INTRODUCTION

There's an old saying that 'you are what you eat,' and in the third of our Christmas Lectures we're going to explore how the foods you eat are turned into you. Most of you are turkeys! Many of you are fishy! And some of you – I'm sorry – are simply vegetables.

First, I'm going to start off an experiment. We have some volunteers who have put a piece of their hair into separate envelopes. James is going to dash across London with the samples to the Biology department of Queen Mary, University of London. A team of helpers there are going to try to work out what sort of food our volunteers eat, just by examining their hair. They'll be using a sophisticated machine called a mass spectrometer. At the end of the lecture we'll see what they have found out. But first let's find out what we're made of.

WHAT WE'RE MADE OF

For a start, 60% of me is made of plain water. After water, the largest part of me is protein, mostly in my muscles. This makes up about 19% of me. Next comes fat – 17%. Most of the fat is adipose tissue – which is storage fat found under the skin. Storage fat is an important energy store that also helps to keep us warm – but it can also have serious consequences for our health, as we'll see later. Some of the fat is runnier, and makes up about one per cent of me. This type of fat is found in my cell membranes.

Then carbohydrates: glycogen in my liver and sugars, like glucose in my blood, make up about 3 per cent of me. That's most of the bulky stuff, but we're not quite finished with the amazing chemical laboratory that is my body. About a kilogram of me is made up of minerals – mostly calcium and potassium, some iron, and a few others. And finally, I contain tiny amounts of vitamins, which are molecules my body needs, but can't make on its own.
So this is me. This is what I’m made from, and what you’re made from too. And all of these chemicals got inside me from the things I’ve eaten. Virtually all of the food I digest provides energy to keep me going. But we need to keep eating for more reasons than just energy. We also need it for cellular renewal.

**CELLULAR RENEWAL**

Snakes are made of the same sorts of chemicals as us, in mostly the same proportions. Of course, everybody knows that snakes shed their skins – but did you know that you shed your skin too? You don’t slough skin in one go like snakes do. Instead, you continually shed tiny flakes. And as you shed skin you must replace it by growing new skin. Every four to six weeks the outer layer of your skin is completely renewed! You each shed about two and a half kilograms of skin every year. Much of it ends up as dust. All that dust in your bedroom – that used to be you.

And it’s not just skin that you continually renew. All the cells of your body are replaced; those lining your gut are replaced every two days, and even the chemicals making up your brain cells are replaced about once a year. So you’re quite literally not the same person you were last year. Of course, all the material you need to rebuild these parts has to come from somewhere – and it comes from your food.

**DIGESTION**

Let’s now think about how you turn the chemicals of your food into you. When you eat, your food goes on a journey all the way through you – down your oesophagus, into your stomach, through your intestines, and finally out of… well, you know where it comes out. But you might have noticed that you don’t get as much out as you put in. The difference is what you've digested and absorbed into your blood.

It’s possible to see the journey food takes by using a tiny radio camera. This is small enough to be swallowed, and as it travels through the gut it transmits pictures of the scene inside the body. First it travels down the oesophagus and into the stomach.

**STOMACH**

Your stomach is like a chemical laboratory, and the cocktail of chemicals it produces is called gastric juice. Gastric juice is mostly hydrochloric acid. The acid is as strong as the acid you
put in a car battery and this kills most of the bacteria that you swallow in your food. In your stomach, enzymes in the gastric juice start to break down your food. But that's just the start of the digestive process, and your food is only in there for about 20 minutes. Very quickly, your food moves into the next part of your digestive system, your small intestine.

**SMALL INTESTINE**

The small intestine is the workhorse of the digestive system – it's where most of your food is digested and absorbed. A chemical, called bile, emulsifies fats in your food, and enzymes break food down so it can be absorbed. For this job it has to have an immense surface area, and to achieve that it's not only long, 5 metres long, it's wrinkly, and the wrinkles are covered with microscopic protrusions called villi.

If you spread your small intestine out, how many square metres do you think it would cover? About 250 square metres. That's the same area as a tennis court – it's huge!

After a couple of days in your small intestine, the proteins, fats, and carbohydrates in your food are well on their way to being absorbed. What's left of your food then goes through into the large intestine.

**LARGE INTESTINE**

In this part of the intestine huge populations of bacteria interact with the food that's left. Amongst the products are gases like methane, carbon dioxide and hydrogen. And you can tell me what happens when those gases escape!

We know a huge amount about the digestive system, and we're also making extraordinary strides in understanding how your body uses the raw materials it extracts from your food. That helps us work out what we should put into our bodies – what foods we should be eating, and the role of our diet in our health.

In the next part of the lecture, we'll explore how your choices about the foods you eat can make a real difference to you.

**NUTRITION**

One of the big issues of today is our choice of food – both the types of food we eat, and the quantity we consume. Let me show you why the types of food available, and the choices you make, matter.

The average height of soldiers in the Boer War, 150 years ago, was 163 centimetres. That's five feet four inches. But the
average 14-year-old boy today is taller than the average fully-grown soldier of 100 years ago. People today are, on average, 10 centimetres taller than they were 100 years ago. That's a huge difference. There are many reasons for this, including childhood illnesses and parasites. But the main one is better nutrition.

The daily diet of working-class children in 1900 was almost pure carbohydrate. It was dull by today's standards, and not as nutritious. It didn't contain the kinds of proteins you need to allow you to grow to your full potential. There were not enough of the high-quality protein foods, like milk. If your body doesn't get enough of those proteins, you don't grow as tall. A hundred years ago, most people drank tea, and they didn't grow as tall. It was only at the end of the 19th century that the food industry came up with inventions like corned beef and Bovril – beef extract. Inventions like this began to provide ordinary people with more protein.

Today, of course, most of us get plenty of those high-quality proteins. Today we have a different kind of problem: we get too much of some types of food – not proteins, but fats and sugars. Fats and sugars are really useful foods because we use them for energy, and we've evolved to store them in our bodies. The problem is, we're so good at storing them that we keep on accumulating them.

Your body has evolved an extraordinary capacity to absorb and store excess fat and sugar. Believe it or not, your body could absorb 10 kilograms of sugar in a single day. That's a huge amount. We're good at absorbing sugar because our bodies depend on energy, and it used to be scarce. Our digestive systems evolved to absorb food very efficiently, so that we can get the maximum value from foods (like this cabbage). In earlier times, we'd have obtained much of our energy by eating lots of foods like this. Pound for pound, a cabbage contains much less energy than crisps. So believe it or not, a large cabbage only contains as much energy as a few crisps. We like foods that are rich in sugar and fat – foods that contain lots of energy – because they used to be scarce. Now, energy-rich foods are very easy for us to find, and that causes a huge problem for our bodies.

ENERGY

To understand the scale of the problem we need to find out how much energy a packet of crisps contains. This information is on the packet: 172 calories (724 kilojoules). In your body,
you release that energy by combining your food with oxygen. The oxygen doesn't add any energy – all the energy that's released is in the crisps.

724 kilojoules sounds like a lot of energy. But let's compare it to the energy you need to run your body. When you are sitting down, your body's running your digestive system: breathing, keeping your brain going, and keeping you warm. To do all this takes 60 joules per second – as much energy as it takes to light a 60W light bulb. So sitting down it would take you more than three hours to burn off the energy from one packet of crisps.

If you exercise you burn off more. When the captain of a university rowing club rows as hard as he possibly can he burns almost 1000 joules per second. That's 16 times as much energy being used as when you're sitting down. Even then, it would still take about 12 minutes to burn off the energy in a packet of crisps.

ENERGY BALANCE

There's a very delicate balance between the amount of food you eat, and the energy you use. If you exercise as much as our captain does on his rowing machine your energy intake needs to be high too. But if you take in more energy than your body uses, you store the excess energy as adipose tissue, or fat. Being fat increases your risk of atherosclerosis, where fat gets deposited in your arteries. The fat clogs the arteries up and can lead to a heart attack. Excess fat also increases your risk of developing diabetes, and even some forms of cancer. So it's important that we avoid storing excess energy as fat by balancing the amount of energy we take in with the amount we use.

DIETS

We're not very good at getting the balance right. In Britain today, a quarter of the children and half of the adults are overweight. And this has led to one of the great obsessions of our age – trying to lose weight. Lots of people spend lots of time trying to lose weight, and sometimes it seems like there's a new craze every year.

There's the Cabbage Soup Diet – cabbage soup is supposed to suppress your hunger. And you'll all have heard of the Atkins diet, which cuts out carbohydrates almost completely. Then there's the Somersizing diet – which suggests never eating fruit with anything else, and the Ornish diet – which restricts your fat intake. Or maybe you could try the Zone diet, which
modulates your macronutrient balance and glycaemic load?
All of them might help you lose weight, but the truth is – if
they ever do work, it's because you've taken in less energy
than you've used. So either you've eaten less, or you've
exercised more. It's that simple.
And there are dangers with a lot of the diets that have become
fashionable. They don't always provide the balance of nutrients
that we require. Some of them cut back on all types of food,
and they're nutritionally deficient. They break the key
nutritional message: you need a balanced diet. If you were to
follow some of the suggested diets strictly, it'd be very hard to
get enough of the most important nutrients of all: vitamins.

VITAMINS
Vitamins are essential nutrients, which means they each serve a
critical role in one bodily function or another. Vitamin A, for
example, is the light-sensitive molecule in the retina at the
back of your eye. You need less than one milligram a day,
about as much as you'd find in a single carrot. But without it,
you risk blindness.
Other vitamins have such general roles in helping our bodies
work. If they're absent from our diet for too long, we'll die.
Why should our bodies have to rely on our foods for tiny
amounts of chemicals that we could just make ourselves?
Vitamin C is a good example to investigate. If we don't get
enough vitamin C, our gums bleed, our wounds don't heal, we
start to go gangrenous. In other words, we develop scurvy.
Scurvy was a particular problem for sailors. We all think that
Captain Cook solved the problem with fresh limes, but in fact
he gave his men malted barley called ‘sweet wort.’ The Royal
Navy wasn't clear of scurvy until the battle of Trafalgar.
Most mammals, even cats and dogs, can make vitamin C – so
why do we have to get it from our food? One explanation is
that the distant ancestors of humans ate lots of foods that
contain vitamin C. For them, the ability to make their own
vitamin C was not needed. So any of these ancestors who
could make vitamin C had no better chance of surviving than
those who could not. In fact, they had less chance of surviving
because making the effort to make vitamin C used up energy.
And tiny though that effort might be, it was a disadvantage.
Those who didn't make their own vitamin C were therefore
more likely to survive and pass on their genes to their children.
Gradually the numbers of people who could make vitamin C
became fewer and fewer, until there were none left. So,
because our ancestors ate lots of fruit, people today can't do without vitamin C in our foods. In the same way, cats can't make vitamin A – they get it instead from the meat of the animals they eat. The general rule seems to be this: if you normally get a vitamin or other essential nutrient in your diet, then, over millions of years, the population loses the ability to make it.

LACTOSE TOLERANCE

There have been more recent changes in how our digestive system works that have resulted from changes in our diet. One example is the development of lactose tolerance. Most people in the world lose their ability to digest the milk sugar, lactose, when they're quite young. They are lactose intolerant. In Europe, however, most of us drink milk, even as adults, in our tea and coffee. How has this difference come about? Cows were domesticated 10,000 years ago, and they provided a fantastic new food source – milk. Most people at the time couldn't digest the lactose in milk, and therefore couldn't drink it. But a few individuals could. Milk, and foods made from it like fermented cheese, is a hugely valuable source of energy and nutrients, so the people who could digest it enjoyed a tremendous advantage. As a result, their genes have been passed on, so today most of us in Europe can digest milk – we're lactose tolerant. That change has happened in just 10,000 years. We are the result of the diets our ancestors ate. And the way our bodies work is a record, a legacy, of what our ancestors ate.

TPN

The scientific study of nutrition is only about 100 years old, but we know which chemicals are the essential vitamins and minerals that the body needs to function as it should. The fundamentals of good nutrition are now so well understood that Total Parenteral Nutrition bags are now kept in most hospitals. A TPN bag contains everything you need to live on for a day. Bags like these are used for people who can't digest food in the normal way. The nutrients are pre-digested, so they can be injected straight into the bloodstream. What's amazing is that it contains everything you need. You can survive on these bags more or less indefinitely, without developing deficiency diseases. It's almost the perfect food, though most of us would find it rather boring. That's an astonishing scientific achievement – a bag of all the food you need.
We now know how to avoid the obvious diseases of malnutrition, but can we change our diets to actually improve how well our bodies perform? That’s the cutting edge of nutrition science that the final part of the lecture will explore.

**FISH OILS**

One set of nutrients that has received a huge amount of attention is so-called fish oils: omega-3 long-chain polyunsaturated fatty acids. They’re found in fish, but they’re also found in some vegetable oils. These unsaturated fatty acid molecules are long chains of carbon atoms, with hydrogen atoms attached to them and a bit of oxygen on the end. The structure was worked out in the Royal Institution 90 years ago. It’s an extremely flexible molecule that is used to build parts of your cell membranes. One idea is that because of its flexibility it allows the cell membranes to be more elastic. Elastic cell membranes are important in allowing signals to pass from one cell to another. Scientific studies on rats suggest that these fatty acids help give your heartbeat a regular rhythm.

What’s not so certain is the idea that they might help make you cleverer. It’s definitely the case that babies, both before they’re born and just afterwards, need enough of these fatty acids if they’re to grow healthy brains. But virtually all babies do receive their full quota from their mother.

In later life, though we only need tiny quantities of these long-chain omega-3 fatty acids, some studies suggest that larger quantities may help increase attention span. However, not everyone agrees, and nobody yet knows for certain. The science isn’t settled yet but it looks like we’re entering a new phase of nutrition science, one where we’ll start to tailor our diets to gain particular benefits.

Perhaps, in the future, our understanding of nutrition will have reached the point where we can improve our health and resistance to diseases, reach our full potential in sport, and, perhaps, improve the workings of our brains.

**YOU ARE WHAT YOU EAT**

And finally, let’s return to the experiment I started at the beginning of the lecture. You will remember that I sent samples of hair from several volunteers to be analysed in a special machine. From the results we should be able to work out what our volunteers had been eating. How can we do this? As you might have guessed, the kind of food you eat is reflected in your body. Almost all the food you digest is used
for energy – as fuel to keep you going. But a small amount is used to build the cells of your body. So if you eat meat, for example, the material to build your cells comes from that meat. All the different parts of you, all the different types of cells that make you *you*, are built from whatever foods you eat.

To work out what different types of food you have eaten we can make use of the fact that there are very subtle chemical differences between different kinds of food. And when you eat your food, those differences are incorporated into you. The differences aren’t anything you can see or notice; they have no effect on your health or how your body works. But they are a chemical signature of what you have eaten.

A chemical that can exist in slightly different forms is nitrogen. The different forms of nitrogen are called isotopes. One type of nitrogen isotope is very slightly heavier than the other. It’s not one millionth of a gram heavier… it’s not one millionth of a millionth of a gram… it’s not even one millionth of a millionth of a millionth of a gram heavier. A tiny difference!

Nitrogen is an important part of proteins, and proteins are used to build cells, so both forms of nitrogen occur in all forms of life. But the slightly heavier nitrogen tends to accumulate in animals.

As a result, if somebody hands you a sample of protein, you can tell what sort of organism that protein came from by looking at the relative proportions of heavy and light nitrogen. Animal protein contains a higher proportion of heavy nitrogen than plant proteins do.

So if you eat animal protein, then protein with a higher proportion of heavy nitrogen will be used to build all your cells, as well as the keratins from which your hair is made. And if you eat plant protein, your hair will be built out of protein that has a lower proportion of heavy nitrogen in it.

All we have to do is detect the difference between the nitrogen isotopes in the proteins of your hair, and then we could work out what sorts of foods you ate – meat or vegetables. To do this, we need to use the machine called the mass spectrometer. The mass spectrometer works on the principle that the heavier something is, the harder it is to make it turn a corner. In the machine, the nitrogen atoms from the hair sample become electrically charged and are then fired down a tube. A magnetic field is applied in the tube, which pushes the nitrogen particles off course. Heavier nitrogen particles are not deflected as much
as lighter ones. Even though the difference in mass between heavy and light nitrogen is tiny, a sophisticated mass spectrometer can still work out which is which. Then, if we analyse the proportions of heavy and light nitrogen in the samples of hair we took from our volunteers, we can tell whether the hair came from a vegetarian or not.

**HAIR TEST RESULTS**

Now, I know that one of the volunteers is a vegan. And our test results correctly tell us who that is. All they gave us was a sample of their hair, and from that we measured the balance of heavy and light nitrogen isotopes in their hair and worked back to what they’ve been eating for the last few years.

**SUMMARY**

So we can see from the hair these volunteers made that they really are what they ate – and you are what you eat. You can’t lie to your own body, because as we’ve seen, it’s made of the food you eat. It’s a living record of all the meals you’ve eaten, and all the exercise you’ve done. Right now, your body is finishing the process of digesting the Christmas dinner you ate three days ago. By about Sunday, on the first day of the New Year, the hair you’re growing from your head will be made from that food you ate on Christmas Day. So some of you are turkeys; others of you are fish; and you should all be vegetables. When we say ‘You are what you eat,’ it’s literally true.