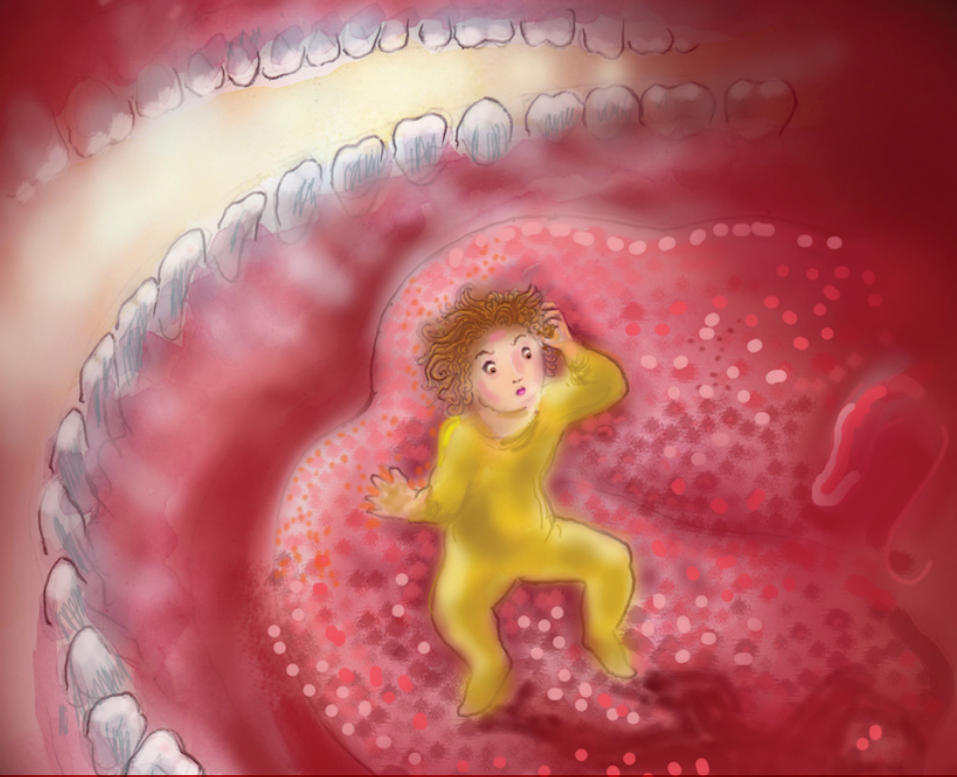


Adventures in the Human Forest



Author: Satya Sivaraman

Illustrations: Panya Chaiyakum

Created by ReAct and Chiang Mai Green City Initiative

Supported by Drug System Monitoring and Development Centre
(DMDC) and Thai Health Promotion Foundation

Acknowledgment and Note

This booklet is part of the 'Dancing with the Bacteria' series of publications aimed at raising public awareness about antibiotic resistance, prevention of infectious diseases, nutrition, food safety and medicine.

The contents of the booklet are an outcome of discussions on these themes at several workshops held in Chiang Mai, Thailand in February and July 2015. The workshops were organised by ReAct along with the Drug System Monitoring and Development Centre (DMDC), Sustainable Alternative Development Association (SADA) and Chiang Mai Green City Initiative.

The 'Dancing with the Bacteria' concept focuses on three sets of activities, all of which are closely related to the microbial world. These include promotion of organic food and farming practices, understanding the link between food/nutrition and health and the rational use of medicine.

Many thanks are due to the academics, health professionals, organic farmers, communicators, environment and food safety activists who have contributed to the content of these publications. Special thanks are due to ReAct for providing financial support towards the production of these booklets.

Introduction

Every morning when you look into the mirror what is it that you really see in the reflection? Most of us would see our eyes, nose, mouth, how our hair is styled, maybe the skin, sometimes the ears and that's it!

Few would bother to wonder about what is it that goes on behind our 'face'- or inside our mouths, our noses, ears on a daily basis. As for the rest of the body we really don't want to deal with its details at all, unless of course a pain or illness forces us to rush to the doctor!

This booklet was born out of the idea that a very large number of people around the world have no real understanding of how the human body works, despite possessing one all their lives! This ignorance is even more remarkable in the times of information overload we live in.

We know everything about the latest mobile phones and cars, about what is happening in distant parts of the world and even the details of planets and stars — but not very much about the structure, components and processes going on inside our bodies. This is true of even otherwise very educated people, for e.g. one

may be a rocket scientist working with very sophisticated engineering technologies but when it comes to a tummy ache or a broken bone his/her situation of helplessness may not be very different from that of people with no educational qualifications whatsoever.

This booklet however is not a medical textbook nor is it a substitute for gaining complete and very accurate knowledge of the human anatomy and its physiology. What it primarily intends to achieve is to just spark the curiosity of the reader to start reflecting on the wonders of the body and embark on a journey of discovery through further study and research.

Why should anyone bother to study the human body and its functions? After all when one has a problem it is always possible to get a doctor (of some kind or the other!), who is more knowledgeable than us, to solve it? Most people think they have enough things to do and worry about in their lives to add learning about our bodies!

First of all we believe that in the modern world if you do not have the basic understanding of the human body you are illiterate no one who does not have a minimum understanding of the human body can really be called 'literate'.

More importantly though, such knowledge of our bodies can help us navigate more easily through the often mysterious world of doctors, medical terms, medicine and healthcare systems. Some day it is precisely this knowledge that could save our lives or that of our loved ones.

And last but not the least, this journey of discovery of the inner workings of the body is a hugely exciting and rewarding one, especially given all the fascinating details it involves. Once you go on this trip we can promise you looking at yourself in the mirror every day will become a completely different experience



Aroon goes on a special trip

102 degrees Centigrade.

Aroon's mother had a worried look as she kept the thermometer away. Aroon curled up deeper inside his blanket, his eyes burning and a dull, throbbing pain in his head. He shivered due to fever and his tongue felt like a piece of wood

Should she take him to see the doctor? It was late in the evening and the traffic on the roads would be bad. She decided to call her general physician and speak to him over phone.

"We have to wait for a few days before deciding to give any medicine" said the doctor

"What about giving him some antibiotics?" asked Aroon's mother anxiously.

"You don't need any antibiotics unless you are sure there is a bacterial infection. Right now he seems to have only a simple cough and cold, which is caused by a virus" said the doctor.

"What is the difference between a bacteria and a virus?" asked Aroon's mother.

Zzzzzzzzzzz....Aroon had dozed off listening to this conversation. He was afraid of doctors ever since one of them gave him a painful injection when he was just six years old. He was very curious however. Bacteria, virus, cough, cold, fever, antibiotics? What did all these mean? What exactly was happening inside his body?

He was deep in sleep when he heard someone speaking to him.

"Come with me if you want to know the answers", said a voice with a heavy French accent, startling Aroon in his dream. Standing before him was a middle-aged man, with piercing eyes and a short, white beard. He was dressed in a dark jacket, with a bow-tie on his neck and a dress-sense that had nothing to do

with the 21st century or even the 20th Century.

"Don't worry. My name is Dr Louis Pasteur and I am here to take you on a tour of the human body and also show you some real bacteria," said the gentleman.

"But...how did you you know I was thinking about these things and what do you know about them anyway?" asked Aroon, a bit startled by this abrupt intrusion into his mind-space by a strange looking professor.

"Obviously, you have not been taught some of these things in your school. I am from France, where I lived in the nineteenth century. I was the first person to come up with the 'germ theory of disease', which links infections to different types of bacteria that either live in the human body or enter it from outside. If you eliminate some of these dangerous bacteria, you can cure the infection".

"Aha! You can perhaps help get rid of my fever and headache" said Aroon.

"Maybe I can. But first you need to know some basic things about both the human body and bacteria before solving your problem. Now come with me quickly before you wake up from your dream. Here, stand in front of the mirror and open your mouth wide" said Dr Pasteur.

"Open my mouth and do what?" asked Aroon, a bit doubtfully.

"Take a deep breath and jump into your open mouth. Now come on, do it quickly, we have no time to waste" said Dr Pasteur glancing at his ancient looking waistcoat watch.

"Ok, as you say" said Aroon, getting up from the bed and going to the mirror at the end of his bedroom. He took a deep breath as instructed and 1,2,3, go!

Wow! He had land straight into the cave of his mouth and in the middle of his tongue! Dr Pasteur stood next to him and Aroon realized both of them had shrunk in size, to perhaps the same height as their little fingers!

The Bacteria Party

Aroon was super excited. It was a strange new environment, the somewhat rubbery, bouncy floor of the tongue, with thousands of taste buds stretching out like a vast field full of little mushrooms. Above him was the pink dome of the palate of the mouth and all around him rows of teeth, an exotic wall of ivory embedded in his fleshy gums. Somewhere at a distance beyond Aroon could see the dark and deep passage that led to the lungs and stomach.

He also felt embarrassed as he glanced at Dr Pasteur, putting a handkerchief to his nose, and wished he had brushed his teeth a bit more carefully in the past.

As if reading his mind Dr Pasteur suddenly said, *"There are more than 1000 species of bacteria living in the human mouth, many of them yet to be identified properly by scientists. Most of these live in the junction between your gums and your teeth, where they take shelter, because they don't like the oxygen that you breathe in".*



Dr Pasteur continued *"Bad breath is caused by the rapid growth of certain species of bacteria when we sleep because in the night we breathe mostly through our nose and the oxygen in the mouth is reduced"*. According to him millions of these bacteria are thrown out when we spit after brushing our teeth every morning.

Aroon felt a little less remorseful for his bad breath now, but resolved to brush his teeth after every meal in future.

"Come, I will show you the bacteria in one of your many cavities in your teeth" said Dr Pasteur. In a few steps they were both staring into the dark crater of Aroon's molar, that looked like a bombed out apartment from a war zone. Dr Pasteur pulled out a special magnifying glass from his pocket and gave it to Aroon to spot the bacteria.

"Ugh! There are zillions of them there! And they are eating my teeth!" shouted Aroon as he saw the bacteria having a big party inside his rotten tooth.

"There is always a very complex film of bacteria with many different species on your teeth called plaque" Dr Pasteur said pointing Aroon to a sample of normal plaque on one of his teeth.

"When you eat too many candies the numbers of acid producing bacteria — which love sugar— goes up and this damages the

hard tissues of the teeth. If you eat sweet things you must also brush your teeth every time you do so and make sure the area between the teeth is also cleaned properly".

"How come there are so many of these bacteria inside my body all the time? I always thought that all bacteria are bad for us and they get into you only if you don't wash your hands properly or if you eat food contaminated by them?" asked Aroon.

"That's not a true picture of the relation between bacteria and the human body" said Dr Pasteur. "There are 10 times more microbes in your body than your actual human cells and the combined weight of the microbes in your body is about the same as what your brain weighs! The microbiome, which is the complex system of bacteria and other microbes inside us, is now considered to be another organ of the human body itself"

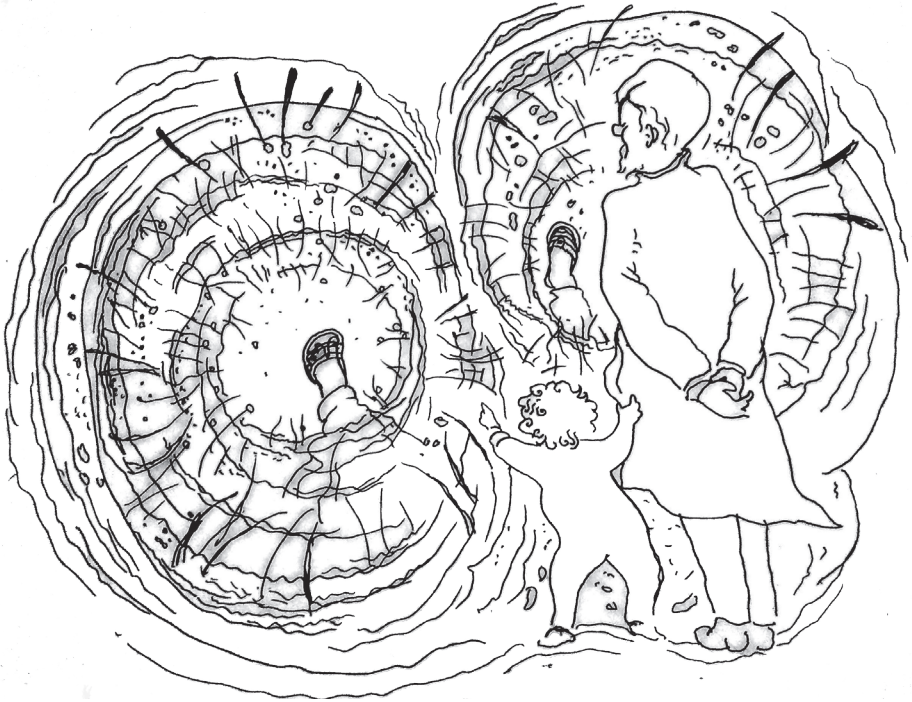
"So if there are more bacterial cells inside me than human cells, who exactly are we human beings?" said Aroon, looking a bit confused.

"The human body is not a machine made with shining, detachable parts. Rather, it is like a forest, that has evolved over millions of years and is full of many different kinds of living organisms and systems all working together in harmony. When this balance is lost, due to any reason, we fall sick", said Dr Pasteur.

Aroon looked even more confused. How is the body like a forest? What was evolution and did it take many million years for the body to become what it is like now? What are these different creatures and systems that make up the body?

Dr Pasteur looked at his watch again and said *"Enough of touring your mouth, let us go somewhere else. See, we can climb up through this passage here into your nose and from there to the ear! Let's go!"*

Did you know that the enamel on the top surface of our tooth is the hardest part of the entire human body or that the tongue has over 3000 taste buds?



Nose

A draft of fresh air hit them as they climbed through the nasal cavity, the opening behind the roof of the mouth, into Arun's nose . Soon enough there was the scent of a flower wafting through that was so overpowering that Arun felt dizzy.

Dr Pasteur noticed this and laughed. *"The outside air bring smells that are sometimes sweet and often foul, but it is because of the nose that you know the difference"* he said.

The human nose it turns out has very small receptors – about 10 million of them– that can sense various odor molecules. When stimulated, these smell receptors send signals to the brain which

interprets them as one out of over 50,000 different odors it can smell !

Soon they climbed to a point where they could see the outside world beyond the nasal passage through the two nostrils. Arun felt a bit strange seeing his own toes from this top-down view and it took him a minute to recollect where he was and what he was doing.

"These small hair-like cells, known as cilia, that are clouding your view are the ones that help trap dust that come in when you breathe the outside air and the sticky mucus you see lining the inside of the nose captures bacteria" said Dr Pasteur. The mucus he explained, also found in many other parts of the body, is the source of the gooey snot that comes out when one has a running nose.

The professor continued, *"The nose also hosts many different types of bacteria, both harmful and harmless. Both categories can cause health problems if they grow in large numbers or if they are displaced from the nose to other parts of the human body. Keeping your nose clean is very important as the nasal passageway is like a window leading to organs like the lungs, mouth and throat"*

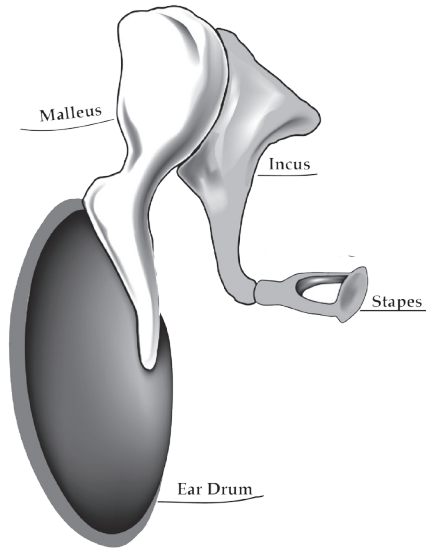
Arun was listening to all this but his eyes were still transfixed on

seeing the world through the most bizarre pair of binoculars that his nostrils made up. All of a sudden Dr Pasteur pulled him forcefully by the shoulder and hustled him through a narrow passage at the back of the nose and into the area where his ear was.

"Sorry, about that Arun, but I think your nose is about to sneeze" said Dr Pasteur a little apologetically for appearing to be rude. Sure enough, within a second of their moving out the entire body they were in convulsed and sneezed with a thunderous sound 'WHooooooooosh' sound! Arun thought his ears are going to explode but the storm finally passed.

'We would both have been expelled out of your nose at 100 miles per hour if we had not escaped!'" said Dr Pasteur.

Do you know, it is impossible to sneeze with your eyes open or that that you have no sense of smell when you're sleeping!



The Ears

They were both now fully inside Arun's ear, standing in front of a curled tube-like thing that looked somewhat like a snail or a squid.

"What is that funny creature?" asked Aruncuriously.

"That is the cochlea, inside your inner ear, which is where the sound you hear through your ears comes to. Look inside carefully . You can see that it is filled with a liquid of some kind and also lined with tiny cells covered with tiny microscopic hair. There are over 25000 such hair that move when sound vibrations reach them and send signals to the brain, which is how you can 'hear' your favourite song or what I am saying right now or your mom

shouting at you!" said Dr Pasteur leading Arun further beyond to the middle ear section.

"Let me introduce you to my good friends Malleus, Incus and Stapes also known as hammer, anvil, and stirrup!" said Dr Pasteur pointing to three small bones joined with each other and one of them, Malleus, resting on a thin strip of stretched skin called the eardrum. According to the professor when sound reached the eardrum the vibrations got transmitted via the three friends Malleus, Incus and Stapes to the inner ear and from there, of course, to the brain.

Arun learnt also that usually in the case of ear problems it is the middle-ear that is most affected, when it fills up with fluid and becomes reddish and painful. The causes can be anything from allergies and changes in air pressure to viruses and bacteria. Very often these resolve on their own and in many cases using antibiotics does not help at all and instead cause other problems.

Soon, Arun and Dr Pasteur headed towards the outer ear. On the way they had to wade through a sticky, paste-like substance that Arun recognised as earwax and grimaced with disgust. Almost as if reading his thoughts Dr Pasteur pointed out that while earwax looked gross, it was very useful too. The wax contained chemicals that fight off infections that could hurt the skin inside

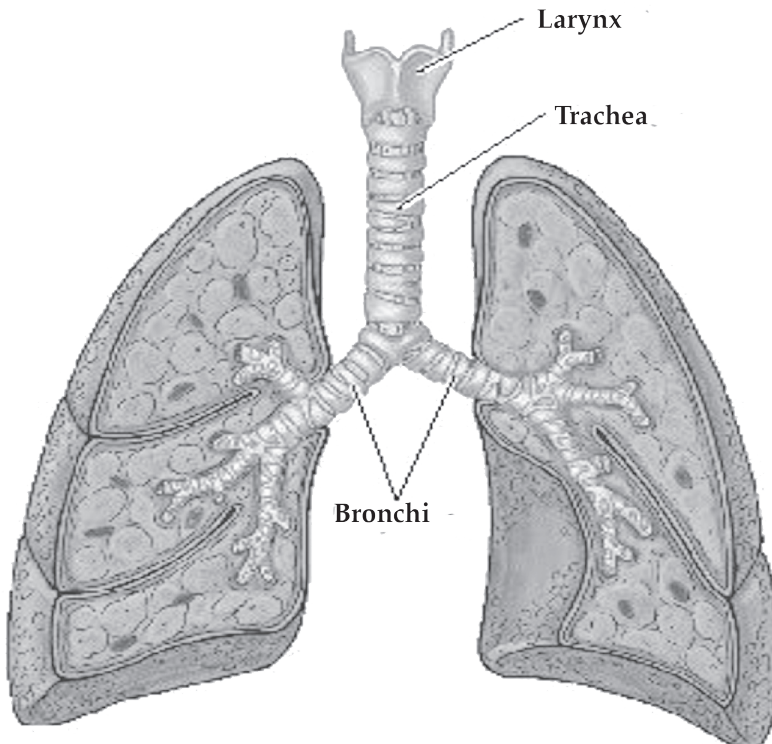
the ear canal and also collects dirt to help keep the ear canal clean.

The stapes or stirrup is the smallest and lightest named bone in the human body and measures roughly 3mm in length and 2.5mm in width. For comparison grain of rice is typically 4mm in length and 1.5mm wide.

Straight to the Lungs

The journey back from the outer ear via the various passages leading to the throat was an exciting one as Dr Pasteur and Arun went on a roller-coaster slide all the way down. At the junction in the throat where the path forked — one leading to the lungs and the other to the stomach they had to pause to decide where to go first. The decision was in favour of visiting the lungs, first.

To do that they had to go past the epiglottis, a flap of tissue that blocks food particles from entering the trachea or windpipe



that connects the throat to the two lungs. Around one inch in width and about six inches long and lined with mucus the trachea, like the nose, also has the hair-like cilia on it that help trap particles and expels them through the mouth as phlegm.

Once again Arun and Dr Pasteur found themselves at a crossroads. This time, they were at a junction at the end of the trachea from where two tubes, called the bronchi, one leading to the right lung and the other to the left one. Each bronchi stem in turn branched off into the lungs in the form of smaller and smaller bronchi, looking like the branches of a tree.

"We are now in one the most interesting parts of the human body. Can you see those tiny tubes, the same thickness as the human hair? They are called the bronchiole and there are about 30,000 of them in each lung and the air we breathe passes through them on the way to the heart" said Dr Pasteur.

At the end of each bronchiole is a special area that leads into clumps of tiny air sacs called alveoli, which is covered with very, very small blood vessels that absorb the oxygen from the air and convey them to the heart.

Arun was amazed to learn that there were about 600 million alveoli in the human lungs, which if stretched out, one by one, would cover area the size of an entire tennis court!

"Have you heard of pneumonia?" asked Dr Pasteur suddenly.

"Yes, my grandfather died of it. Is it something to do with the lungs?" said Arun remembering how in his last days grandpa had difficulty breathing and was rushed to hospital where doctors said he had pneumonia that could not be treated because of something called 'antibiotic resistance'.

"Right, it has everything to do with the lungs. Pneumonia is inflammation of the lungs, caused by infection from viruses, bacteria, or fungi. In one of its common forms, the infection causes inflammation in the alveoli in the lungs, causing them to become filled with pus or fluid. Millions of children die in Asia and Africa because they have either no access to antibiotics or the ones that are available do not work".

"What is antibiotic resistance?" asked Arun, a term he found quite intriguing if not utterly confusing.

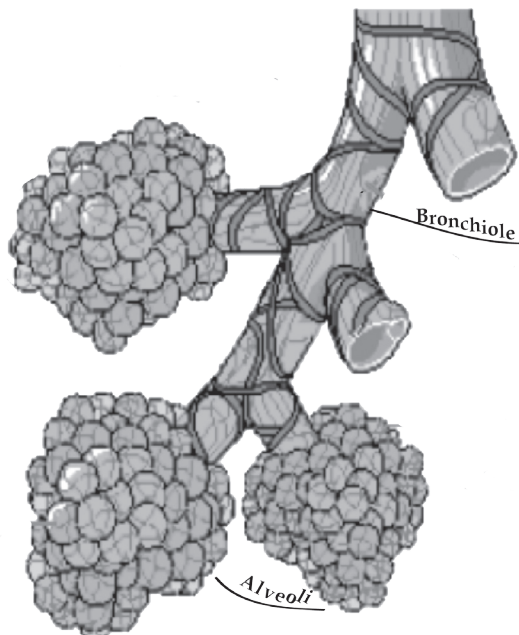
"You are a smart boy Arun. Most children your age may not have heard of that term at all" said Dr Pasteur. Antibiotic resistance, he explained was about the way harmful bacteria, due to variations or mutations in their genes, no longer get destroyed or disabled when antibiotics are used to treat sick people.

It was getting to be a serious problem worldwide he said and if nothing was done quickly it could lead to the emergence of

a bacterial epidemic that was untreatable and kill many, many people.

"But what should one do to avoid antibiotic resistance from developing?" asked Arun, ever the curious boy.

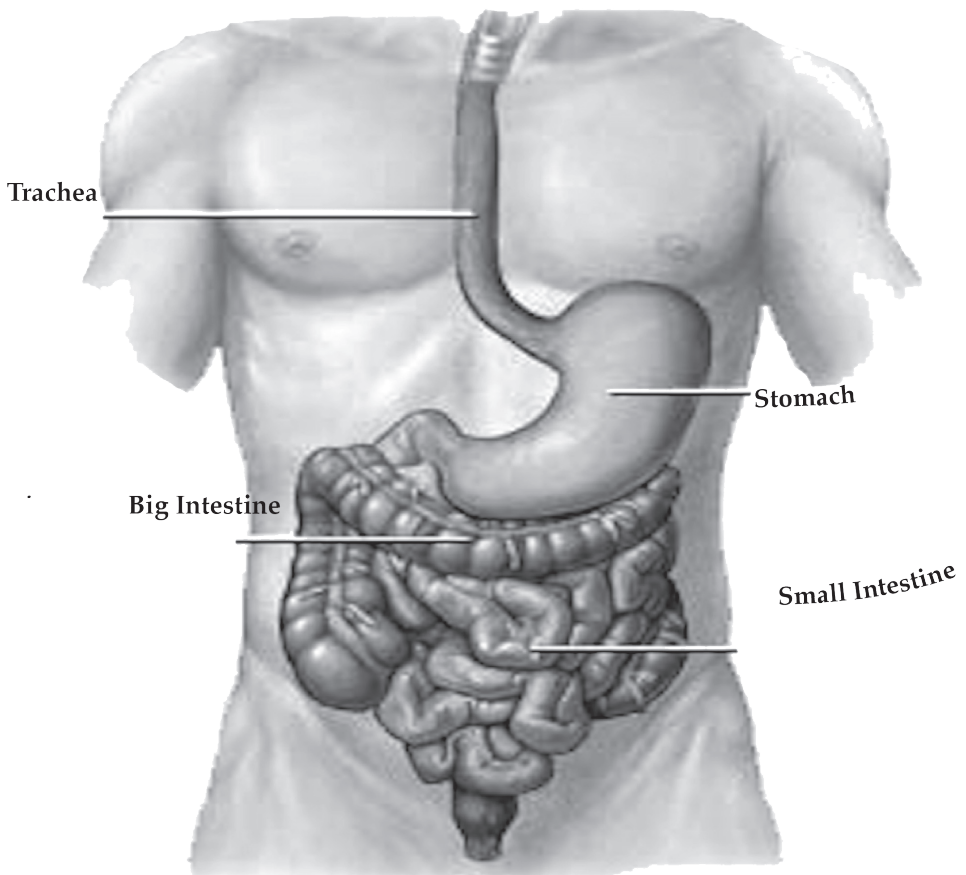
"The answer to your question is a bit long and complicated but I will explain it to you while we take a tour of your intestines, which is also incidentally a long and complicated organ in your body. The small intestine in an adult body can be over 20 feet long and is filled with thousands of species of bacteria!" said Dr Pasteur climbing back up to the epiglottis, the junction at the throat where they had entered the windpipe.



The alveoli is covered with very, very small blood vessels that take oxygen from the air and convey them to the heart

Into the cement mixer

They now slid down the other pathway, a 10 inch long stretchy pipe lined with mucus, called the esophagus which led to the stomach. As they reached the point where the pipe opened out in to the stomach Dr Pasteur held Arun's hand and whispered, *"This is the most dangerous part of the body to be in. One slip and you will be digested by the harsh acids of the gastric juices in your stomach."*



Arun looked aghast at the sight before him. The muscular walls of his stomach were expanding and contracting and somewhat like a cement mixer crushing and churning the fresh batch of food that had entered. The food itself was being dissolved into a clear colorless liquid consisting of mucus, enzymes and acid resulting in a soupy mass. The stomach's wavelike contractions were pushing this messy but still intact substance along to the next stage of the digestion process — into the small intestine where the body would begin to pull out the nutrients it needed.

A normal human being can survive for 20 days without eating but only for 2 days without drinking water!

"There are very few bacteria that can survive in this extremely stressful environment. One of them is called Heliobacter Pylori, which burrow into the cells of the stomach lining and cause low grade inflammation" said Dr Pasteur.

Heliobacter Pylori, he explained, around two decades ago, was found to be responsible for peptic ulcer and gastric cancer . Antibiotics were designed to eliminate them and now in many parts of the world these bacteria have disappeared from people's stomachs.

"Wow! That is cool. If you can isolate a bacteria responsible for a particular disease then antibiotics can be specially made

to remove or neutralise them?" asked Arun.

"That's right in most cases. However, none of this is as neat as you make it sound. There is always a trade off involved. If you get something, you also lose something" said Dr Pasteur.

For example, according to him, *Helicobacter Pylori* while responsible for dangerous illness also plays a positive role by controlling the amount of gastric acids released into the stomach. With their elimination using antibiotics there has been an sharp increase in cases of acid reflux or 'heart burn', where the gastric juices run up the esophagus and sometimes can even cause esophageal cancers. New research findings show, that the presence of the bacteria also reduces the chances of getting asthma and various allergies.

"All this is apart from the risk of developing antibiotic resistance by using too much of these medicines" said Dr Pasteur.

"So what should we do to protect ourselves from infections if using antibiotics is so double-edged" said Arun.

"One of the most important ways of keeping infections away is by maintaining a strong immune system" said Dr Pasteur pointing somewhere to the left of the stomach where Arun could see a purple colored, fist-shaped organ hazily through the lining of the stomach.

"What on Earth is that?" he asked.

"That is the spleen, one of several organs in the body that produce or store red and white blood cells that identify and attack viruses, bacteria and parasites, without harming the body's own healthy tissue" said Dr Pasteur adding, "It is almost like the body's own police or firefighting force meant to keep harmful organisms under control".

Infections become dangerous he explained when the immune system is overwhelmed or unable to function properly. These days according to Dr Pasteur more and more people had weak immune systems because of unhealthy lifestyles and the artificial, changing environment they lived in.

"The human body evolved over several million years but in the last few thousand years we have drastically changed our diet, the amount of physical exercise we get and the amount of exposure we have to poisonous chemicals" he said.

Your blood takes a very long trip through your body. If you could stretch out all of a human's blood vessels, they would be about 60,000 miles long. That's enough to go around the world twice.

The food processing factory

Engrossed in their conversation, they did not notice at all that they were now at the part of the stomach where it meets the small intestine and before they could react both had fallen through into a 20 centimeter long, tubular structure called the duodenum. All of a sudden both of them were covered with half-digested food that still had some burning acid in it. Luckily for them the acid got neutralised by a mix of enzymes, bile and an alkaline mucus pouring into the duodenum.

"Ouch, that stings!" shouted Arun.

Dr Pasteur laughed aloud and said, *"Now, you are really in a soup! Don't worry though, you are safe"*

The small intestine's job it turned out was to absorb most of the nutrients from what we eat and drink. Specialized cells in the intestinal walls grab onto sugars, amino acids, fatty acids, vitamins, and minerals, which are then sent off into the body for energy or as building blocks for new tissue.

"This is where most of the bacteria in the body live and play a critical role in helping digest your food, extract vitamins and throw away toxic stuff" said Dr Pasteur. On the long journey through the small intestine Arun could see that there were millions of bacteria around him, working away on various process.

Among the useful functions bacteria in the intestines perform, are fermenting unused food material, training the immune system, and preventing growth of harmful bacteria. They also help in producing vitamins for the host and producing hormones to direct the host to store fats. In return, they get inside the intestine, a protected, nutrient-rich environment in which they can thrive.

"Amazing! I would never have believed that there was anything such as a 'good bacteria' in my body if I had not witnessed this with my own eyes" said Arun staring at the bewildering variety of bacterial species around him in their incredible numbers.

"When you use antibiotics needlessly you end up killing a lot of these beneficial bacteria along with the harmful ones. That usually leaves only the bacteria that survive the impact of antibiotics to fill up the vacant space. That is how antibiotic resistance increases and infections become untreatable" said Dr Pasteur.

About 90% of all the food we eat is absorbed in the small intestine.

The palace of poop

It was now time to go through the last and perhaps the most painful part of the entire tour — crossing the large intestine or colon— a five feet long tube where what remains of the food squeezed of all useful content by the small intestine moves to.

The colon absorbs water from these wastes, creating stool and gases released after friendly bacteria digest any amino acids remaining in the waste. Usually human stool is brown because of iron-filled red blood cells in the intestines. As the cells are broken down the iron component rusts and turns brown. In fact the browner your poop the healthier you are.

"Most people think of human poop as disgusting waste but it is now being used to cure people who have severely resistant bacterial infections" said Dr Pasteur. These infections take hold when the beneficial intestinal bacteria are killed or damaged for various reasons and reintroducing them using a healthy person's stool prevents the harmful bacteria from becoming the dominant species in the human gut.

Too late to escape! As Arun and Dr Pasteur held their noses and closed their eyes it was a rapid descent down the slippery slope to the rectum, the point where stool exits!

"Don't flush me down the toilet! Please, I beg you!" shouted

Arun, thrashing his arms about. He was drowning in murky waters with the smooth ceramic of the toilet bowl offering nothing to hold on to! Help!

"What happened darling? You had a bad dream it seems" he heard his mother say, waking him up all of a sudden.

"Where am I? Where is Dr Pasteur? We fell into the loo!" said Arun excitedly.

"No sweetheart. You are here on your bed exactly where I left you a while ago" said his mother. *"And who is this Dr Pasteur, anyway?"*

Arun's mother shook her head and thought, 'Must be the side-effect of his high fever'.

As she touched her son's brow to check his temperature he definitely seemed better than before. The glum, sorrowful look he had for the past few days was gone. In its place was a broad smile spreading on her son's face.

