.

Use your Wernicke's area (4) to put the words in the right grammatical order. (See page 21 for info on how these areas were discovered.)

You will need your ears and the part of the cortex that deals with listening (5) to hear your words and the rest of your cortex to check they make sense.

It's (not) that easy! Yet amazingly, scientists have found that good speakers can speak up to three words a second even when someone is mumbling in their ear.

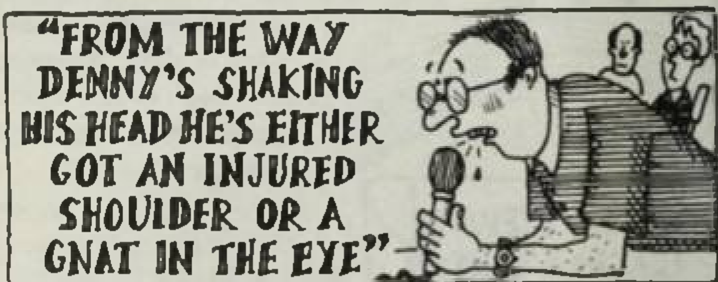
Unspeakable speech problems

But of course, things can still go wrong. Usually at embarrassing moments, like when you're talking to someone really famous and important. Here are a few problems that may be caused by the brain.

1. Stupid sayings

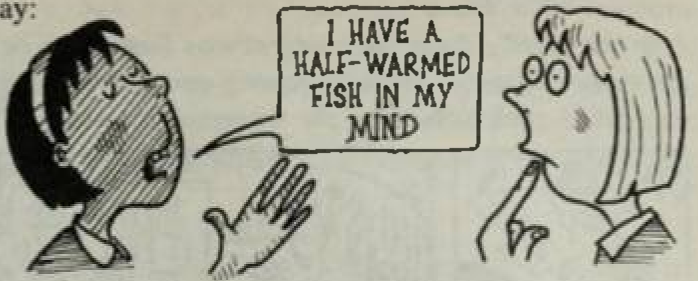
This is when you say the right words in the right order but because your cortex hasn't had time to consider the meaning of what you are saying it sounds really stupid. Fast-talking sports commentators are particularly good at this. Here's British sports commentator David Coleman:

And US baseball commentator and manager Jerry Coleman:



2. Spoonerisms

This means mixing up the first letters or sounds in a series of words. For example, instead of saying, "I have a half-formed wish in my mind," you might accidentally say:



Usually you wouldn't realize you had made a mistake. It's most likely caused by a fault in the Broca's area (that's the part of the cortex that deals with speaking words, remember?). Spoonerisms are named after British clergyman Dean William Spooner (1844–1930), who made rather a lot of them.

Bet you never knew!

1. *About one in a hundred children suffers from stuttering. Stuttering is jerky, hesitant speech in which the first sounds of some words are often repeated. Sufferers report that they know what they want to say, but they can't say it.*

2. *Scientists aren't quite sure what causes stuttering, but it seems to affect boys more than girls and it seems* *to be made worse by worry. It's probably linked to a problem in the Broca's area.*

3. In the Middle Ages the problem was thought to be due to the tongue not working properly, and useless cures were tried, such as burning the tongue with a hot iron.

4. Nowadays stuttering can be overcome by helping the sufferer to feel more relaxed when talking. Techniques used include learning to speak more slowly and to begin words with a more gentle movement of the lips and tongue.

Bulging brain expressions

Two psychologists are chatting . . .

Maybe you could ask this LAD to help with your homework?

Answer: Possibly. Some psychologists believe part of the brain can grasp grammar without being taught. They call this area a Language Acquisition Device, or LAD for short. So who knows – maybe your LAD is already helping you and without it, learning new words or even a new language would be much harder.

A whole new language

Sometime in your school career you will have to learn a foreign language. There are about 5,000 languages in the world, and they use a huge range of sounds.

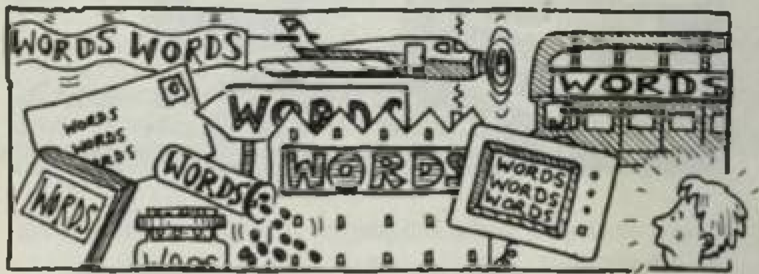
For example, some languages in southern Africa such as Xhosa and Zulu include unusual clicking sounds. Well, whatever languages you learn, once you've learned to speak the words you then have to learn how to read them. And by some eerie coincidence that's what you're doing right now.

Read all about it

OK, so how are you doing with reading this book? Finding it easy, or feeling bothered by some of the incomprehensible inapprehensible numinous words?

Go on, try remembering them – they're numinous words for bamboozling science teachers.

Scientists think that children learn about ten new words a day at school – but that's not such a bad thing because everywhere you look there are written words.



Grown-ups who read a daily paper might get through about 100,000 words every week. This includes all the words they might read in an office job, road signs, and even the back of cornflakes boxes.

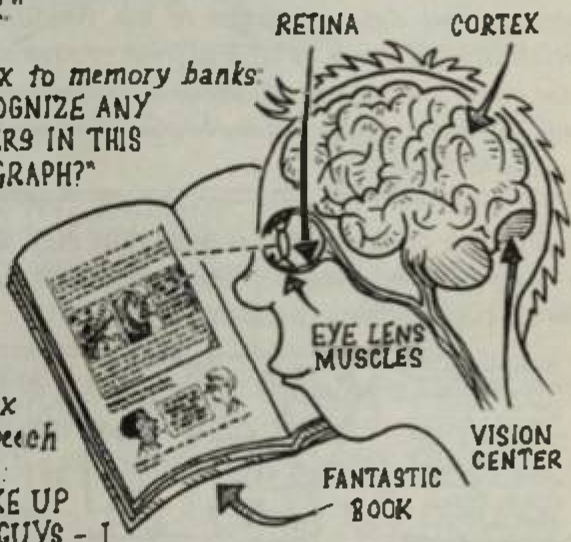
Riveting reading

Reading is great. You can settle down with a good book and forget about the rest of the world. But you won't even reach the end of this sentence without the help of your brain. Here's your chance to discover what your brain is up to when you read. Simply listen in to some more of those fascinating Neuro-phone calls . . .

1 *Cortex to eye lens muscles:* "THIS PAGE LOOKS A BIT BLURRED – GET FOCUSING."

2 *Cortex vision center to cortex:* "THE PAGE IS COMING THROUGH FROM THE RETINA NICE AND CLEAR."

3 *Cortex to memory banks:* "RECOGNIZE ANY LETTERS IN THIS PARAGRAPH?"



4 *Cortex to speech areas:* "WAKE UP YOU GUYS – I NEED THESE LETTERS TURNED INTO WORD SOUNDS."

5 *Cortex to memory banks:* "HEY, CHECK OUT WHAT THESE WORDS MEAN. I'VE FORGOTTEN!" (The answers should come through in about 200 milliseconds.)

6 *Cortex to eye muscles:* "THIS IS FASCINATING. CARRY ON SCANNING THE PAGE. HOW FAR TO THE END?"

A note to the reader:
Now ask your brain to move your eyes to the next chunk of text. This should take 30 milliseconds. Hey! Come back! You haven't read this part.

Bet you never knew!
Many really smart kids have difficulty reading. It's often due to a condition called dyslexia (dis-lexy-a). Scientists can't explain what causes dyslexia, but there are several different forms of the condition. Some dyslexics see words as back to front or even moving on the page. In one form of the condition the sufferer sees the words on a page but the brain can't turn the words into sounds.

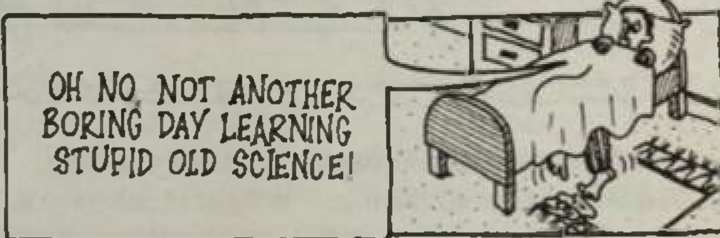
Teachers think reading is vital, but they don't mean reading for fun – oh, no. Teachers expect you to read boring books so you can learn lots of facts.

Sound like a real pain? OK, so maybe you could use some really expert scientific advice? Well, better read on, 'cause the next chapter could seriously expand your brainpower.

LOATHSOME LEARNING

Do you find learning fun? Do you tumble out of bed shouting . . .

Or do you crawl out of bed thinking . . .



Well, cheer up! Learning is one of the most vital tasks of your bulging brain, and it CAN be fun – but only if you've got something interesting to learn. Like now – so read on.

NAME: Learning

BASIC FACTS: Here's how you learn . . .

1 Someone tells you something.

2 You remember it.

3 You use this information to help you in whatever you are doing.

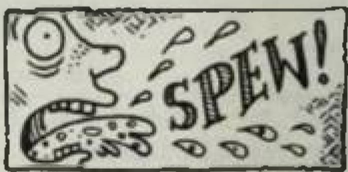
DISGUSTING DETAILS: Some psychologists believe that learning gets harder over the age of 25. This could be because the memory starts to weaken. But other scientists claim that learning gets easier as you get older. So why don't they send grown-ups back to school?

A few facts to learn (and make sure you do)

1. You learn things all the time – not just in school. You learn whenever you notice anything new or try out a new skill.

2. Learning can be nice or nasty:

NICE THINGS TO LEARN: CHOCOLATE ICE CREAM TASTES YUMMY.

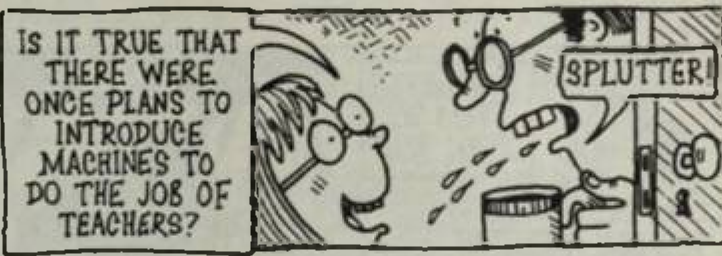


NASTY THING TO LEARN: EAT TOO MUCH AND YOU'LL WANT TO THROW UP.

3. Most people learn by trial and error. Remember learning to ride a bike? But once you've learned something you can do it effortlessly and without thinking. Like riding that bike.

Teacher teaser

Put a fly in your teacher's morning coffee with this tricky teaser. And remember, if your teacher doesn't believe you – this fact is TRUE. Tap gently on the teachers' lounge door. When it opens, smile brightly and inquire:



Answer: Yes. In the 1960s US psychologist Burrhus F. Skinner invented a teaching machine called a didak. The machine showed a sentence and you had to complete it. If you got the answer right you got a chance to answer harder questions. Oh, goodie!
THE GOOD NEWS: The machine never told you off.
THE BAD NEWS: It couldn't answer your questions and didn't know how to chat.

Bet you never knew!

It doesn't matter whether they have real teachers or machines to help them – some kids have trouble learning. There are loads of possible reasons for this. Sometimes the difficulties are caused by dyslexia or an eye problem so the child can't read easily. More often the child isn't interested in the lessons. Or perhaps the lessons require skills such as speaking or writing that the child isn't good at. Oddly enough, one psychologist who studied how the brain learns suffered learning difficulties as a boy.

Horrible Science Hall of Fame

John B. Watson (1878–1958) Nationality: American

As a boy John B. Watson had a problem with learning. Maybe that's why he was forever getting into trouble, starting fights and terrorizing his hometown in South Carolina.

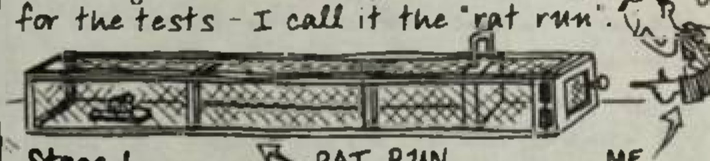
As he grew older John got mixed up in crime. But when he turned 16 he had a sudden change of heart and started to study really hard at home. He had to study really hard because he had decided to go to college and become a scientist.

But at college John continued to find learning difficult. He couldn't understand his teachers and their boring lectures (sound familiar?).

But he did become fascinated by how rats learn things. Here's what Watson's notebook may have looked like . . .

The Great Rat Experiment

Today's the BIG day!!! I'm planning to find out if rats can learn from a nasty experience. I've been working hard all week building a 9.84-foot-long (three-meter-long) alley for the tests – I call it the "rat run".



Stage 1

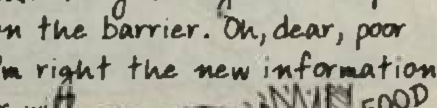
Now to try it out. Will the rat do the obvious and go and grab the food? YES! YES! YES! ...

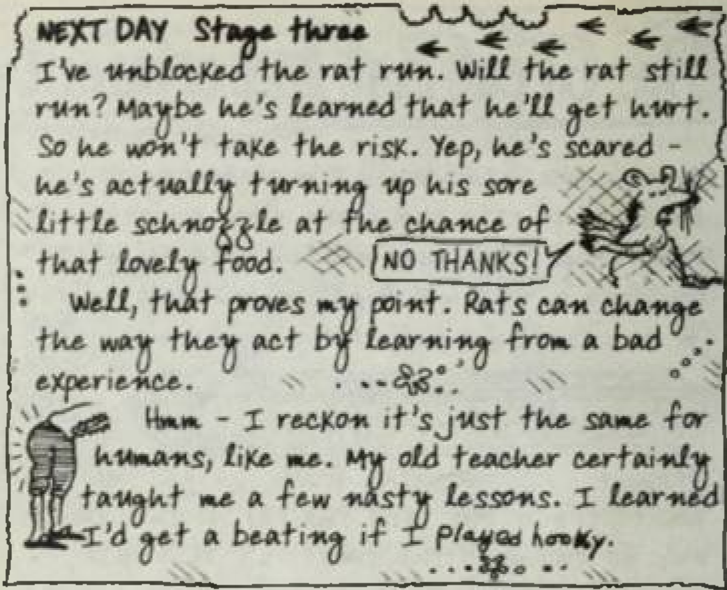
The rat runs down the rat run and grabs the food. Atta boy! This proves that learning happens when you give a rat something new – like the food. This changes the rat's behavior. Now to test my idea a bit further.

NEXT DAY Stage 2

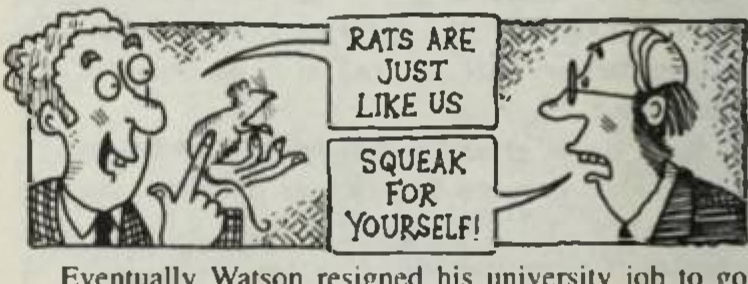
I've blocked off the rat run with a thick glass barrier. Will the rat still go down it? Here goes...

Yes – like a streak of lightning and bumped his little nosy on the barrier. Oh, dear, poor old ratty. If I'm right the new information about the barrier will change the rat's behavior – let me see...





Watson's experiments inspired a whole new movement of psychologists called behaviorists who believed that you could help rats – or humans – learn with rewards or punishments. But although Watson was certain that you could learn about human behavior from studying rats, there were squeaks of protest from other scientists when he compared humans to rats.



Eventually Watson resigned his university job to go into advertising. Here he put his ideas on learning into practice by selling baby powder. Watson thought:

1. Rats chased down the rat run because they learned there was food at the end. So by giving the rats a reward you could change their behavior.

2. You could use advertising to give people the impression that by buying your brand of baby powder they would feel happier and be better parents. This feeling would be a kind of reward. So people would choose to buy your brand.

But did the plan work? What do you think?

a) Watson was fired after featuring a rat on the advertising posters.

b) Watson's plan failed. People can't be compared to rats. We don't have to feel good when we go shopping.

c) Watson's plan worked and he became a millionaire. His ideas form the basis of modern advertising.

Answer: c) If advertising teaches you that buying a product will improve your life, then you'll probably feel like buying it.

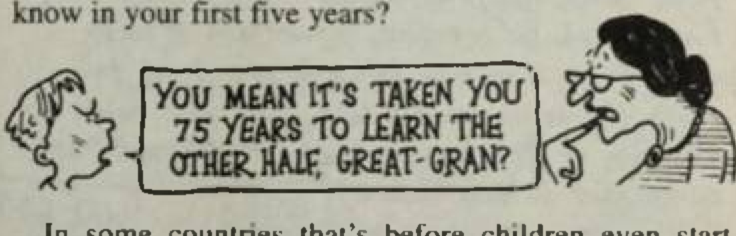
Are you intelligent?

Are you good at learning things? If so, you may be intelligent. But you might be surprised to know that psychologists don't agree what intelligence is all about. Many, though, believe that intelligence means an ability to solve new problems. Anyway, whatever you call it –

Answers: 1. FALSE. Your brain size has nothing to do with intelligence. For example, at 17.6 pounds (8 kg), an elephant's brain is more than five times heavier than ours, but no one wants an elephant to win this year's Nobel Prize. **2.** TRUE. Being smart has more to do with building up lots of neuron connections in the cortex. If you've got the vital connections you can learn things faster and people think you're really brainy. **3.** FALSE. But scientists think that children who play lots of computer games develop extra connections in the area of the cortex that controls delicate hand movements. This helps them play the games faster and win more often. **4.** TRUE. Eating fish really can boost your brainpower. Sea fish are rich in a chemical called iodine. This makes your body cells burn energy faster and your brain think faster. Also, fish and white meat and egg whites are rich in chemicals called amino acids that your brain uses to make neuron chemicals such as noradrenaline. As a result your brain feels more alert and clear thinking. It can learn faster and become more intelligent.

Bulging brain development

Did you know that you learned half of everything you know in your first five years?



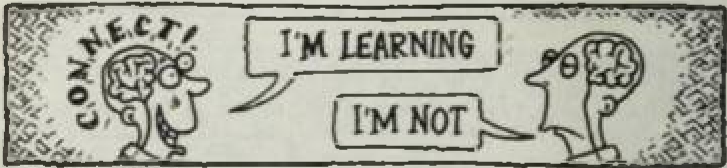
In some countries that's before children even start school! Oh, so you don't remember this vital learning period? Well, here's a quick reminder.

intelligence, being clever, smart, or brainy – here's a quick intelligence test to put you through your paces.

True or false?

1. People with small heads aren't as intelligent as people with big heads. This is because people with big heads have bigger brains. TRUE/FALSE

2. As you learn, you develop extra connections between the neurons in their cortex. TRUE/FALSE

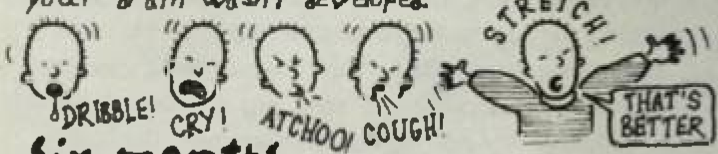


3. Playing lots of computer games can make you more intelligent. TRUE/FALSE

4. Eating fish is good for your brain. TRUE/FALSE

The first five years...

0 to six months
When you were born you could breath, suck, swallow, and then throw up, dribble, cry, sneeze, cough, and stretch. And that's about all, because your brain wasn't developed.

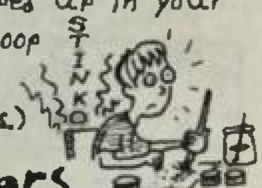


Six months
Your brain had doubled in size. The neurons were growing and branching and forming millions of synapses. You could roll over and smile. You could also copy the expressions on grown-up faces. (Don't try this now - you'll only get told off.)

One year
You had learned how to pick things up with your hands, and you had just spoken your first word. Before then grown-ups probably spoke to you in baby talk and you tried to make the same sounds back. But you hadn't got the hang of the tongue and lip movements so it came out as baby noises. You were just beginning to learn to walk, and falling over quite a lot.

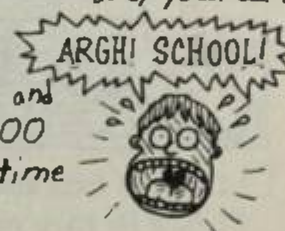
Two years
You could walk run and speak about 274 words. Two vital words you learned were "pee" and "poop". You were able to recognize the feeling when you had to go, and now you could even tell people about it. Soon afterward you learned how to use a potty without making an embarrassing mess. And if things went wrong you could take off your underwear without help.

Three years
You could speak up to 1,000 words in short sentences and feed yourself (but not at the same time). You were also learning to draw. Sometimes you were so wrapped up in your drawing or games you might poop or pee in your underwear. (Hopefully this no longer happens.)



Four years
Your brain was four times bigger than when you were born. You were asking lots of questions using about 1,500 words and going to the bathroom all by yourself.

Five years...
You could tell stories and hop and skip, and you knew about 2,000 words. And around about this time you started school....



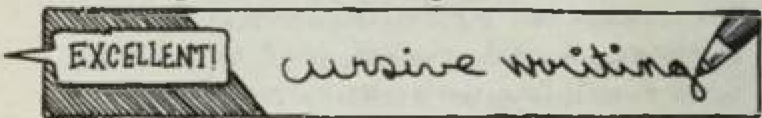
The next few years

After you turned six, things in your brain got a little less hectic, but the neuron links in your cortex kept on forming. Sometime between the ages of six and ten most children learn the following skills:

Check here

☐ How to play ball games really well.

☐ Reading and cursive writing.



☐ Writing and telling stories.

☐ Drawing, painting, and making models.

☐ Simple cooking and cleaning and even washing up. Oh, yes – this is part of growing up, I'm afraid.

☐ Loads of facts and new words at school.

So how far have you got?

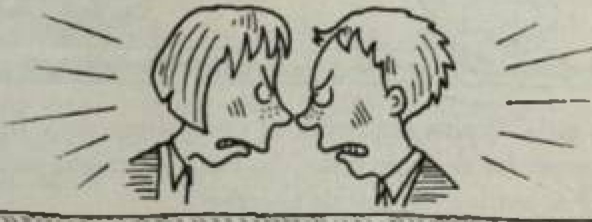
Of course, not all kids develop at the same speed. Some are late developers. That doesn't make them stupid – scientific mega-genius Albert Einstein didn't learn to talk until he was four. And girls' and boys' brains develop on different timetables anyway. For example, for reasons scientists can't quite explain, the parts of the cortex that deal with speech develop earlier in girls than in boys. So girls often learn to talk earlier. And boys' and girls' brains go on developing in different ways at different times.

Boys vs. girls

Not surprisingly, psychologists have found that boys and girls are better at different things.

Bet you never knew!

For example, girls may be better at talking than boys. Oh, so you knew this already? Brain scans performed at Yale University School of Medicine show that men only use the left side of their brains to talk but women use both sides. But who comes out on top overall – the battling boys or the gutsy girls?



Read on and find out in . . .

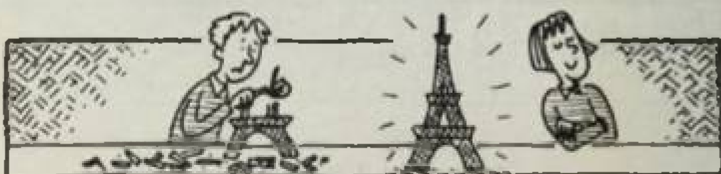
The battle of the sexes

Scientists have found that boys and girls tend to be better at different things. Of course, you might be different, and scientists always argue about the results.

1. One study showed that boys are often quicker at solving tricky math problems in their heads. Very gifted boys use the right side of their brains to concentrate on the problem. But girls tend to use both sides and waste time putting their thoughts into words.

2. When boys and girls are given 3-D puzzles to assemble, the boys are better at imagining what the finished puzzle will look like. Once again girls tend to waste time explaining to themselves in words how they will solve the puzzle.

3. But girls' brains are better at controlling their finger movements for delicate tasks. So the girls might well be quicker at putting the puzzle together.



4. Boys tend to have a good sense of direction. They are very good at building up a clear idea of a route in the right side of their brains.

5. But they're not so good at remembering landmarks. Girls with their better memory for words can remember the landmarks even if they're sometimes less sure about the direction.

Important note: In conclusion, every scientific study has found that boys and girls have differing abilities in some areas and use their brains in different ways. But, and here's the important part, OVERALL, THEY ARE EQUALLY SMART. So can it, OK?

And there you have it. Learning is a vital function of your bulging brain. Now, have you learned everything in this chapter? Well, one thing's for certain – you couldn't have learned anything without a memory. Luckily, the next mind-expanding chapter can help you. And you'll soon find those memories flooding back . . .

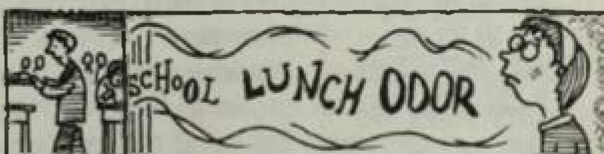
MIXED-UP MEMORY

Welcome to this unforgettable chapter. It's about memory. Just what is this mysterious ability? And how does it work? And will you remember anything after you've read this book? Er . . . now, what was I talking about?

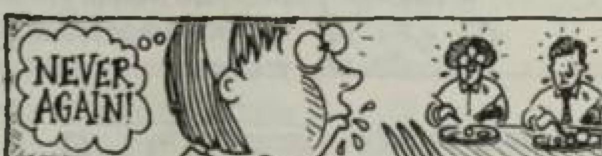
Bulging fact file

NAME: Memory

BASIC FACTS: Memory works like this . . .



1 You sense something.

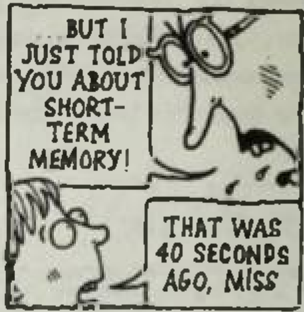


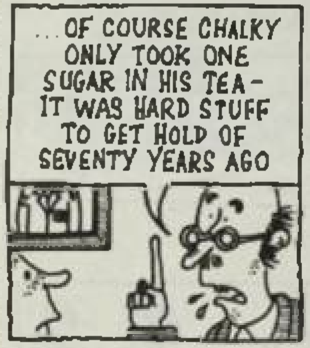
2 You put it in your memory.

3 You can recall the memory when something reminds you of it. The reminder might be a word, an event, or even a smell.

DISGUSTING DETAILS: You've got not one but *three* memories.

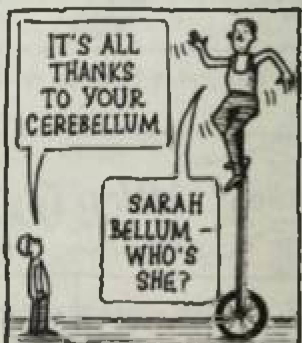
1 Short-term memory. Useful for phone numbers, etc. You forget these memories in 30 seconds. Some kids store their science knowledge in here.





2. Long-term memory. This is stuff you remember for years. It's where Grandpa stores all those boring old yarns of life when he was a boy. These first two memory systems are based in your cortex.

3 A special memory for skills like riding a bike that you can use without being aware of having to remember them. This memory seems to be based in your cerebellum.



Mysterious long-term memory makers

Two areas deep in the cortex, the thalamus and the hippocampus (hippo-camp-us), help create longer-term memory. People with injuries to the thalamus have difficulty in remembering the injury. And in 1953 an American man had the hippocampus on both sides of his brain removed. This was intended to stop fits caused by uncontrollable neuron firing. The fits stopped. But although the man can recall old memories from before the operation, he can't remember anything that's happened since then.

Bet you never knew!

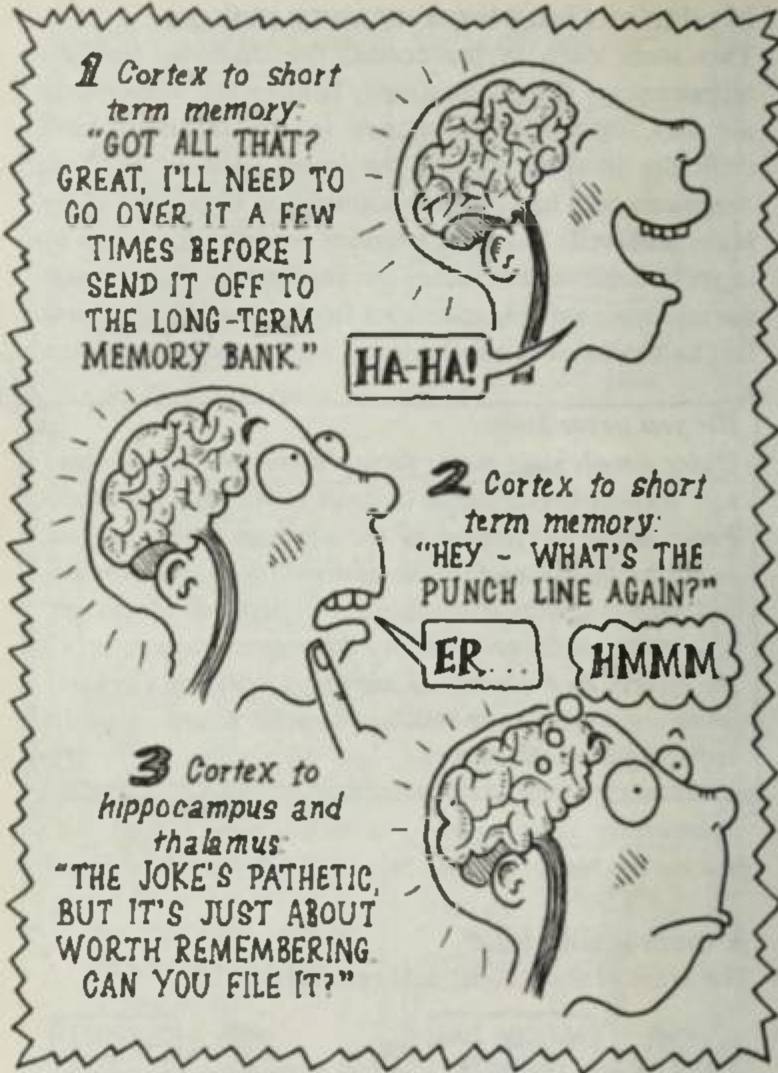
Older people also suffer from this problem. And this, too, seems to be linked to damage to the hippocampus. From the age of about 30 the neurons in this region begin to die off, and by the time people reach extreme old age they've lost about 30 percent. Although scientists aren't too sure why this process takes place, the effects on the memory are fairly obvious. Perhaps some of your more mature teachers are already suffering from the effects.

Hopefully your memory is much better? Well, let's pick up the Neuro-phone and check out how it works.

A memorable joke

The brain is about to try and remember a joke.

(OK. I didn't say the joke was any good.)



Scientific note

Scientists aren't quite sure how this happens. It seems to involve a change in neuron chemistry. This makes it easier to send a message along a particular route through the maze of neurons in your cortex. (Each neuron pathway is storing a particular part of a memory. Some store colors and others can store shapes.) The memory of the joke should remain in your brain even if you can't recall it. People call this "subconscious memory."

A few weeks later . . .

No doubt you'll be pleased to hear there's room in your memory for lots more jokes (and other stuff). Remember all those billions of neurons and synapses in your cortex? Well, scientists reckon you can squeeze enough facts in your memory to fill 20,000 encyclopedias. Do that and your brain really would be bulging. You might even win a memory competition.

The Horrible Science memory competition

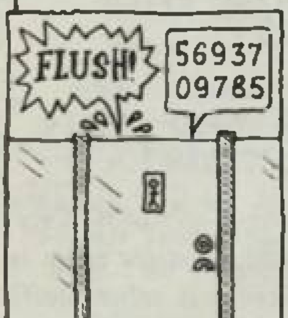
This competition is unforgettable. All the prize winners have shown powers of recollection that will live long in our memories.

Fourth Prize

German conductor Hans von Bülow (1830–1894)

Hans was never one to forget a good tune. One day he took the train from Hamburg to Berlin and read the music of a new symphony. That evening he conducted the entire symphony without any mistakes *entirely from memory*.

Third Prize



You'd think that remembering boring numbers would be hard. But in 1995 **Hiroyuki Goto of Japan** recited the mathematical number pi to 42,195 places with no mistakes. The performance took over 17 hours including breaks to go to the toilet. At the end I expect he was flushed with success.

Second Prize

Devout **Mehmed Ali Halici of Turkey** recited 6,666 verses of religious text in 1967. Could you do that in your school assembly? Come to think of it would you like an assembly that was 18 hours long?

First Prize

Goes to **Russian Solomon Veniaminoff**. Solomon wanted to be a violinist but an ear disease slightly damaged his hearing. In the 1930s he decided to become a journalist. Later he worked as a stage entertainer where he wowed the crowds with his unforgettable talent for remembering incredibly long numbers or lists of words. From time to time he also helped psychologist Alexander Luria (1902-1977) with his work on memory. Here's Solomon's story. Of course, we can't remember the exact details but this story is based on the real facts. . .

The man who never forgot

Moscow, May 1928

The slender young man was clearly on edge. "My name is Solomon," he stammered. "My editor sent me to see you because of my memory."

"What's wrong with it?" asked Alexander Luria curiously as he leaned back in his rocking chair. Solomon nervously swept his black hair from his eyes.

"People say that I have an exceptional memory. The fact is I can remember every single thing that has happened to me since I was one year old."

"Fascinating but unlikely," smiled Luria. There was an uncomfortable silence broken only by the ticking of the large old clock on the mantelpiece. Then Luria sighed.

"Oh, well, I suppose we'd better test you. I'd like you to try to remember this sequence of numbers."

The scientist quickly jotted down a series of 30 numbers and then read them out to the young man.

Solomon looked even more worried and gazed briefly into nothing. His dark, dreamy eyes seemed fixed on a distant object that Luria couldn't see.

Then he repeated the numbers perfectly.

The scientist's mouth dropped open. "But that's astounding!" he gasped.

"I could say them backward if you like," said Solomon quietly. And he gave a shy, fleeting smile.

1958

Thirty years later Alexander Luria sat in the warm sunshine gazing vacantly at his garden. He was lost in thought, and as usual he felt rather tired. In front of him lay a pile of old papers covered in his spidery handwriting. The paper was crinkled and yellow with age.

"So how do I turn all this into a book?" he mused to himself. "Where to begin, that's the first problem."

"Why not begin at the beginning?" said a voice. Luria looked up in surprise at the man sitting quietly in the corner. The visitor's hair was gray with age and his figure was stooped and thickset.

"Oh, Solomon, I'm so sorry, I quite forgot you were here. Now, what were we saying?"

"We were discussing the book you were going to write about memory and our 30 years of working together. That's why you invited me here at 4:24 P.M. yesterday."

"Has it really been that long?" asked the scientist wearily.

"Well, on and off, when I wasn't working on the stage."

"I think I'll begin my book on that day in June, when was it? 1929 – when you first came to see me."

"It was 1928," said Solomon firmly, "and the month was May. I remember you in your gray suit sitting in your rocking chair. And that old-fashioned clock you had. And then those 30 numbers . . . what were they now? 62, 30, 19, 41..."

Luria gazed in growing shock at the first page of his yellowing notes. Yes, there in his own handwriting was the exact sequence of numbers repeated with eerie accuracy over a gap of 30 years.

"But that's astounding!" he wheezed breathlessly.

"That's what you said at the time," said Solomon with his familiar shy smile.

"But you must have remembered millions of pieces of information since then. You're a lucky man, Solomon, I do admire this gift of yours."

"It's no gift!" exclaimed Solomon bitterly. "As I told you in 1928, it's a curse. I often wished I could forget things. Sometimes all these facts and numbers and lists jostle in my mind like a huge crowd – like words in poetry or sparks in a fireworks display. They drive me crazy! The greatest gift is to forget things. But that's one gift I will never possess. Forgetting is a wonderful thing."

And his eyes sparkled with tears.

Solomon's secret

After years of patient study Luria figured out the secret of Solomon Veniaminoff's astonishing memory. It was due to the way his mind worked. Solomon suffered from a disease called synesthesia (sin-ees-thees-ia). Incredible though it sounds, this rare brain disease made Solomon experience sounds as colors. He told one psychologist.

By remembering the colors he saw when hearing things and by imagining numbers as people he found it easy to remember tons of information. But the only way he could ever forget something was to imagine it was written on paper and he was burning it.

Boost your memory

Would you want a memory like Solomon's? Probably not – but with a more powerful memory you could get high marks in your science tests every time and even remember your dad's birthday. The good news is you don't need a special brain to develop an excellent memory.

Bet you never knew!

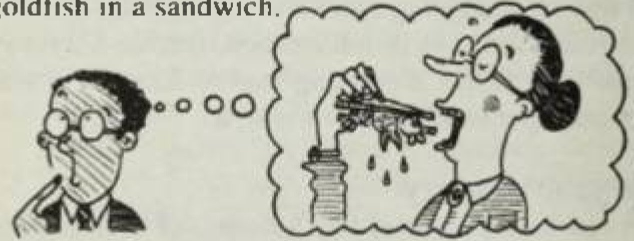
One painful way to improve your memory is to stick electrodes into your brain. Experiments in the 1900s by surgeon Wilder Penfield in Canada found this gives you vivid flashbacks from your past. I expect some of them proved a bit shocking.

Picture this . . .

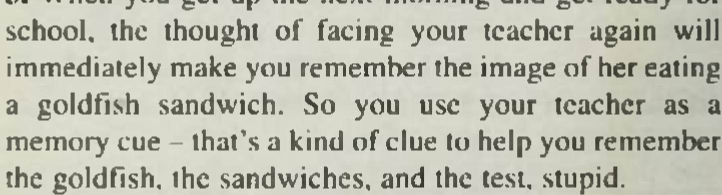
But don't worry, there are many less painful methods of improving your memory. Here's one of them. Suppose tomorrow you have a science test and you need to remember to feed the goldfish and take your sandwiches to school.

1. *Try* to remember to do these things. This should store the information in your short-term memory.

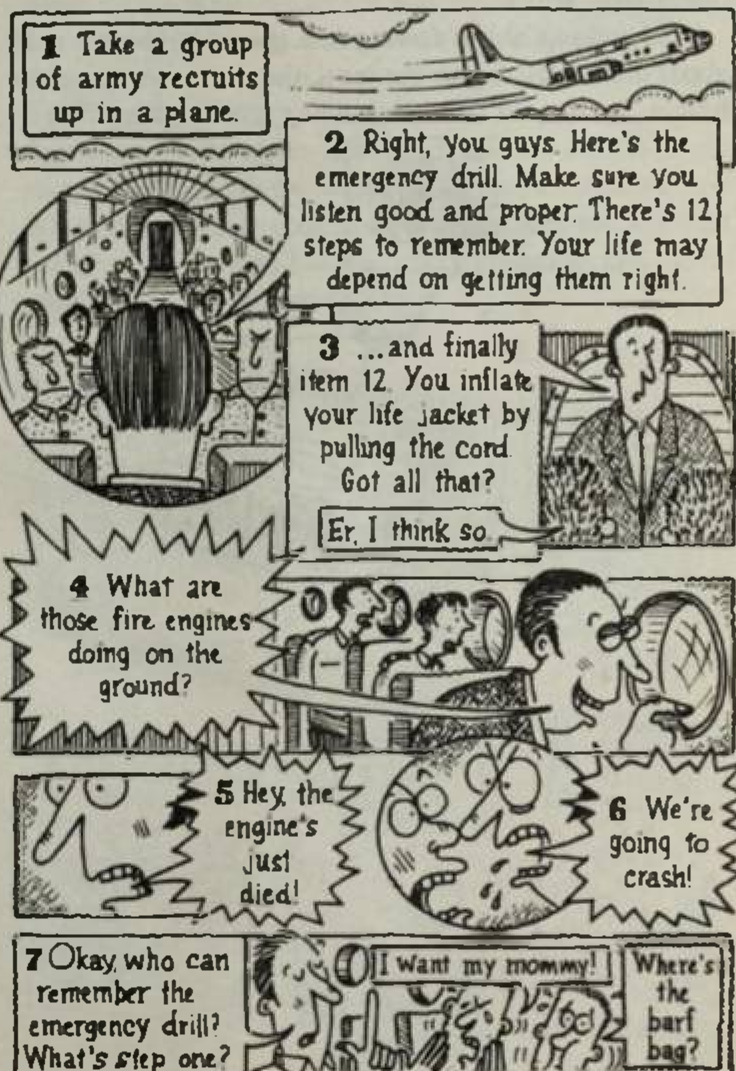
2. For reasons that scientists don't quite understand, you can remember pictures better than facts. It might be because you can link pictures with other memories more easily and in some way this makes them easier to recall. So make up a mental picture to help you remember. For example, you could imagine your teacher eating a goldfish in a sandwich.



3. When you get up the next morning and get ready for school, the thought of facing your teacher again will immediately make you remember the image of her eating a goldfish sandwich. So you use your teacher as a memory cue – that's a kind of clue to help you remember the goldfish, the sandwiches, and the test, stupid.



Your memory can be affected by your feelings. In the 1950s Mitchell Berkun, a scientist working for the US Army, dreamed up this horrible experiment.



Of course, the whole incident, including the fire engines on the ground, had been set up by Berkun. The terrible test showed that the recruits could only remember half the instructions when they were scared out of their wits.

And talking about feelings . . . the next chapter's all about them – the highs, the lows, the excitement, and the horror. So, do you feel like reading a bit further?

FORCEFUL FEELINGS

Are you a touchy-feely person who is always laughing or weeping? Do you pride yourself on being the strong, silent type? Well, whatever you're like on the surface, your brain is bulging with powerful feelings.

Feeling the force

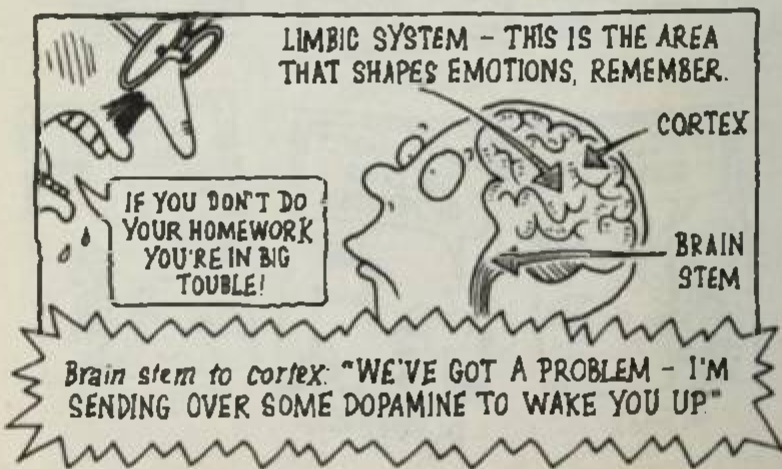
Scientists claim there are six types of emotions that people feel all over the world. Huh – what do they know? When was the last time you saw an emotional scientist? Well, we've managed to find one and photograph the full range of his six emotions.

Of course, feelings can get horribly mixed up. That's why people cry when they're happy or sometimes feel a bit down after some good news.

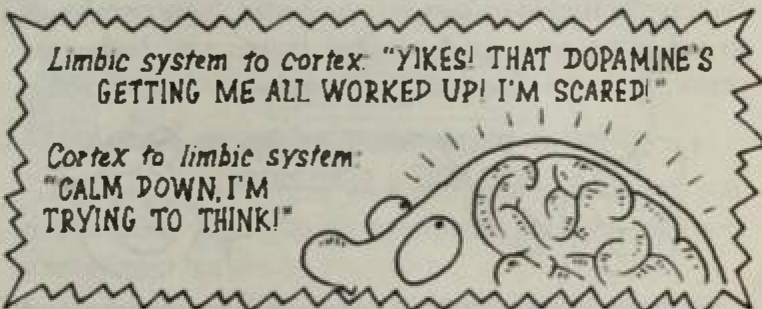
Scientists have hardly begun to explain why our emotions get so tangled. However, as you're about to discover, emotions can be triggered by several different chemicals. With so many of these chemicals sloshing about at the same time it wouldn't be surprising if your brain got some mixed messages.

Complicated feelings

Feeling emotion is actually more complicated than you might think. For one thing, you need to coordinate three areas of your brain. And that really gets the Neuro-phone lines buzzing. Just listen to this: Your teacher is telling you off . . .



Scientific note:
Dopamine (dope-a-mean) is a chemical that seems to make your neurons more active and fire more signals. Obviously the emotion you feel depends on what's going on. It could be terror or joy or anything in between.



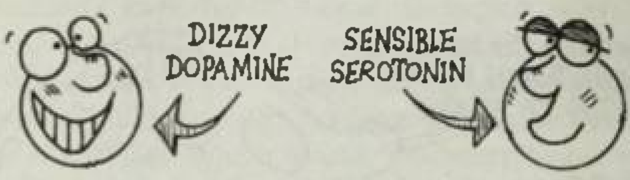
Bulging brain expressions
One neurologist says to another:

Is that some kind of stove?

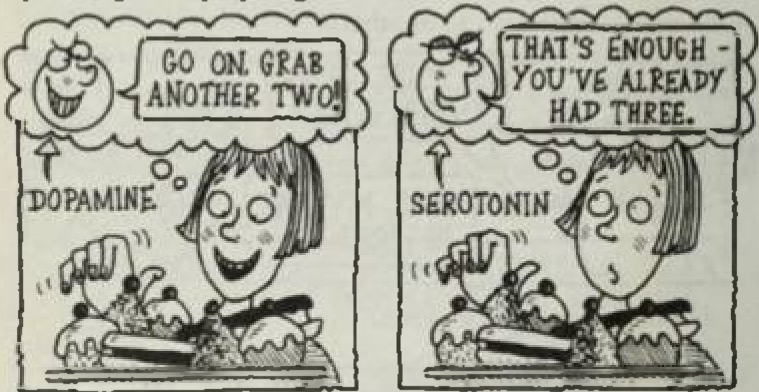
Answer: No. The reticular (ret-tick-u-lar) activating system or RAS for short is the area in the brain stem that makes the dopamine. By the way, you might be interested to know that in small kids the RAS is easily switched on and that's why they get so easily scared. As you grow up the RAS calms down because your cortex learns when there's a real monster and when it's just a curtain blowing in a darkened room.

Dizzy dopamine vs. serious serotonin

So dopamine shakes up your limbic system and you feel emotion. But you don't always do what you feel like doing. That's because of another brain chemical called serotonin (seer-ro-tone-in). This is squirted by neurons linking the limbic system and the cortex. Serotonin tends to calm the neurons down and makes you feel more sensible. (It can also make you feel happy and relaxed.)



Imagine you've gobbled some delicious pastries and you're greedily eyeing the rest.



In other words, serotonin tells you *not* to do things. It's like having a sensible teacher stuck between your ears. (Now that *is* a scary thought!)

By now you might be wondering why your cortex needs to get involved in feelings. After all, you feel things in the limbic system, and you've got dizzy dopamine to get you all worked up and serious serotonin to calm you down. Well, the cortex is there to think things over and make the ultimate decision.

And of course, getting your cortex involved helps you stop to think when you get emotional. This can help you control your temper.

Bet you never knew!

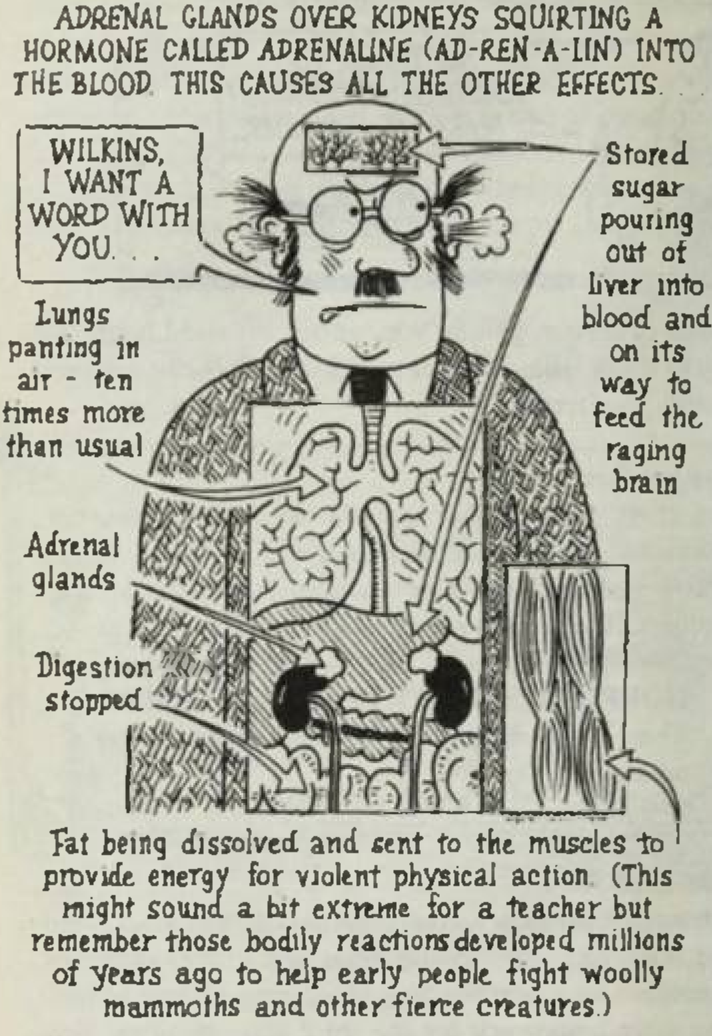
Scientists believe that people with low levels of serotonin can become bad-tempered or even violent. That's because they find it harder to control their feelings. And talking about uncontrollable feelings . . .

HORRIBLE SCIENCE HEALTH WARNING
There's a feeling of TERROR lurking on the next page.

Fear and fury

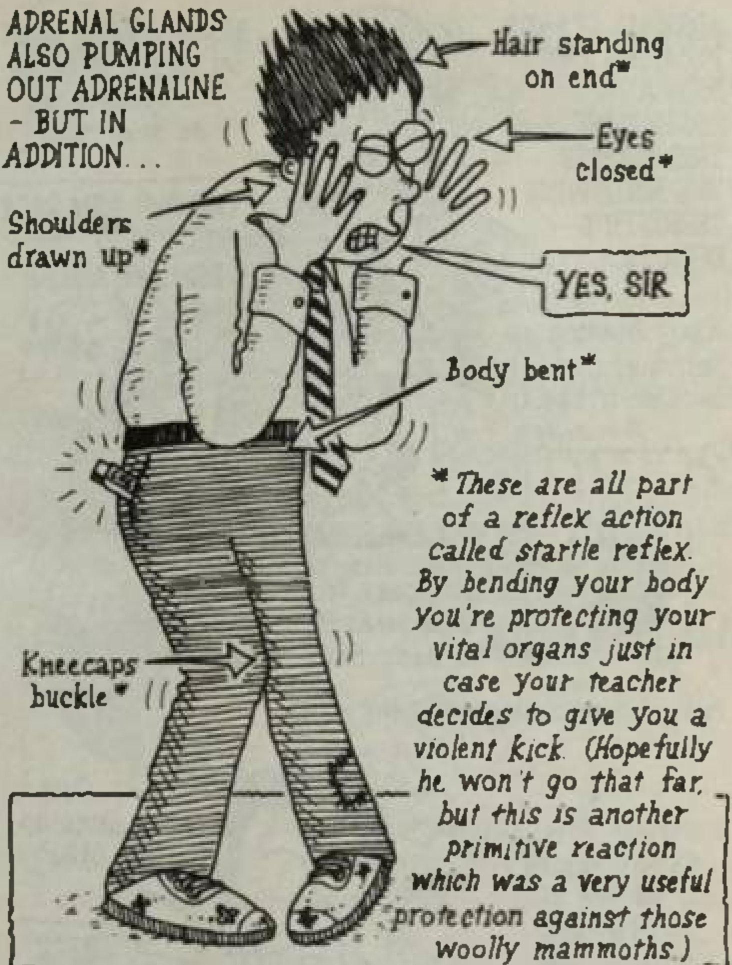
Although feelings are controlled and felt in your brain, your body also joins in and helps you to feel emotions. Sometimes in a horrible way. Just imagine you haven't done your homework for the third time running. Your teacher is seething. Never mind, here's your chance to make interesting scientific observations on the effect of anger and fear.

An angry teacher



Did someone mention scientific observations? Well, maybe you're not in the mood. Inside you might be feeling a bit wobbly, petrified even. Maybe a bit like this . . .

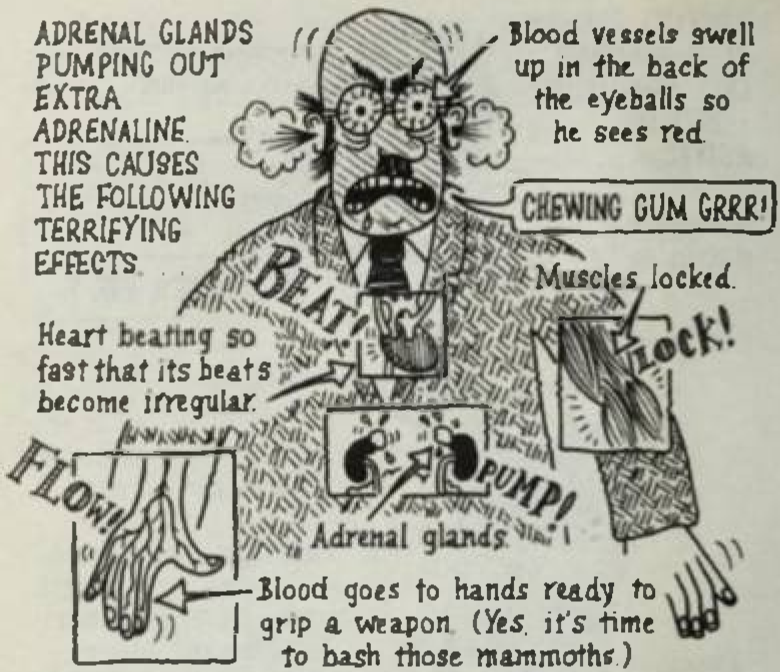
A scared child



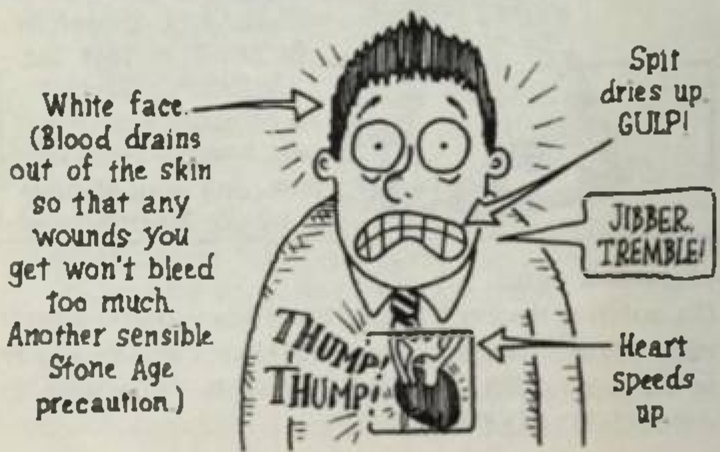
Important note:

Oh, no! Your teacher's figured out it was you who absent-mindedly left chewing gum on his chair. Oh, boy, you're in for it now. TAKE COVER! YOUR TEACHER IS ABOUT TO GO BALLISTIC . . .

A teacher who is just about to explode



An even more scared child



The long, long, long wait outside the principal's office

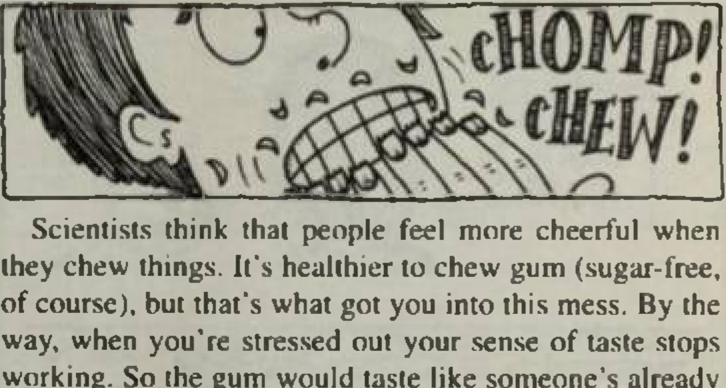
So you've been sent for a little chat with the principal? Oh, dear, this could prove painful. Here are a few things to think about while you're waiting for the ax to fall.

Four fearful feelings facts

1. You feel stress. This is the fear you feel when you're scared but you can't run away. Well, you can but they'll only catch you and then you'll really catch it. Some kids feel stress when they start a new school, and some feel it every day they go to school.

2. Chewing your fingernails yet? Masticating keratin* is a common response to stress.

*(Mas-tic-kate-ing) = fancy term for chewing. (Ker-rat-in) = the substance your nails are made of.



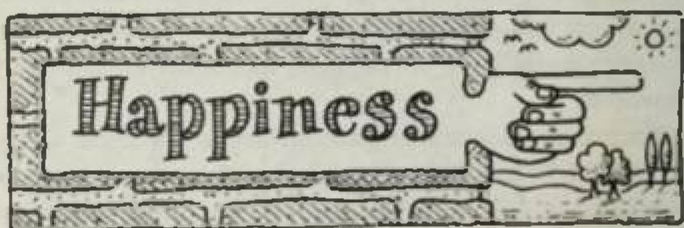
Scientists think that people feel more cheerful when they chew things. It's healthier to chew gum (sugar-free, of course), but that's what got you into this mess. By the way, when you're stressed out your sense of taste stops working. So the gum would taste like someone's already chewed it.

3. Your adrenal glands are squirting a hormone called cortisone (cor-ti-zone). The aim of this chemical is to prepare your muscles for action later on. Sugar pours into your blood, your brain feels more alert because it's getting more sugar, and the nerves are firing like crazy. But you feel rotten – all nervy and jittery. Yikes!

4. You'd better apologize to the principal – you might even be let off without a punishment. But there's one feeling that's even worse than being stressed. It's worse because it makes you feel really miserable, really sad. It can spoil your whole life . . .

Bet you never knew!

Depression is a brain condition that makes you so miserable you want to go to bed and cry and stay there forever. Scientists think it may be the result of a shortage of brain chemicals such as serotonin. If you ever feel this way, try taking a deep breath. Let it out slowly and relax. Yep, that's it: for some reason relaxing actually helps you feel better. Remember this rotten scary fearful miserable feeling is caused by a few chemicals in your bulging brain.



The secret of happiness

For hundreds of years people have searched for this elusive secret and gotten very uptight and miserable because they couldn't find it. But it's here – in this very book! Ahem, wait for it . . . This next part is based on research by US psychologists Paul Costa and Robert McRae. In the 1970s, Costa and McRae interviewed large numbers of different people and tried to discover what it was in their personalities that made them happy or sad. Here's what they found. To be happy it helps if you enjoy meeting new people.

Don't expect too much from life. That way good things come as a pleasant surprise.

But always look for the bright side of every situation.

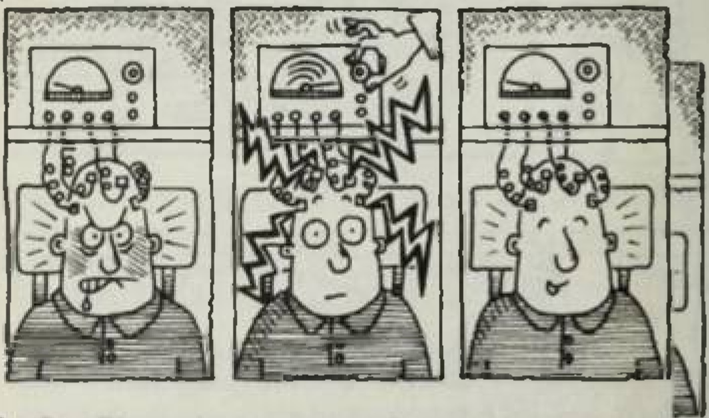
And if you can't find happiness by using these simple techniques, then don't worry. Science has found ways of making you cheer up whether you like it or not.

Bet you never knew!

1. In the 1950s it was common to treat diseases of the mind by cutting the nerves to the front part of the cortex. This made the patient less emotional (maybe that's because it's hard to be emotional when you've got a thumping headache).

2. US surgeon Walter Freeman invented his own version of this horrible treatment. Walt stuck an ice pick through a patient's eye socket into the brain and cut the nerves that way. I expect he only wanted to pick their brains, ha-ha. Hardened doctors were known to swoon at this revolting spectacle. The patients also felt sick and confused afterward.

3. In 1963 scientist R. G. Heath tried a new technique to control feelings. He stuck electrodes in the brain of a man with a brain disease that caused uncontrollable rages. By pressing buttons the man gave electric shocks to different areas of his brain.



But you don't have to drill holes in your skull or wield ice picks or even suffer electric shocks to feel emotional. Try tuning into your favorite music. Yep, why not enjoy the feel-good factor with our exclusive relaxation tapes?

The Horrible Science ♫ Feel-good Tapes ♫

Recorded by Austrian psychologist Manfried Klein...

SPONSORED BY SOOTHIE-BRAIN HEADACHE TABLETS.

BEFORE AFTER

Chill out to the brain-calming tones of musical gems such as "The Brandenberg Concertos" by German composer J.S. Bach (1685–1750).

IMPORTANT NOTE:

Yeah, it's dead boring classical stuff by an even more dead composer. But Klein found that people all over the world go gooey when they listen to it. Yes, even people like you who think classical music is best enjoyed by zombies and elderly teachers. So get in the groove, chill out and feel mellow...

Could you be a scientist?

The situation you're in and the reactions of other people can affect the way you feel. Sounds like common sense, doesn't it? But psychologists have tried to find out precisely how important these factors are. And they've dreamed up a few brain-boggling experiments.

1. In the late 1960s two psychologists from New York University played Frisbee in the waiting room of Grand Central Station. They laughed and joked and got in the way. After a while they threw the Frisbee to a third scientist who was pretending to be a stranger. She joined in the game. What happened next?

a) Other people joined in the game.

b) Everyone ignored the Frisbee players.

c) The scientists were arrested for causing a nuisance.

2. The same team put three people in a room and gave them forms to fill in. Then they wafted smoke through vents to make it look like the room was on fire. Two of the people were actually psychologists in disguise, and they ignored the smoke. What did the third person do?

a) Ran about shouting . . .

b) Ignored the smoke.

c) Got a fire extinguisher and squirted the scientists with foam from head to foot.

3. US psychologist Philip Zimbardo set up a tasteless experiment. A nice, friendly scientist was given the job of persuading complete strangers to eat fried grasshoppers.

Next, another scientist rudely ordered people to eat the insects. What did the results show?

a) People were more likely to eat the grasshoppers when they were asked nicely.

b) The test was scrapped when someone threw up. This is odd because grasshoppers are a delicacy in parts of Africa such as Morocco. They have a lovely crunchy texture and taste like dried shrimp.

c) People ate the grasshoppers on both occasions. But they said they felt different when they were ordered to eat them.

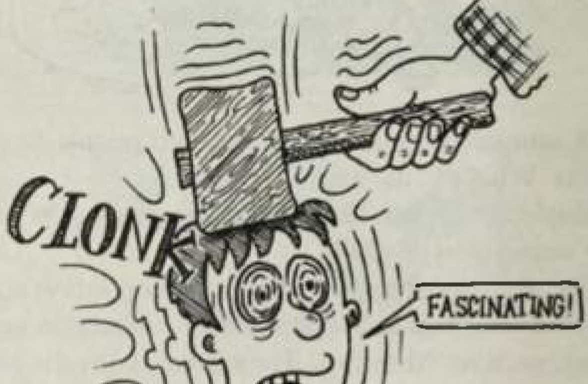
Answers: All the experiments show how your view of the situation can shape your feelings.

1. a) When one person joined the game everyone else felt good enough to want to take part. The scientists actually had trouble halting it. In another experiment the "stranger" pretended to be grumpy and no one else got involved.

2. b) If everyone else ignores an event – even a dangerous fire – it's hard to feel excited about it.

3. c) When people were asked nicely, they said they ate the grasshoppers because they didn't want to upset the nice scientist. When the people were ordered to eat, they said they felt like trying the grasshoppers.

Mind you, there's one situation where you'd feel nothing. It's when you get knocked out cold by a bash on the head. And if you want to find out what it does to your brain, take a look at the next chapter. It's a real knockout.

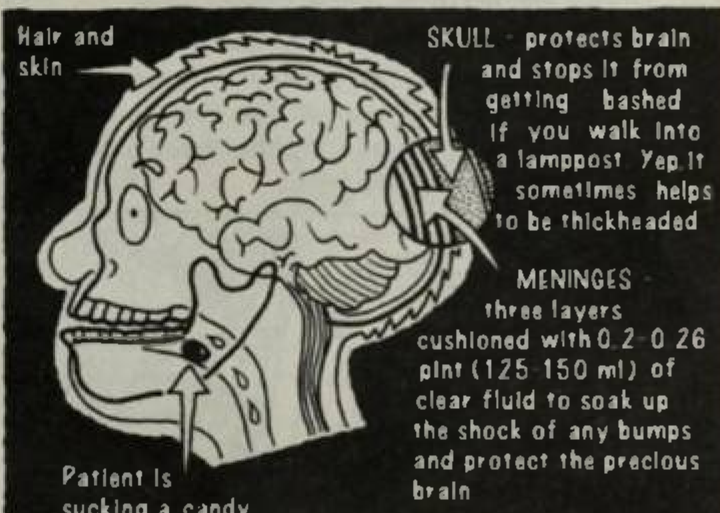


BANGS 'n' BASHES

As you've probably realized by now, the brain is an intricate and delicate bit of equipment. So, not surprisingly, a bash on the head can damage the brain in all sorts of horrible and unexpected ways. Luckily, you do have a bit of natural protection.

Bulging brain protection

Your bulging brain is naturally well protected. Let's take a look at this CAT scan.



A nasty blow

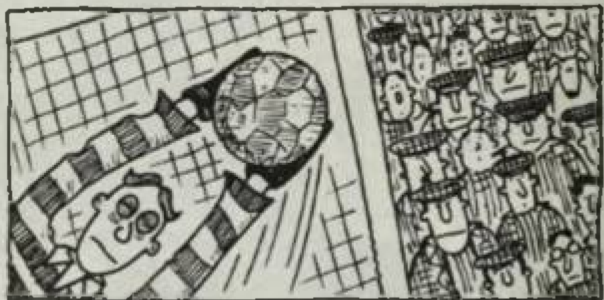
Despite these elaborate defenses, a bash on the head can make you lose your memory – or cause amnesia, to use the scientific term. In this state you can't remember what hit you, or even that you've been hit. And you may lose consciousness. And consciousness is actually the most incredible thing your bulging brain can achieve.

Bulging fact file

NAME: Consciousness

BASIC FACTS: It means being aware of your thoughts and feelings. Scientists aren't too sure how this happens. The whole of your cortex seems to be involved in making you aware of your thoughts and what they mean.

DISGUSTING DETAILS: It's possible to run around and perform simple actions while unconscious. In a 1956 championship soccer game, Bert Trautmann was knocked unconscious in a collision with an opposing player. But battling Bert somehow made a vital save and completed the game.



His team, Manchester City, won the cup.

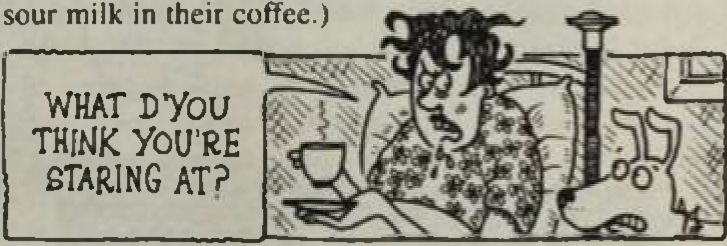
Bulging brain bumps

Here are some vital facts to bump up your knowledge.

1. When you get up in the morning your brain gets a rude awakening. As you lift your head up your brain slops forward and bangs against the front part of your skull.

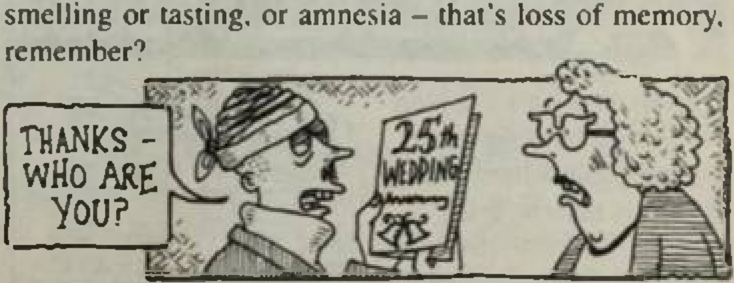
Luckily your meninges and the fluid around the brain stop it from getting too battered.

2. Some neurologists think the shock makes some people feel bad tempered in the morning. (It's either that or the sour milk in their coffee.)



3. In car crashes the effect of the brain being thrown forward is far more damaging than a blow to the head. The shock is more likely to tear blood vessels and the brain itself, leaving wounds that cannot easily be treated because they're inside the skull.

4. The effects of an injury can depend on which part of the cortex gets damaged. It can lead to problems reading, smelling or tasting, or amnesia – that's loss of memory, remember?



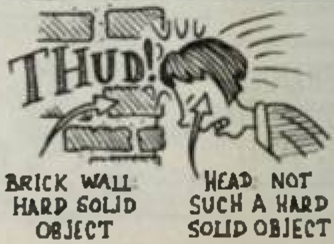
5. In 1997, Vicky, a ten-year-old British girl, banged her head and started writing backward and upside down. Vicky could read her own writing but it must have baffled her teacher. A year later she got overexcited watching football and banged her head again. The next day, for reasons that neurologists can't explain, her writing returned to normal.

Bet you never knew!

In 1998 a retired Scottish soccer player said that his memory loss was due to heading the ball too much. His wife said that he often chatted to his grandchildren and then forgot whom he was talking to. Before the 1950s, soccer balls were made of heavy leather, and when it rained they sucked in water and got heavier. If they hit you on the head they could knock you out.

HORRIBLE HEALTH WARNING!

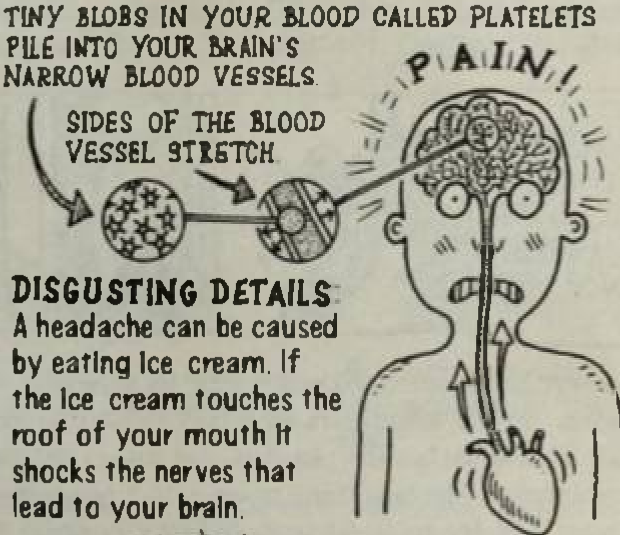
So let that be a warning. Don't go bashing your head against hard solid objects such as brick walls, floors or teachers. It's horribly unhealthy.



Bulging fact file

NAME: Headache

BASIC FACTS: A headache is a brain-pain. But wait a minute – didn't someone say the brain can't feel pain? This is true, but when you're under stress more blood squirts into your brain.



DISGUSTING DETAILS: A headache can be caused by eating ice cream. If the ice cream touches the roof of your mouth it shocks the nerves that lead to your brain.

The best thing to do is to touch the roof of your mouth with your nice warm tongue. This relaxes the nerves.

Alternatively, you could let the ice cream melt a bit before stuffing your little face.

Teacher teaser

To succeed in this teaser you need split-second timing, oodles of charm, and skin like a rhinoceros. All you do is choose a morning when your teacher has been teaching an extra difficult class. He'll probably have a headache and will be gulping down a few painkillers with his tea.

Tap quietly on the door to the teachers' lounge. (remember teachers have feelings, too). When the door opens your teacher will be looking grim. So smile sweetly and inquire:

Answer: Yes, it does, and here's why. By frowning you squeeze several kilometers of blood vessels in your head. This squashes the platelets and makes the pain more intense. The best thing to do with a headache is to relax and try to feel happy. When you smile the blood vessels relax and your headache should ease.

Ahh, that's better!

Horrible headache cures

And that's a lot better than the ancient Roman treatment for a headache. Roman doctor Scribonius Largus recommended whacking the patient on the head with an electric fish. This fishy shock treatment was supposed to cure the ache. It didn't. Mind you, if you lived in the Stone Age there weren't any of those nice painkillers or even an electric fish around.

Stone age brain surgery

1 Take a sharp piece of flint.

2 Scrape the hair and skin off the patient's head.

3 Ignore any screams from the victim—*sorry*, patient.

4 Carry on until a hole appears in the skull.

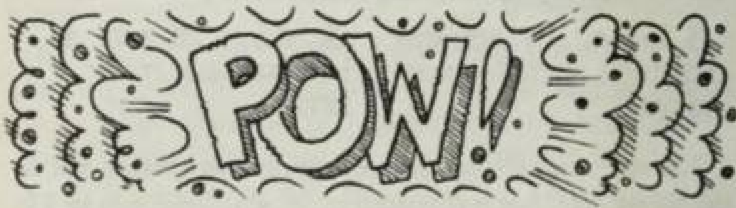
No one is sure why this operation was carried out in the Stone Age, but it was used in ancient Greece to tackle persistent headaches. Although it didn't do much good, the victims often survived with their brains bulging out of the gory hole. Stone Age skulls have been found in which the skull had started to heal.

Actually this treatment – known today as trepanning (trep-panning) – is still performed by surgeons. You'll be relieved to know they use modern instruments rather than lumps of rock. It's done in an emergency to relieve a buildup of blood pressure in the brain caused by a blood clot. And, as you now know, people can survive with a hole in the head. A person can even survive with a hole made by an accident.

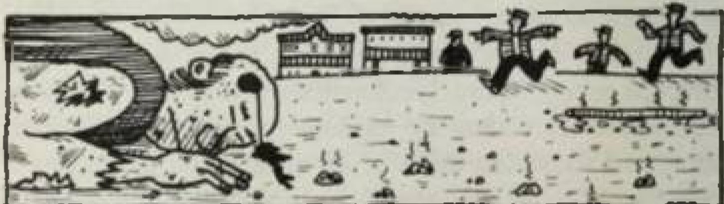
Groaning Gage

Everyone liked Phineas Gage of Vermont. The young railway foreman was a lively and happy-go-lucky guy. Until one day in 1848 . . .

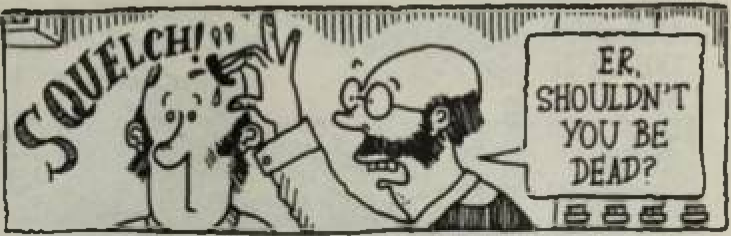
Phin was blasting a path for a new railway. He was trying to push some dynamite down a hole using an iron bar. When disaster struck . . .



The dynamite blew up, and the iron bar shot straight through Phin's head. The bar was found a few yards away spattered with bits of poor Phin's brains.



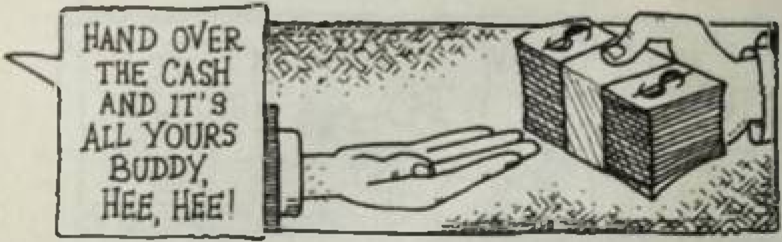
Phin was knocked out by the blow but quickly came to and even managed to walk to the doctor's. The hole was big enough for the doctor to put his fingers inside Phin's skull.



Amazingly, Phin lived – although he was ill for a few weeks. But as a result of his injuries he was a changed man. He was moody, foul-mouthed, rude, and often drunk.

He lost jobs frequently, but his wits remained sharp. He made money by exhibiting himself in fairs with the iron bar stuck through his head.

Scientists were eager to study Phin's battered brain. So he sold his body to *several* medical schools for cash up front.



After Phin's death the medical schools argued over who owned the body and, of course, the brain. The doctors were keen to remove Phin's brain and look at the damage.

The doctors found that Phin's brain hadn't been able to repair the damage it suffered. The damaged front cortex area wasn't vital for life, but it had clearly shaped Phin's personality.

The famous iron bar ended up in the museum at Harvard Medical College. Hope they cleaned it up first.

But you don't need a near-fatal brain injury to lose consciousness. No, in fact you do it far less painfully every night when you curl up your tootsies and snuggle up in your nice warm bed. And if that's where you are right now, why not take a peek at the next chapter? It's a real dream.

Or is it a nightmare?

NASTY NIGHTMARES

This chapter is about sleep. It's about dreams and it's about nightmares . . .

Warning to sensitive readers: Are you easily scared and reading this chapter in bed? Well, if you must scream, scream quietly.

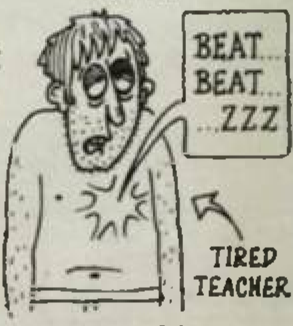
But try not to be too petrified – nightmares and dreams are fascinating effects made by your bulging brain in the middle of sleep. Here are a few more facts to sleep on.

Bulging fact file

NAME: Sleep

BASIC FACTS: When you go to sleep you lose consciousness. Your sleeping brain produces delta brain waves (see page 39) and you're unaware of your surroundings. Oh, so you knew that already? Well try and stay awake for the next bit.

DISGUSTING DETAILS:



Staying awake for two weeks can kill you. Scientists believe that the body needs a period of rest each day. Without it, the body gets more and more exhausted and vital functions like heartbeat begin to falter.

So sleep is good for you. And while you're lying in bed you can always listen in to those chattering Neuro-phone wires as your brain tries to help you to nod off.

Sleepy signals

Cortex to all brain areas: "I'M REALLY WIDE AWAKE. DO I HAVE TO GO TO SLEEP?"

Pineal gland to cortex: "NIGHT-NIGHT, CORTEX. SOME OF THIS NICE MELATONIN WILL CALM YOU DOWN"

SCIENTIFIC NOTE
Melatonin (mel-a tone-in) damps down the activity in the cortex. The pineal gland pumps out melatonin every night on a 24-hour cycle

Cortex: "YAWN, I'M FEELING REALLY SLEEPY."

*RAS** *to cortex:* "COME ON, CORTEX, TIME YOU WERE TUCKED IN. HERE'S SOME NICE SEROTONIN** TO HELP YOU SLEEP"

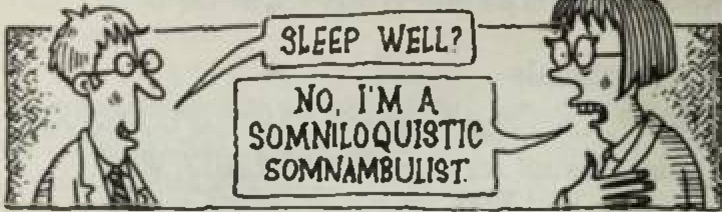
SCIENTIFIC NOTE
At this point your brain should lose consciousness. But you won't notice it. Why? Because you'll be asleep, too, stupid

Cortex: "Zzzz."

* That's the reticular activating system in your brain stem, remember.

** That's the "sensible" chemical that damps down your feelings. The serotonin should calm your cortex down even more.

Bulging brain expressions
Two psychologists are chatting.

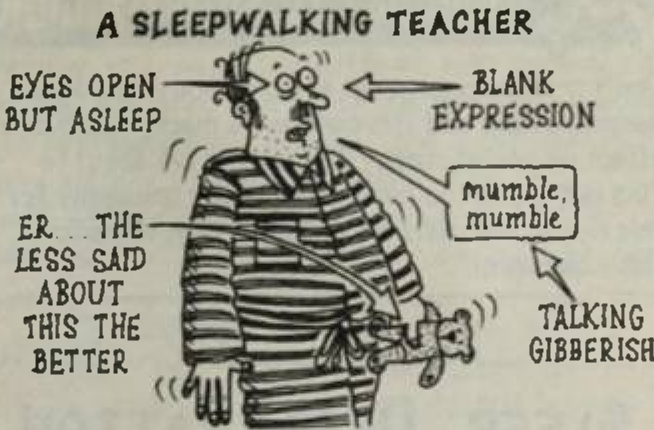


Is this dangerous?

Answer: No, but it's annoying for everyone else. Somniloquy (som-nil-o-kwee) means talking in your sleep. Somnambulism (som-nam-bew-lis-m) means walking in your sleep. So the psychologist walks and talks in her sleep. Well, it could be worse: in 1993 a British businessman had to be rescued by firefighters after falling into a garbage can. He had fallen in while sleepwalking in the nude.

Spot the sleepwalker
One in twenty children walk in their sleep, and some adults do this when they're feeling stressed. Does your

mom/dad/brother/sister/hamster sleepwalk? Here are a few signs to look out for.



Mind you, some teachers act this way on a Monday morning when they are supposedly awake.

Bet you never knew!
It's harmless to wake a sleepwalker, but it's a good idea to do it gently. After all, it's a bit confusing for someone to wake up suddenly and find themselves out of bed. On waking up, sleepwalking people can't remember where they've been. So break the news gently, OK?

A bit of an eye-opener

Any sleep, even with some sleepwalking thrown in, is better than no sleep at all. In the 1960s scientists kept volunteers awake to measure the effects of lack of sleep on their brains and bodies. What you are about to read is a story based on real events that happened in these tests. So try to stay awake for the next few minutes . . .

HORRIBLE HEALTH WARNING!

Don't try this experiment at home. You might keep parents awake and this can have a magical shrinking effect on pocket money. And, as you are about to find out, losing too much sleep is very unhealthy. For this reason scientists are no longer keen to perform this experiment.

SLEEP DEPRIVATION EXPERIMENT DIARY

by Arthur Sleep (volunteer)

Notes by Dr. Irma Wake (day shift) &

Dr. Hugh Kant-Dropoff (night shift)

Monday night
I'm wide awake and feel like I could stay awake forever! I drink coffee to keep me going. The only problem is that Dr. Kant-Dropoff insists on coming to the toilet with me to make sure I don't doze off in there.

4a.m. Tuesday morning. Feeling a bit sleepy: I could do with some shut-eye. I fight the feeling off and play some pool.

TUESDAY MORNING
Dr. Kant-Dropoff writes. . .

Arthur is fine. His heartbeat and reflexes are normal. I wired him up to an EEG machine and his brainwaves are normal. I'm a bit sleepy now myself - could do with a nap. Oh, well, off to bed - I'm handing over to Dr. Wake who will monitor Arthur during the day.

Tuesday night - I nearly dropped off tonight but Dr. Kant-Dropoff rudely shook me and shouted "Wakey-wakey" in my ear. I feel really mad at him.

Dr. Kant-Dropoff writes. . .

Arthur seems more tired and irritable tonight. Shouted at me at 3 a.m. after I stopped him from falling asleep.

WEDNESDAY
Dr. Wake writes. . .

Arthur is slurring his words today. He keeps repeating things and he moves about slowly. He can still play chess, though, and even beat me in a game. Obviously the areas of his brain dealing with thinking are still functioning normally.

Wednesday night - I'm not talking to Dr. Kant-Dropoff after last night's fight. Played loud music to keep awake. I could see Dr. Kant-Dropoff didn't like it - ha-ha!

I'm really tired all the time now. If I close my eyes I could fall asleep. Got to keep going

Dr. Kant-Dropoff writes. . .

Arthur has been extremely quiet tonight.

Thursday

I don't like the way Dr. Wake shouts "rise and shine" each morning. Why does she have to be so cheerful? I mean it's not as if I've been asleep. I bet she gets a good night's sleep, though. She must have something against me. Yes, that's it. She's getting at me

Dr. Wake writes. . .

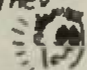
Arthur is clearly exhausted, and his pulse rate keeps going faster and then slower.

Thursday night - My beans on toast tasted funny tonight. I feel sure Dr. Kant-Dropoff put some drug in my food. But why? WHY? Maybe he's getting back at me for playing loud music. I'll show him. . .

Dr. Kant-Dropoff writes. . .

Arthur seems to be suffering from strange ideas. This is typical of people who lose too much sleep. We'll have to monitor the situation closely.

Friday - Refused to finish my cornflakes this morning - the milk tasted odd. Dr. Wake gave them to me so she must be in on the plot with Dr. Kant-Dropoff. Ha-ha! They think I don't suspect they tamper with my food.



4:15 p.m. When I stood up the floor was heaving like the sea. I must have been poisoned!

Dr. Wake writes. . .

Arthur appears to be seeing things. I must contact Dr. Kant-Dropoff and discuss ending the experiment.

FRIDAY NIGHT
Dr. Kant-Dropoff writes. . .

Arthur has locked himself in the toilet. He keeps shouting for me to keep away and stop poisoning him. I will monitor the situation from the outside. I'm afraid he will use violence.

I'll be safe here. All quiet - I think Dr. K-D's gone away. Phew. I can relax! Just close my eyes now for a minute... Zzzzzzzzzz

SATURDAY MORNING
Dr. Kant-Dropoff and Dr. Wake. . .

We broke into the toilet and found Arthur fast asleep. He didn't stir when we moved him to a bed.

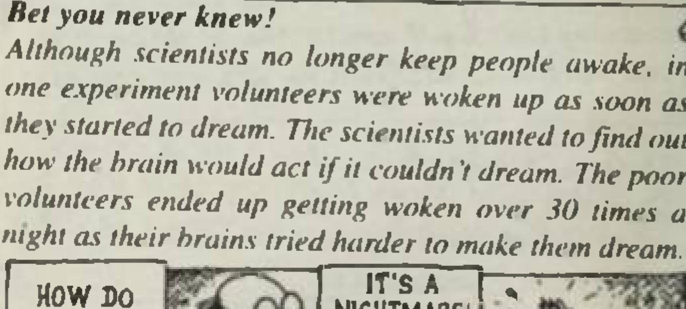
Sunday evening - I've just woken up. I still feel really sleepy but all my tiredness has gone. The last few days seem like a nightmare. Did I really imagine the doctors were trying to poison me? And here they are now, all smiles with some tea and biscuits. They wouldn't harm a fly. That's the last time I miss a night's sleep...

CONCLUSION BY
Dr. Wake and Dr. Kant-Dropoff

Arthur seems fully recovered. His pulse, heart rate and brain waves are normal. The experiment proves lack of sleep can cause mistaken thoughts and cause other problems such as disorders to the pulse and heartbeat. It appears these can be corrected by a longer than usual period of sleep.

Bet you never knew!

Although scientists no longer keep people awake, in one experiment volunteers were woken up as soon as they started to dream. The scientists wanted to find out how the brain would act if it couldn't dream. The poor volunteers ended up getting woken over 30 times a night as their brains tried harder to make them dream.



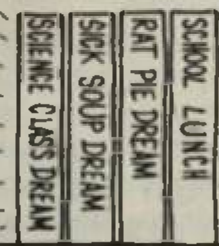
But why is dreaming so important?

Bulging fact file

NAME: Dreams

BASIC FACTS: Dreams are mixed-up memories that pass through your mind when you are asleep. Your cortex often puts them together to make a story.

DISGUSTING DETAILS: Scientists think that in the future a special kind of video camera could be invented to pick up signals in the neurons of your brain and turn them into pictures. So you could watch reruns of your happiest dreams and even your scariest nightmares – if you're brave enough.



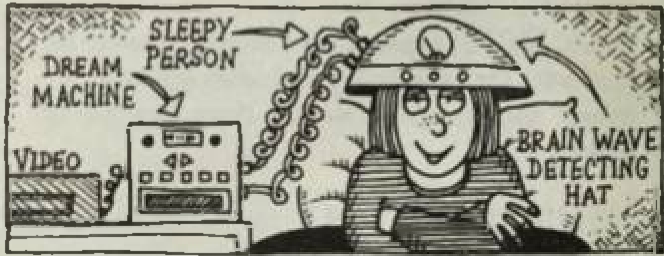
Let's imagine it's already possible. This is how it might happen.

The Dream Machine

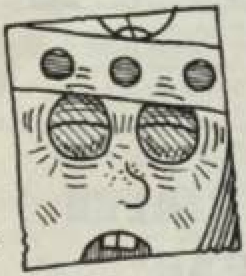
Congratulations on buying the NEW Dream Machine – the incredible machine that turns dreams into exciting videos.

PLEASE READ THESE INSTRUCTIONS CAREFULLY...

1 To set up the machine, plug it into your video. Strap the brain wave detecting hat to your head.

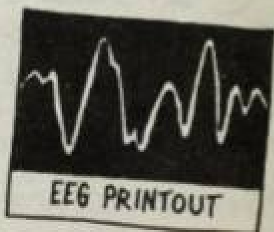


2 Go to sleep. Nothing will happen for at least 45 minutes as your body drifts from light to deeper sleep. As you relax your mouth might drop open and start to dribble – this is entirely normal.

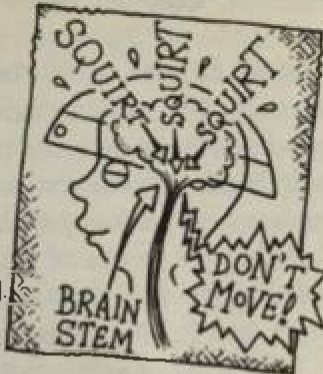


3 After you have been to sleep for about 45 minutes your eyes will start moving under your eyelids. This is also perfectly normal. It is known as rapid eye movement (REM) sleep and it accompanies dreaming.

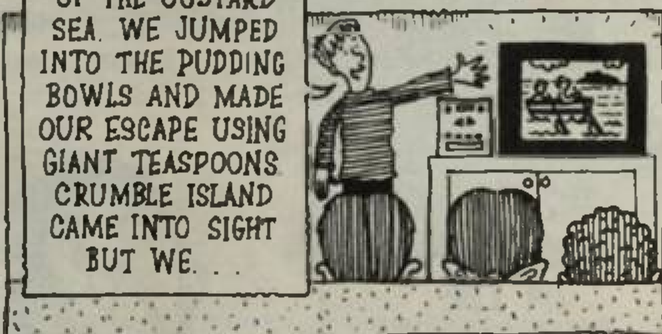
4 As you dream, your brain waves will speed up and become irregular. This triggers the dream machine to start recording your dreams.



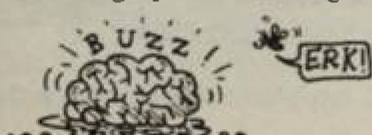
5 You will not be able to move your body while dreaming. Your brain squirts a chemical into the brain stem that blocks nerve messages to your muscles. This is a sensible precaution to stop you from sleepwalking.



6 Relax and enjoy your dream show. Your brain will be going into REM mode about six more times during the night. And the following morning you can replay your video and entertain the whole family with your amazing dreams!



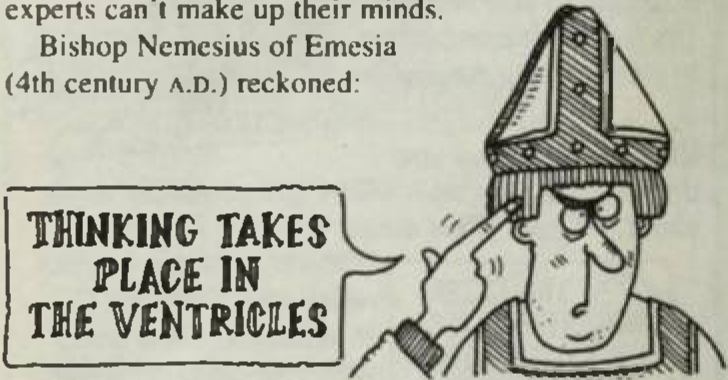
So what do you think of this invention? It sounds really good, doesn't it? Well, here's something else that will really get your little gray cells buzzing . . .



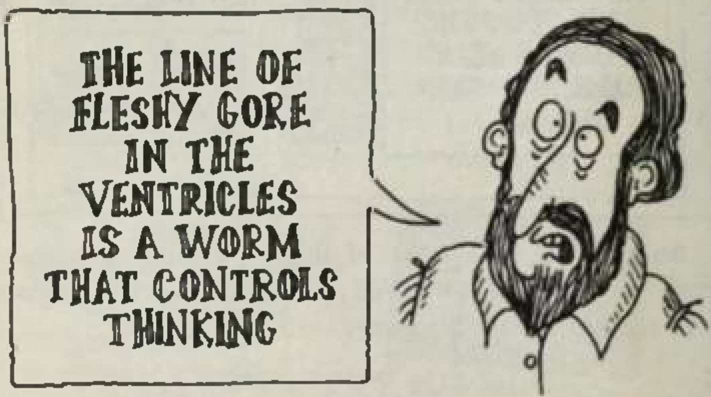
EPILOGUE: SOMETHING TO THINK ABOUT

With its billions of neurons and synapses your bulging brain is the most complicated object in the known universe. So it's no wonder that people find it hard to get their heads around the science of the brain. Even the experts can't make up their minds.

Bishop Nemesius of Emesia (4th century A.D.) reckoned:



These are the fluid-filled spaces inside the brain, remember? One thousand years later, Italian scientist Mondino de Luzzi (14th century) was convinced:

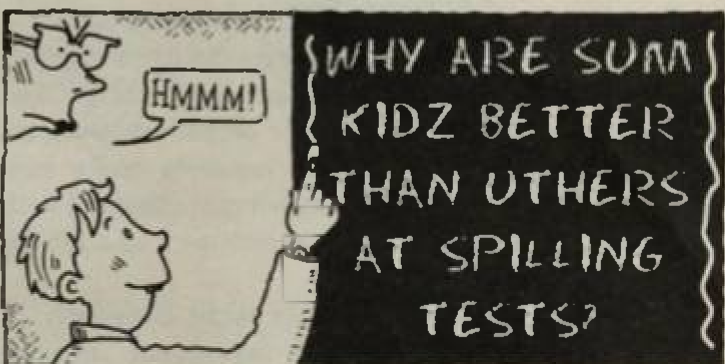


Yuck! He must have had worms on the brain.

And even modern-day scientists can have misleading ideas about the brain. For example, until the 1980s many scientists believed you could decode what the brain is thinking by looking at the pattern of neuron signals. But it's now known that this pattern varies according to your mood and your level of concentration. This means that you can have exactly the same thought and yet each time produce a different pattern of neuron signals.

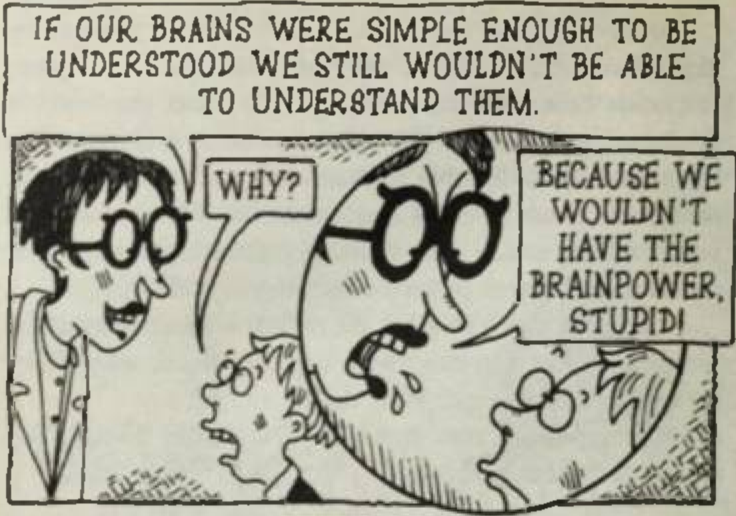
At present much of what we still don't know about the brain boils down to one awkward little word: why? Why do we have emotions? Why do we sleep?

Or, even over two hundred years after Franz Gall started wondering about it:



Question, questions, questions. What do you think?

Thanks to the brilliance of the human brain, people have walked on the Moon and explored the depths of the oceans. But at present we still know more about the surface of the Moon or the ocean floor than the workings of our own brains. No wonder some people think we'll never find out the whole truth about our brains. They would say:



(This does make sense – just you try thinking about it!)

But, on the other hand, it's the mystery that surrounds the brain that makes brain science so exciting. And although bulging brains in tanks or dream machines are still a few years off, scientists regularly make new discoveries. They might find a new brain chemical such as serotonin that affects mood. Or perhaps a new job for an area of the brain.

For example, in 1998 scientists at the University of Iowa carried out a remarkable experiment. Healthy volunteers and people with damaged amygdalas were shown photos of faces. The volunteers thought that some faces looked untrustworthy, but the brain-damaged people couldn't make these judgments. The scientists believe that in addition to shaping feelings of fear and anger the amygdala makes us distrust others. (The amygdala is part of your limbic system – see page 35 if you don't remember.) So what do you think? Would you *trust* the scientists to get it right?

Well, one thing's for sure. Scientists will never cease to search for answers to the questions posed by the brain. And it's the ability to ask questions and to seek out answers that makes us human and our brains so unique.

That really *is* something to think about.

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