

## **FEEDING OUR FUTURE NUTRITION ON EARTH AND IN SPACE**

The history of food is the history of humanity.

A lot of our social life is organised around food.

And it is a story that has continued as man has ventured into space.

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In space I hated sweet I remember they gave me a coffee with sugar and I couldn't drink.

One of the Apollo astronauts is very proud that he is the only human who has eaten spaghetti on the Moon surface.

As we plan longer missions and future voyages of exploration, research into food and nutrition is at the forefront of the effort to travel to, and build bases, on other planets in our Solar System.

The target for a Mars mission is to be able to recycle 40% of the food

Most of us in Europe are lucky enough to take food for granted. Yet if you really think about it, we still spend a great deal of our lives getting, preparing and of course eating the stuff.

In fact for most of human history the majority of people spent all of their lives just producing the food they needed to survive.

And in many parts of the world this is still the way millions of people live.

It was only in the 19<sup>th</sup> and 20<sup>th</sup> centuries that many of us left the fields and migrated to towns and cities to work in the factories and the offices of the modern world.

The reason that food is such an integral part of our lives is because it provides the fuel that we convert into the energy.

This tractor needs fuel to work. But instead of running on diesel, our bodies unlock the energy we need from the food that we eat. This makes food and eating a huge part of our lives.

But food is much more than just fuel. From the moment you were conceived and began to develop in your mother's womb, your body has been getting most of the raw material it needs to build and repair itself from nutrients in food.

And it's exactly the same in space. To spend more than a few hours in space we have to take supplies of food and water with us.

I'm a life scientist working for the European Space Agency, ESA. At ESA there are thousands of scientist and engineers involved in research into how we can live in space.

We have a big challenge ahead of us. As we plan missions to other planets, we have to find ways of building space farms and actually producing food and water in space.

Many of these projects are being tested on The International Space Station, the ISS. The ISS has been built 400 kilometres above our heads in an international effort of research and space exploration. Travelling at 28,000 km per-hour it orbits the Earth 16 time's everyday.

But to really understand food and nutrition in space, let's find out exactly why we need food, and how we convert it into the fuel and other essentials for life.

For any physical or mental activity, let alone competing on this course, our bodies need energy.

Every time we speak, blink and even dream we use energy.

The cells in our bodies use the energy stored in food for everything from building proteins, copying genetic information, and of course moving our muscles.

Believe it or not our brains use more energy than any other single organ in your body. Just thinking uses 20% of the energy we need.

How is energy stored in food in the first place?

Food is mostly made up from three groups of chemical compounds; carbohydrates, fats and proteins.

Carbohydrates and fats are mostly used for energy; whilst proteins are the building blocks for every cell in our bodies.

But what foods do we need to eat to get these essential ingredients.

Foods like bread and pasta are full of carbohydrates. We get fats from milk, cheese and vegetable products such as oil. And we get proteins again from animal products, or some vegetables such as soy.

Food also gives us the important minerals and vitamins that our bodies need to rebuild themselves and control vital chemical reactions.

Like the crude oil that is pumped out of the ground and then converted into petrol

and diesel for our cars, our bodies have to process food to get at the stored energy that is chemically locked up in food.

The 1<sup>st</sup> part of this process is digestion.

Go.

As soon as food has entered the mouth and the fats, proteins, and carbohydrates have begun their journey through the body, the process of digestion begins.

Digestion is a process that requires food and gives off heat and energy. It does this by breaking down the complex molecules of food into simpler more readily absorbed molecules.

Digestion happens as the food travels along the alimentary canal – or our gut.

The gut is a muscular tube that uses peristaltic action to squeeze the food from our mouth to our anus, via our stomach and intestines.

During this passage nutrients are extracted from food in several processes.

This starts in the mouth where food is broken into small pieces by the mechanical act of chewing.

Our salivary glands also get to work and produce an enzyme called amylase, which breaks the chemical bonds in carbohydrates releasing sugars.

The partially digested food is then transported through the oesophagus into the stomach. The churning action of the stomach further breaks down the food and mixes it with gastric juice.

The stomach is a muscular sac. When empty it is the size of a sausage, but it

stretches to the size of large melon when full.

Food remains in the stomach for between 30 minutes and 4 hours.

In the stomach. Zymogen cells secrete pepsinogen, which is converted into the protein splitting enzyme, pepsin.

The gastric juice in the stomach is mostly hydrochloric acid and is about one million times more acidic than tap water.

It provides:

- the optimum pH for pepsin
- and also denatures proteins into polypeptides
- and softens connective tissue in meat

The next stage of digestion happens in the small intestine where further enzymes break down the polypeptide chains into amino acids; carbohydrates into glucose; and fats into fatty acids and glycerol. These are the end products of digestion.

These simple molecules, together with the vitamins, minerals and water, are then absorbed into the bloodstream in the small intestine and transported to where they are needed in the body.

The most important energy molecule that the digestive system extracts from food and transfers to the blood stream is glucose, commonly known as blood sugar. If you have low blood sugar levels you will have a lack of energy.

Excess glucose is stored as glycogen, in the muscles and the liver, and converted back into glucose when required.

Glucose is supplied to our body's cells by the blood stream. But our cells cannot get the energy directly from glucose so they convert into a form that they can use, the

molecule ATP.

Glucose molecules are broken down a process known cellular respiration.

This process consists of three of life's most important bio-chemical reactions:

Glycolysis

The Krebs Cycle

The Electron transport chain

Collectively the system converts each glucose molecule into approximately 30 molecules of ATP.

It is an extraordinary fact that the billions of cells in our bodies produce half of our own body weight of ATP everyday and then burn it for energy.

After the digestive system has extracted all these vital ingredients from the food we eat, what's left passes to the large intestine where water is extracted and waste material is produced which eventually passes out of our bodies.

So that's how our bodies digest food, but exactly how much and what kind of food should we be eating to stay healthy?

We've seen how our bodies get the energy and the building materials that our bodies need from the food that we eat - but exactly how much food do we need?

To understand this we have to carefully calculate how much energy is contained in food? One way of measuring this is with a bomb calorimeter.

The energy in food is counted in kilocalories. Common usage has shortened kilocalories to calorie.

1 calorie corresponds to the amount of food that when burnt, will raise the temperature of 1 gram of water by one degree Celsius.

The average grown man needs approximately 2500 kcal a day and a women about 2000.

A lot of the calories we consume are needed just to keep us alive - before we do any work. This is called our basal metabolic rate. And we use between 800 and 1400 calories to keep our brain, heart and all our other organs ticking over.

A balanced diet that supplies the correct amount calories and nutrients is fundamental for a healthy body and a healthy life.

Our nutritional needs depend directly on the amount of work our bodies do. A sports-person needs many more calories than someone who spends all day in an office, or classroom, getting very little exercise.

If you consume more food than your body actually uses for energy it is stored as fat.

Our bodies have evolved to store excess energy supplies in fat in case we need it in the future when there is a food shortage. The trouble is that for most of us in the developed world we usually have plenty of food and we don't need to rely on the stored fat.

In the last two decades sedentary life styles and unhealthy diets has led to the problem of many overweight adults and children worldwide. Being overweight is a major contributor to series diseases such as high blood pressure, cardiovascular disease and type-2 diabetes.

If we eat more food than our bodies need our diet is said to be unbalanced.

In space an astronauts' food intake has to be the ultimate balanced diet. They have to give top performances every day in the most hostile environment in which human beings can survive. So their food has to be both nutritionally balanced and tasty, but weigh as little as possible.

A wrong estimate of their nutritional needs may be harmful to their health. It can lead to tiredness, muscular atrophy and cardiovascular problems. So the astronauts diet is carefully monitored whilst in space by flight surgeons like doctor Filippo Ongaro.

The nutritional intake is monitored in the sense that we know what has been brought on board for that astronaut, so we are able to know in terms of nutrients and terms of calories what the astronaut is going to eat. And that choice has been made on the basis on the needs that astronaut has, that has been calculated on Earth including of course the physical exercise, on the space station the astronaut is exercising a couple of hours per day so there is a lot of calories that are burned just by physical exercise.

Extensive research has shown that astronauts actually use slightly fewer calories when in space.

But its not just calorie intake that needs to be monitored in space. ESA nutritionists have discovered some important differences between a balanced diet on Earth and a balanced diet for an astronaut in space.

The iron intake in space should be lower than on earth because in space the astronaut has a lower plasma volume and a lower erythrocyte volume. So at the beginning of space flight there is a breakdown of their haemoglobin, which contains the iron. So more iron is available. So that's one of the exceptions the iron content of the astronauts diet should be lower than the diet on earth.

Vitamin D is also very important for healthy bones. Our bodies usually make vitamin D when our skin is exposed to sunlight. Spacecraft are shielded to protect the astronauts from harmful radiation and excess sunlight.

Astronauts in space in the ISS don't have that much sunlight so they don't have they

can't synthesise vitamin D. So what we right now add is about 800 international units of vitamin D with the space food.

But it's not just about what we eat. When we eat can also drastically improve our performance. This is where astronauts can learn from the field of sports science.

Well there are many parallels in what a physician is doing together with the astronaut, is, is very similar to what a coach or a medical doctor does together with the athlete, so it's really improving, optimising his level of health from a mental and a physical perspective.

Here at Henley on Thames some of the world's top rowers train to achieve their optimum physical and mental performance.

Olympic rower Tony Garbet knows all about getting the optimum performance out of his body.

How important is a balanced diet for an athlete like you to keep fit during training?

I find it really important to make sure you eat correctly. The big thing to talk about I guess is carbohydrates coz without the glycogen stores which is what's stored in the muscle, that is absolutely key and if you get that wrong you are going to be in trouble.

What I advise people really is to try and look at what they call complex carbohydrates which is bran or porridge oats, wholemeal bread, it gives the energy a little bit longer, so you don't have the dips in energy thus the dips in performance.

When we go into more say weight based training I always try and think about having more protein as well, so I combine the two together. And they have done some recent studies recently to say that actually taking on protein and carbohydrate after hard strenuous exercise within the 20-minute window helps recuperate the

body.

But it's effectively a natural balanced diet, its quite simple stuff making sure that your having it evenly spaced out throughout the day in regular intervals.

So we've heard how food can be used to optimise an individual's physical performance. But there's a lot more to food than simply its affect on the body.

As important as food is as the fuel and raw material our bodies need, it is not the only reason we eat.

Another very important role food plays in our lives is a psychological one.

Eating and sharing food with other people is probably the oldest communal act that we know of. It is no exaggeration to say that the societies we live in today had their beginnings in the act of obtaining and sharing food in groups.

You can see this in all social animals.

Long before we started farming we worked together hunting and gathering our food. The eating and sharing of food forms the basis of societies throughout the animal kingdom.

Nowadays this has of course changed and we get most of our food from the supermarket, and we eat alone a lot more than our ancestors.

But eating together is still a fundamental part of our daily lives. And the importance of it is recognised astronaut psychologist Professor Dietrich Manzey.

If we want to socialise with friends, with other family members, even people we do not know very well, we make appointments for a common dinner or a common lunch, we have work lunches so a lot of our social life is organised around food.

The ISS is big enough that astronauts do not meet too much during the day. So what we have decided for the ISS programme is that we want the crew to at least once a day to have a common meal.

We make sure that the dinner at night is made all together. So you have the time over dinner and the time after you can talk together, have a social event, have a joke, discuss. This is important for the cohesion of the crew.

We want to give them the possibilities to communicate informally together and this is highly valued I think from my point as a psychologist's.

The table is very small for six but you have to find a way to be all-together and to prepare your food. Then you have special food for Christmas or a Birthday.

We bring some food from a nice chef in Europe and this is really appreciated by our own astronauts but also by the whole community of astronauts.

Food is also a kind of national thing so to get food from your home country which fits to your own personal preference is I think very important from time to time.

We've seen how crews on the ISS get to choose from a range of foods particular to their own personal taste and culture.

This demonstrates the huge diversity of foods that different cultures have as part of their staple diet.

However, as diverse as the food that we have grown up with is, and is now available for crews in space, it wasn't always so.

The food that the first astronauts experienced is a testament to their pioneering spirit. They had to endure cubes of cold dehydrated food that relied on their own

salvia to re-hydrate. And tasteless pastes squeezed out of toothpaste like tubes. The food was unappetising and not surprisingly they really disliked squeezing it out of tubes directly into their mouths.

By the time of the Apollo Moon missions' in the late 1960's the quality and variety of food had improved enormously. The Apollo spacecraft had hot water, which made rehydrating foods easier and improved the taste.

And for the first time astronauts were able to enjoy their food in space.

One of the Apollo astronauts is very proud that he was the only human that has ever eaten spaghetti on the moon surface.

In the 50 years since we first put humans in space. Space food went from unappetizing concoctions to three-star dishes made by some of the world's most renowned chefs.

ESA has cooperated with European chefs to provide high quality space food. They also created special meals for astronauts to celebrate New Year, birthdays and the arrival of a new crew.

Over 200 recipes are now available. During training, astronauts are invited to choose which meals they would like to eat on their next mission.

Dishes range from chicken teriyaki to fruit salad, beef stroganoff and butterscotch pudding.

A few months before the mission they make you choose between from something like 500 different meals and you test the food. Not in one day because it would be very hard so you do that in a different day and you can say I prefer this food, and you can say I don't like this food. But the nutritionists are looking at your food in terms of a balance of vitamins and quality for your body.

So even if you don't like a type of food you might have it in your package.

I remember from my flight for instance I was surprised because for breakfast I had fish and you know we have croissant and café but you don't have fish, so you have to get used to it.

But it's not just the odd nasty surprise in their food package that astronauts have to look out for. It seems that spending time in space affects the astronauts' sense of taste.

What astronauts anecdotally tell us is that they lose taste and smell sensations in space and that's probably one of the reasons why the space food is so high in sodium content because more salty food taste better than other food.

For me I really I like salted food but in space I wanted even more salted food you know. And on the ground I don't like too much sweet but in space I just hated sweet. I remember they gave me a coffee with sugar. I couldn't I couldn't drink coffee with sugar because it was too much sugar. So your taste has a tendency to change a little bit in space compared to the ground.

Having created this fantastic range of foods for astronauts the next consideration is how to get it into space.

Even great a chef's food has to be preserved before it is taken into space.

Food scientist Mike Lewis is responsible for developing techniques that will preserve astronauts food. But he is just the latest practitioner of techniques that have been used for millennia.

Mankind has been preserving foods in lots of ways going back four thousand years. Salting, sugar preserving, food preservation is very old and very traditional.

The main purpose of preserving foods is to inactivate the micro-organisms or microbes that are naturally present.

All preservation methods involve preventing the growth of bacteria, fungi, and other micro-organisms, as well as retarding the oxidation of fats which cause rancidity.

In today's Hi Tec food industry a variety of techniques are used to preserve food. Many of which we may not even be aware of. Foods that we buy may have been chilled, disinfected or irradiated in order to slow down microbial action.

Most of the food consumed by astronauts in space has been preserved in some way.

The two most common methods of preserving space food

are sterilisation, where food is heated to 121 degrees centigrade in a sealed can.

And dehydration, where water is removed hindering the development of microbes and reducing the volume of the food.

But whichever technique is used to preserve food for use in space the original properties of the food are inevitably altered.

And George Grimble is researching the consequences of this.

Does food preservation degrade the quality of food and degrade its nutritional value and the answer has to be that it depends on the process that is being used to preserve the food.

A lot of research has gone on to try and minimise nutritional changes during food processing for example peas, if you buy them and they've been on the market stall for two days would have lost a considerable amount of their Vitamin C and one of the advantages for example of quick freezing is to minimise those sorts of sorts of changes.

What you'll often find is that particularly sensitive components in food, for example Vitamin A or Vitamin E, can be degraded by atmospheric oxygen and what this means

is that you have to take into account during the processing the amount of vitamin that's degraded and then add an amount back into the food to make sure it reaches the right level.

Astronauts don't have to rely only on preserved food. The ISS gets resupplied every few months so astronauts occasionally enjoy fresh food when a resupply craft has just arrived.

The biggest differences between space food and foods on Earth are in the packaging methods.

Space food must be carefully contained so it doesn't float around in the free fall environment.

Food has to be kept in a kind of sauce. If it's too dry like if you took rice that's too dry the rice could fly over.

Loose food particles on board the ISS could cause serious problems. Not only for the machinery of the space ship itself but for the astronaut's health.

This is dangerous because it can get into your eyes but moreover you can breathe it and you can put that in your lung and this is very bad.

For this reason even something as common as salt and pepper have to be provided in liquid form.

But liquids can float away as well, so drinks like coffee, fruit juice and tea are packaged as powders and sealed in squeezable containers. Astronauts just add water to the drinks to rehydrate them and drink them with straws.

The ISS has a kitchen that is equipped with food storage compartments; food warmers; a food preparation area; a table with restraints (so the astronauts don't

float away whilst eating); and metal trays that stop the food packages from floating away.

But this all depends on food that is regularly resupplied from Earth.

In the next section I'm going to find out how ESA plans to feed astronauts on missions as long as 3 years.

Here on the International Space Station, the next meal is only a supply ship away, but how do we feed a crew of six astronauts on a three-year mission to Mars?

ESA, and the other international space agencies, are planning manned missions to the Moon and Mars in the future.

For that length of time a crew of six would need many tons of food and drinking water – let alone all the other vital supplies that they would require.

Scientists are researching how to extend the shelf life of food for up to five years, whilst maintaining a variety of great-tasting foods.

However, the most powerful rocket in the world today can only carry a payload of a few tons into space. And a trip to Mars would need many tons of food and supplies.

The only practical way to supply long-term missions is to launch the equivalent of a farm into space and grow at least some food (whilst recycling water and waste) to supply the crew for long periods of time.

And when we start to build bases on the Moon and Mars we will also have to grow food, and recycle the waste, to enable us to stay on these distant planets for years at a time.

ESA has also a number of research projects for growing and recycling food in space.

ESA scientist Cristel Paille works on one of these, the MELiSSA project.

The Melissa project addresses actually the supply of air, water and food for the crew in a closed regenerative system in the sense that we take actually the waste which are produced by the crew being well faecal material, urine that we degrade and from that we are we re-generate the water, the air, and we produce as well food.

Today the target for a Mars mission is to be able to able to recycle roughly 40% of the food, why 40% of the food, because if you recycle or produce 40% of the food for the crew directly you produce 100% of the oxygen, and 100% of water that the crew will need.

The question of which food stuffs to actually grow in the precious reclaimed resources is not simply a scientific one.

There is another criteria which is important it's the quality of the food you will need to produce. You can fill the requirement for nutrition with wheat only but have to consider the acceptance. And if we feed the crew with only wheat we of course will probably have some difficulties.

You just want to eat a fresh tomato or a fresh cucumber or fresh fruit.

Melissa has already successfully trialled a closed water recycling system. But this technology is not just applicable in space.

We know that today everyone is challenged by environmental issue and global warming issues specially. The water quality, the air quality, the contaminates and everything. And we know already know because we some success that Melissa technology is applicable to Earth, it is already used in a terrestrial application and I think it is important that people realise this.

Since the beginnings of the exploration of space, there have been many technological spin offs: from advanced composite materials, to GPS that we all use in our phones and sat navs everyday.

And, in a world off increasing population, and decreasing resources, systems such as Melissa, developed for space travel, could be the most invaluable spin off yet.

We've seen in this programme that food is literally the fuel of life - on Earth and in space.

Ensuring adequate supplies of food always has, and always will be, the most important activity that all living things from plankton to planetary explorers do.

As we've seen, the logistics of long term space flight require huge technological innovations to supply crews with the food they need (both for their physiological and psychological well being) as they travel to distant planets.

The Earth is self-sustaining ecosystem. A manned space-craft that will be away from its home planet for years will also have to be a self sustaining ecosystem – or to put it another way a miniature planet Earth.

In many ways the technological challenges of ensuring future food supplies on Earth are the same as in space.