6

LET'S SCIENCE!

Francesco Mascaro

DIAGNOSTIC IMAGING

How to see
what's invisible
to the naked eye

IBSA FOUNDATION for scientific research

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Repubblica e Cantone Ticino
Dipartimento dell'educazione, della cultura e dello sport

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Graphic project by Ulderico Iorillo and Valentina Pochesci

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PREFACE

How familiar are we with the repercussions of scientific research and medical practice for our daily lives? What are the "passions" and motivations that drive researchers and healthcare professionals? What do we know about their professions?

Society strives to make science and its implications known to ordinary people in many different ways. Just think, for example, of the variety of leaflets promoting the importance of a healthy lifestyle and well-being in general. Of course, school does its part as well, introducing the principles of scientific literacy and raising awareness of a series of issues that help foster scientific thinking among young people.

These considerations are in fact the starting point for the *Let's Science!* project, carried out by the IBSA Foundation for Scientific Research in collaboration with the Department of Education, Culture, and Sport of the Canton of Ticino (DECS). The partnership has made it possible to identify interesting topics that have been addressed by the project, getting scientists working in the canton involved. Two different worlds that are often far apart – scientific research and school – have thus been brought together, promoting dialogue between professionals and students through themed workshops, in order to develop awareness of both the topic itself and how to communicate it.

But what was the range of topics the project would address and what considerations led to certain strategic decisions? Science and research are advancing rapidly, especially in biomedicine and related disciplines, and the continuous expansion of fields of investigation requires a constant effort to stay up to date, in order to both maintain a historical perspective and accommodate the numerous innovations. Access to scientifically accurate information, conveyed in accessible language, opens up the opportunity for children to get to know and become passionate about topics that are generally considered "difficult".

And that's the idea behind the *Let's Science!* series, which aims to broaden the range of scientific topics that can be explored at school. The topics, which are interdisciplinary and directly related to individual health and well-being, are presented in an innovative way: the scientific text is in fact accompanied by a story that draws on the experience of cantonal middle school classes, who, under the guidance of their teachers, developed original scripts, which were then translated into comics by professionals in the industry.

The only thing left for us to do is invite young readers to explore the fascinating fields of research presented by *Let's Science!*, which in turn open up opportunities for further questions and insights. Who knows, one of these readers might in turn one day become the one taking important steps forward in understanding the complexity of life and the delicate balance that allows us to be healthy and happy. Enjoy reading!

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PART ONE

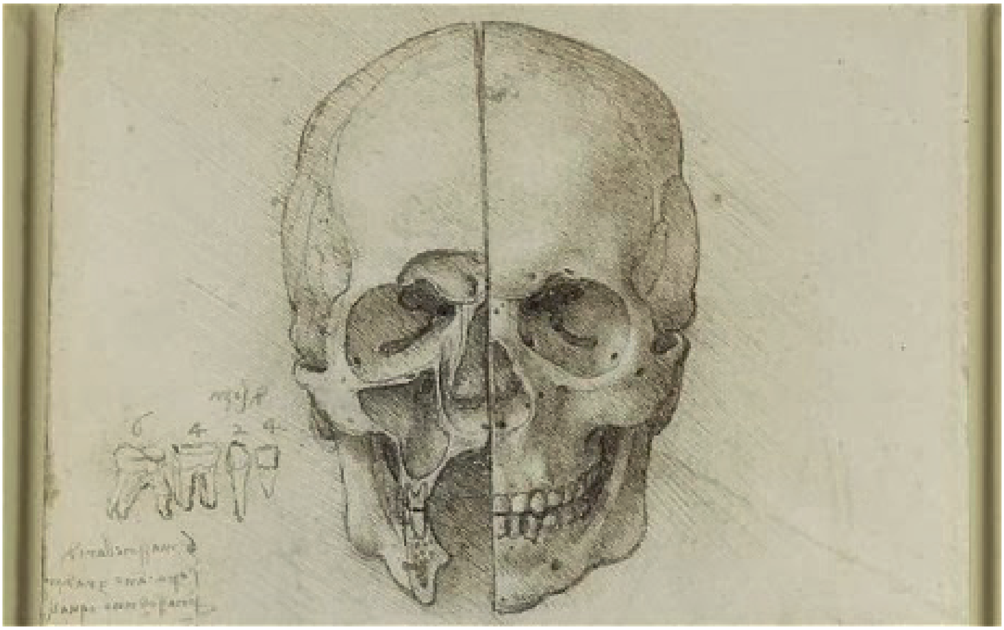
Diagnostic imaging

INTRODUCTION

Have you ever wondered how it is possible to observe the inside of our body and understand how it works without dissecting it? Scientists began systematically studying the anatomy and physiology of the human body to understand its structure and function a long time ago, especially by studying corpses (the first medical treatise exploring anatomy dates back to 1270 and was the work of the cleric William of Salicet, who wrote the *Liber in scientiae medichae*).

For a long time, the only way to look inside the human body was to conduct autopsies and then depict the findings in anatomical drawings, of which Leonardo da Vinci was a master. The great artist and scientist, considered one of the greatest geniuses of all time, dedicated himself to the study of the human body for many years [**figure 1**]. In reality, even before him, nearly all painters and sculptors had studied anatomy to improve their artistic abilities and depict the structure of the human body and the movement of the muscles

Figure 1 Anatomical drawing of the skull by Leonardo da Vinci



as realistically as possible. Leonardo, however, fascinated by the "wonderful human machine", went even further. He produced the first anatomical illustrations of the human body as seen from inside. Thanks to the numerous dissections of corpses he was able to carry out, he began to describe and depict the internal organs, joints, the functioning of the circulatory system, the nervous system, human reproduction, and so on.

Today, we have technological means that enable us to observe, study, and understand the anatomical structure and functioning (and dysfunctioning) of living bodies as well. This, as I'm sure you'll understand, is a great advantage that enables us, above all, to save human lives.

In this booklet, together we'll see how the technology behind modern diagnostic imaging was developed. To do this, we'll review the discoveries, machines, and technologies that have marked the history of just over the last century.

THE DISCOVERY OF RADIOACTIVITY

The discovery of radioactivity was destined to change everything. In 1895, the whole world learned about the discovery of X-rays from a famous article written by physics professor Wilhelm Conrad Röntgen, called *On a new kind of radiation*.

The discovery was made almost by chance, on the evening of 8 November, 1895. For several weeks, Röntgen had been shut away in his laboratory in Würzburg studying cathode rays, experimenting with a tube through which he passed a beam of electrons. At some point, he noticed that a panel sprinkled with a fluorescent substance, placed a short distance from the tube, had begun to glow dimly. He then covered the tube with very thick sheets of black cardboard and continued to work completely in the dark, but the glow was still visible. Whatever it was, it was capable of passing through the cardboard. But that's not all! He also noticed that, when he placed his hand in the path of the beam of rays, he could see the shadow of his bones on the panel. After repeating the experiment several times to make sure he was not mistaken, he tried to block the mysterious ray by placing various materials in its way, and found that the only one that could block it was lead. He then asked his wife to hold her hand still on the plate and, after emitting rays directed against the plate for 15 minutes, he obtained the first X-ray in history: an image of the bones of his wife's hand and her wedding ring [**figure 2**]. He decided to call the mysterious beams "X-rays", after the mathematical sign indicating an unknown quantity.

Why are they called X-rays?

On 28 December, 1895, Röntgen submitted his account of his discovery to the Würzburg Society of Medical Physics, asking for it to be published quickly.

Figure 2 X-ray of Wilhelm Conrad Röntgen's wife's left hand

Within a few days, the news became public knowledge, thanks to widespread coverage in the international press.

In 1901, Röntgen was awarded the Nobel Prize in Physics "in recognition of his extraordinary service in discovering the important type of radiation that was later named after him". In Germany, X-rays are still called *Röntgenstrahlen* (Röntgen rays).

The great physicist donated the prize money he had received to the University of Würzburg to fund new research.

The following year, in 1896, Antoine Henri Becquerel discovered natural radioactivity while investigating the phosphorescence of uranium salts. He realised, in fact, that some materials emitted radiation even without needing to be excited by a light.

In 1898, Marie and Pierre Curie succeeded in isolating a small amount of a new element, 330 times as radioactive as uranium, from tons of pitchblende (a natural mineral containing uranium). It was named polonium, in honour of Marie's country of origin (her maiden name was actually Maria Skłodowska). A few months later, they discovered another element, 900 times as radioactive as uranium: radium. Marie realised that the emission of radiation was an atomic property of uranium and named the phenomenon **radioactivity**.

Together with Becquerel, Marie and Pierre Curie won the 1903 Nobel Prize in Physics for their research on radioactive phenomena, while the Curies alone won a second Nobel Prize in 1911 for the discovery of polonium and radium.

THE DEVELOPMENT OF DIAGNOSTIC IMAGING

Thus began a new era of medicine at the end of the nineteenth century, bringing with it the first applications of X-rays in the medical field. One of the pioneers was John Francis Hall-Edwards, a British doctor and keen photographer. He introduced the use of X-rays in Birmingham hospital to diagnose fractures and was the first to use radiography during surgery and to perform an X-ray of the spine.

In the following years, X-rays were used more and more often. A noteworthy example is that of the **Petites Curies**, small cars equipped with mobile radiology devices that were used during the First World War for French soldiers at the front. More than a million radiological examinations were carried out. This first radiology service, set up and run by Marie Curie, helped to treat and save the lives of many soldiers.

What were the Petites Curies?

Marie Curie was thus an exceptional woman: the first to receive a Nobel Prize and the only one to have received two to this day. Recognised for her extraordinary research and discoveries, she contributed significantly to world change and history, a true *femme engagée*.

It was finally possible to look inside the human body with different eyes and methods! The first X-rays launched a course of continuous development that enables us to explore our body from the outside through the creation of images. This discipline is called **diagnostic imaging** or **biomedical imaging**.

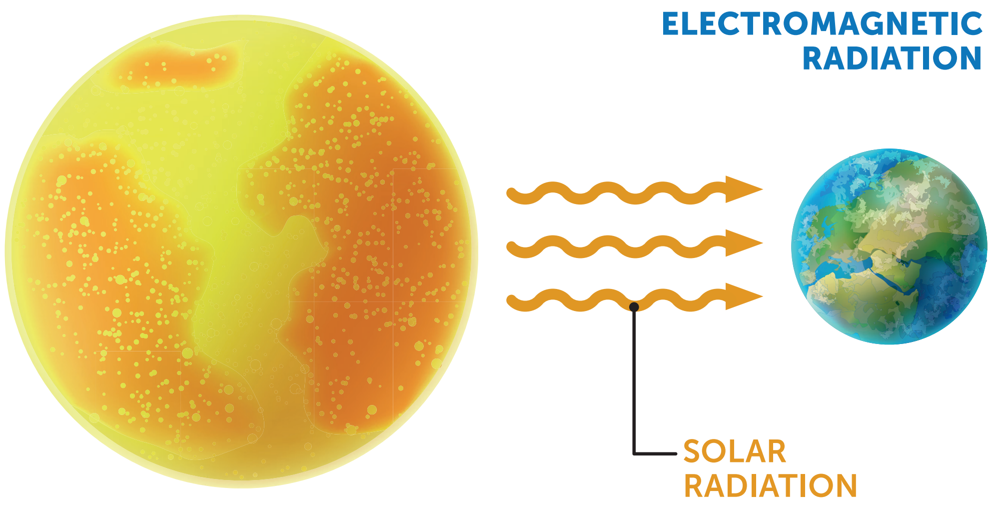
RADIATION

Before talking about diagnostic imaging in radiology, it is important to define the various aspects of radiation, its effects, and how to protect against it.

Radiation is the emission or transmission of energy in the form of waves or particles through space or a material. An example is when we look at the Sun and see the light and feel the heat it gives out. In practice, energy is being transferred from the Sun to the Earth, which means we are in the presence of radiation [**figure 3**].

Generally, the radiation that is used in diagnostic imaging occupies the highest frequency range of the **electromagnetic spectrum**, which is the totality of all possible frequencies of electromagnetic radiation. Its **high frequency** and **short wavelength** give this kind of radiation the properties necessary for use in the field of diagnostics.

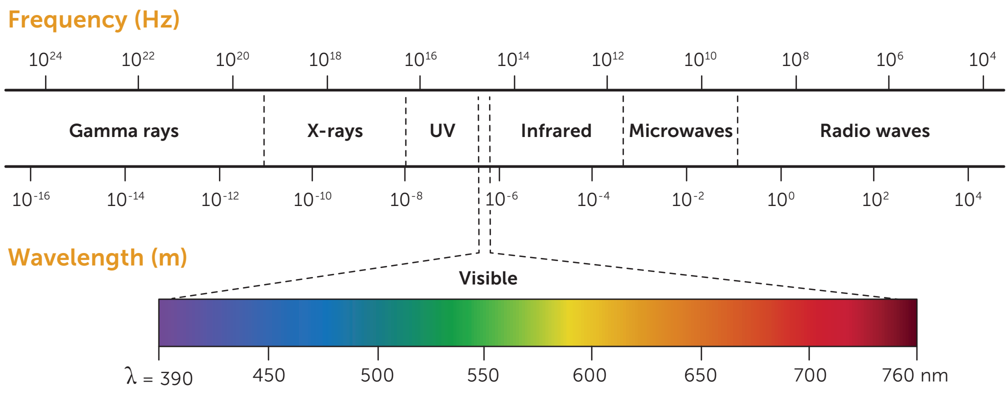
Figure 3 Solar radiation on Earth



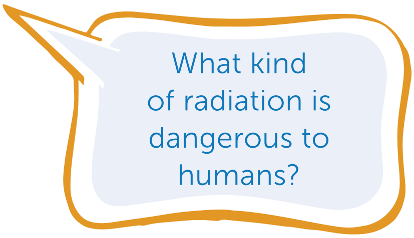
The energy is carried by particles called **photons** that travel at the speed of light. The energy of these photons is inversely proportional to their wavelength; this means that the shorter the wavelength, the greater the energy associated with the photon. The same relationship can also be described in terms of the frequency: the higher the frequency, the greater the associated energy. The equation for calculating the energy associated with a photon has the following formula: E = (h·c)/lambda, where **h** is the Planck constant, **c** is the speed of light in a vacuum, and **lambda** is the wavelength of the photon. The fact that h and c are constants explains why the energy associated with the photon is inversely proportional to the wavelength, lambda. The unit of measurement with which the energy associated with photons is expressed is the eV (electronvolt), where one J (joule) is equal to 6.24×10^{18} eV.

Visible radiation is perceived as **light**. This part of the electromagnetic spectrum is between a wavelength of 760 nm ($7x^{10-7}$ m), seen as red, and 390 nm ($4x^{10-7}$ m), seen as violet. The radiation used for diagnostic imaging, such as X-rays and CT scans, corresponds to a wavelength of 10^{-10} m. The shorter the wavelength, the higher the frequency and energy of the radiation [**figure 4**].

Figure 4 The electromagnetic spectrum



If the energy of the radiation that strikes a material is sufficient to modify the structure of the atoms or molecules with which the radiation comes into contact, it is called **ionising radiation**. Otherwise, it is called **non-ionising radiation**. These are two important principles that represent the initial distinction in diagnostic imaging, to understand whether a certain type of radiation is harmful to human beings or not.



Remember John Francis Hall-Edwards, who we mentioned above? His pioneering experiments with X-rays did not take this aspect into account: the rays damaged the cells of his body to such an extent that he had to have both his left arm and some of his right fingers amputated. This is why working in these fields requires a lot of precautions and the patients have to be adequately protected as well.

Some other techniques used to produce images are based on **ultrasound**, such as sonograms, while still others, such as magnetic resonance imaging, are based on the use of **electromagnetic fields** and **radio frequencies**. Ultrasound and magnetic resonance imaging are not harmful to humans because they are not capable of ionising biological atoms or molecules. They are therefore also used on pregnant women and children.

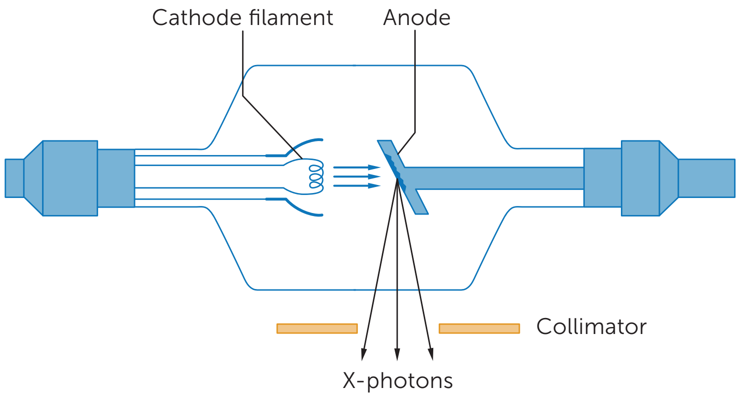
◎ PRODUCING X-RAYS

The main type of ionising radiation used in the field of diagnostic imaging is **X-rays**. They are produced using an X-ray tube, the prototype of which is the Coolidge tube, or hot cathode tube.

The X-ray tube [**figure 5**] is a vacuum glass ampoule with a cathode and an anode at opposite ends. The **cathode** consists of a filament that, if brought to incandescence, gives off electrons from its surface (remember that electrons are charged particles and have a negative charge, which is why the cathode is also called a negative electrode). The combined effect is that a potential difference is applied, which can generally reach up to 140,000 V (volts), and which allows electrons at the level of the cathode to accelerate towards the **anode** (since the anode is positively charged, a very strong electric field is created along which the negatively charged electrons move from the cathode to the anode; see the blue arrows in **figure 5**).

The anode consists of a metal disc or plate usually made from tungsten (the same type of material that the filament of incandescent bulbs is made from). When the electron beam (also called a ray) from the cathode hits the anode, most of the kinetic energy of the electrons, about 99%, is dissipated in the form of heat. Thanks to certain physical phenomena, the remaining 1% is emitted in the form of X-rays (X photons).

Figure 5 Diagramme of an X-ray tube



The X-rays produced by the X-ray tube can now be directed towards the patient: most of the rays interact with the tissues of the human body, while a small portion passes through the tissues until it reaches a special detector. The collected information is then encoded to produce the image [**figure 6**].

The main methods used for diagnostic imaging that require the presence of an X-ray tube, and thus the production of X-rays, are:

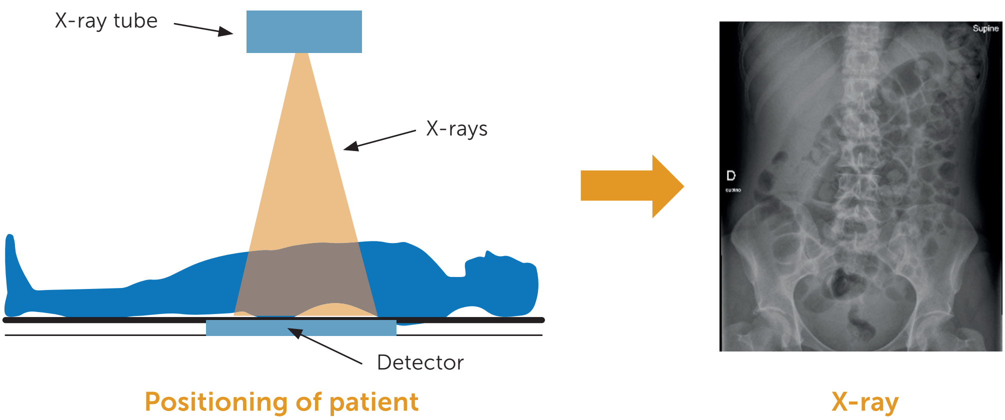
- conventional radiology;
- fluoroscopy or radioscopy;
- computed axial tomography (CAT) or computed tomography (CT);
- mammography.

Since X-rays are able to ionise biological molecules, they are harmful to the cells of living organisms. It is therefore important to understand their effects and how we can limit them.

How do you protect people against radiation?

Over the last century, people have tried to discover the effects of radiation on human beings. There are still many open questions that the scientific community is trying to answer. Radiobiology and radiation protection

Figure 6 X-ray of the abdomen in supine position



are two disciplines that help us understand the effects of radiation on humans and the protective measures that should be taken to limit its harmfulness.

◎ RADIOBIOLOGY

Radiobiology is the branch of biology that deals with the effects of radiation on living matter.

The damage to biological tissues from **radiation** is caused by its interaction with the cell at a microscopic level. In particular, radiation is capable of damaging nuclear deoxyribonucleic acid (nDNA), causing more or less complex changes to the two filaments it's made up of.

In principle, human cells are able to repair damage from ionising radiation on their own. Once the damage has been repaired, the cell continues to carry out its function within the human body. However, if the cell is unable to repair the damage, it can undergo **apoptosis** (programmed cell death), a biological process that also protects humans from the onset of damage caused by ionising radiation.

When cellular DNA is too damaged, on the other hand, or in the event of malfunctioning repair mechanisms, the damage caused can result in tissue damage and clinically observable phenomena such as necrosis.

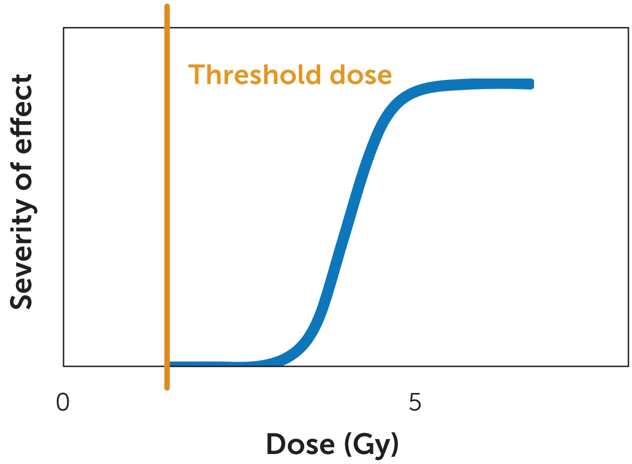
Finally, the introduction of faulty DNA repair can produce a viable cell with mutations that can lead to the development of tumours or hereditary abnormalities.

The physical, chemical, and biochemical interactions of ionising radiation with DNA take place in a fraction of a second, while it can take just a few minutes for the effects to manifest clinically, or it can take as long as dozens of years after the irradiation took place.

We distinguish between two types of radiation effects on humans: deterministic effects and stochastic effects (also referred to as probabilistic effects).

Deterministic effects usually occur immediately after exposure to ionising radiation, appear when a threshold value is exceeded, and lead to organ dysfunction. The higher the dose the individual absorbs, the more severe the damage. These effects include erythema, skin burns, and damage leading to infertility [**figure 7**].

Figure 7 Deterministic effects of radiation on humans



The **stochastic or probabilistic effects** are due to mutations produced at the cellular level. No threshold has been identified for these effects; it is hypothesised that the risk of developing cancer increases linearly with the dose. The higher the dose of ionising radiation to which the individual is exposed, and the greater the frequency at which the individual is exposed to this dose over the course of their life, the greater the likelihood of them developing cancer or of deformities in their offspring will be [**figure 8**].

The radiation energy absorbed by a unit of mass at a given point in the irradiated anatomical region is called the **dose**. In the International System of Units (SI), the absorption of 1 joule of radiation energy by 1 kg of matter is called a **gray** (Gy) [**figure 9**]. The risk of cell damage increases with the amount of energy released.

The risk indicator used for radiation is the **effective dose**, expressed in **sieverts** (Sv), which takes into account the type of radiation and the type of tissue irradiated. The Sv is ultimately a measure of the health effect of ionising radiation.

Have you ever wondered how many tests using ionising radiation (e.g. X-rays, CT scans) we can undergo during our lifetime? It is a legitimate question, which we can answer by looking at the regulations that healthcare professionals are subject to. The prescription of tests using ionising radiation, as well as other tests, is a medical responsibility. In deciding whether to subject an indi-

Figure 8 Stochastic effects of radiation on humans

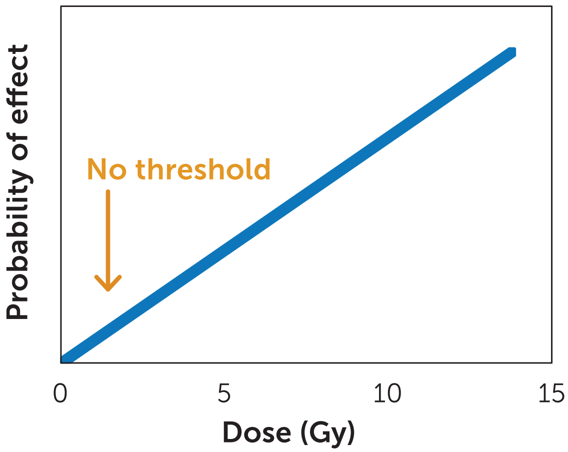
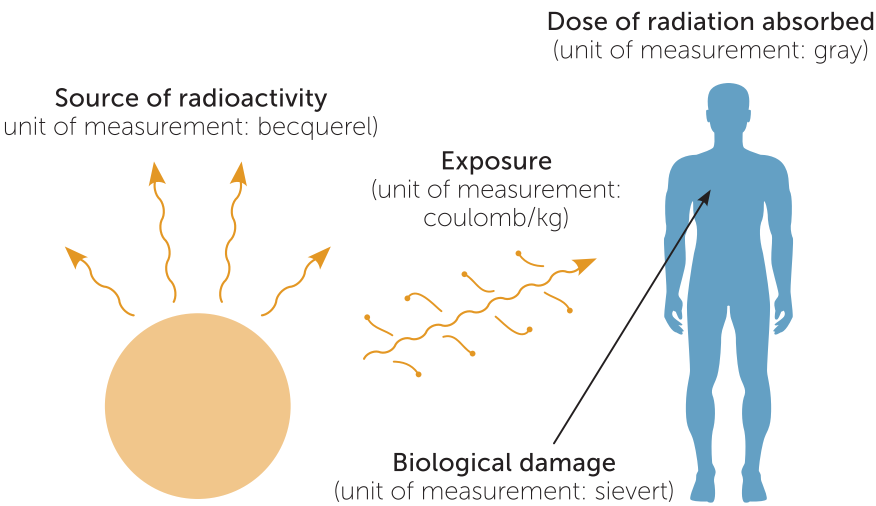


Figure 9 Units of measurement of radioactivity



vidual to a test, the health benefit to the individual should be weighed against the biological risks caused by ionising radiation; that is, a principle of justification must be applied. This means there is no maximum number of tests that can be performed on an individual over their lifetime, but instead the reasons for, benefits of, and risks of each test must be evaluated on a case-by-case basis.

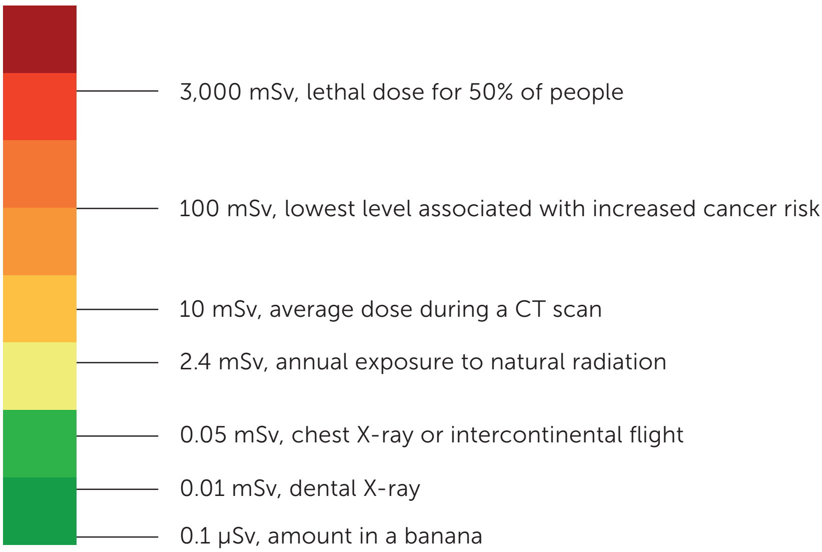
What is the ALARA principle?

So how do we limit the risks to individuals? Limiting the risks to people who undergo tests that use ionising radiation is also guided by the ALARA principle (as low as reasonably achievable). In the field of diagnostic imaging, the ALARA principle states that tests using ionising radiation must be carried out with the intention of keeping the dose (the radiation energy absorbed by a unit of mass at a given point) that the person receives as low as possible, without impairing the quality of the image produced and thus the diagnostic outcome and, in some cases, the therapeutic outcome.

One of the challenges that organisations are working on is the introduction of an individual dosimetric passport that would enable the dose that a person receives as a result of medical applications over the course of their life to be monitored effectively.

From the dose comparison scale, we can see that radiation is naturally present all around at a level dependent on the region you live in, and is present in some foods. Our body is generally able to respond effectively to prevent possible damage [**figure 10**].

Figure 10 Comparison of doses expressed in millisieverts (mSv)



◎ RADIATION PROTECTION

Radiation protection is a discipline that arose as a field of application of radiobiology and deals with how to protect individuals, their descendants, the population in general, and the environment against the harmful effects of ionising radiation [**figure 11**].

Its objectives are to prevent deterministic effects and to limit the likelihood of stochastic effects to an acceptable level (reduction of clinical risk).

The basic principles of radiation protection can be summarised by the term **JOL**:

- **J** justification of activities that use radiation;
- **O** optimisation of radiation protection measures;
- **L** limitation of individual doses.

Lead is used to protect us from the ionising radiation used in diagnostic imaging (X-rays and gamma rays). It is an element with a high electron density and high stability and, moreover, it is very malleable. These properties make it possible to produce the radiation protection devices used in radiology [**figure 12**].

In addition to protective devices made from lead, there are few basic rules to follow to protect against or limit the effect of radiation, including:

Figure 11 Penetrating power of the types of ionising radiation

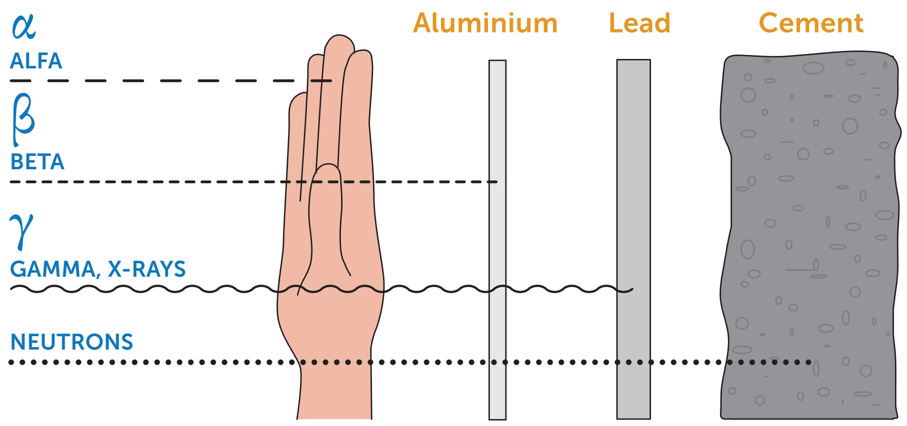


Figure 12 Radiation protection devices

Full-body apron

Protective gonad skirt

Protective thyroid collar

- keep your distance from the source of radiation, as the intensity of the radiation decreases with distance (important for radiology operators);
- place one or more shielding devices between the source of radiation and human beings;
- minimise the duration of radiation exposure.

People who are exposed to radiation at work, including in sectors other than medicine (e.g. flight operations, underground excavations, etc.), are equipped with a personal **dosimeter**, which monitors the radiation representative of the effective dose for the whole body over a given period of time. The effective dose, expressed in sieverts, is an indicator of biological risk: the higher the dose, the higher the potential risk of biological damage. These figures represent a way to monitor and verify the safety of professionals working with radiation and must be evaluated and interpreted periodically, taking the legal limits in force into consideration as well.

DIAGNOSTIC METHODS THAT USE IONISING RADIATION

CONVENTIONAL RADIOGRAPHY

Conventional radiography was the first imaging method discovered and is the most readily available. It uses the X-rays produced by an X-ray tube, which are directed at the patient. Radiographic images are produced by means of a detector and subsequent processing of the information. It takes less than a second from the moment the X-rays are produced to the moment the image is displayed.

In general, conventional radiography is the most commonly used imaging method for examining the limbs, chest, and sometimes the spine and abdomen. These areas contain important structures with densities that differ from those of surrounding tissues.

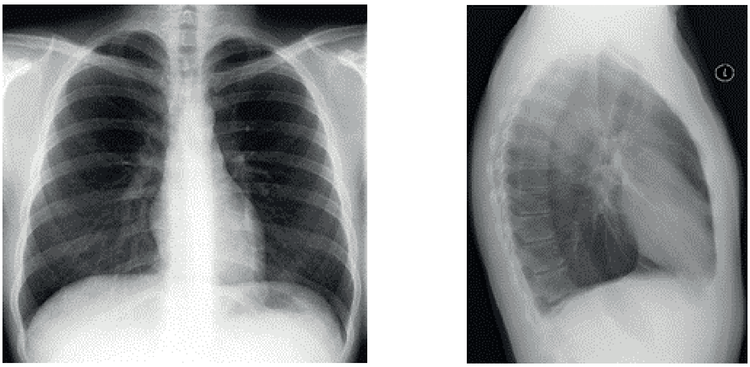
Which diseases is conventional radiology used to diagnose?

For example, conventional radiology is the first-choice method for detecting:

- fractures (bones are denser than soft tissues, which means their structure can be easily observed to find fractures);
- pneumonia (the high contrast between the air present in the lungs, which show up as black on the X-ray, and the liquid, which shows up as white, enables us to assess the possible presence of the disease);
- intestinal occlusion (it is possible to assess the presence of gas-fluid levels, consisting of an accumulation of liquid and gas).

Considering that the different anatomical structures are superimposed, it is advisable to perform at least two x-rays from different angles. This allows us to better visualise the anatomical structure being x-rayed [**figure 13**].

Figure 13 Example of a chest X-ray performed with the patient in two different positions



◎ FLUOROSCOPY OR RADIOSCOPY

Fluoroscopy (or radioscopy) is a technique to obtain real-time images of the internal anatomy of a human being; X-rays are used for this method [**figure 14**]. It enables dynamic visualisation of the functional processes of the body (for example, the blood flow in the vessels or the digestive activity of the stomach). An important area where it is used is for diagnostic and therapeutic examinations such as angiography, as well as in some surgical procedures. In the latter case, the images are used to direct and position devices within the patient's body.

In angiography, during procedures on blood vessels, special tools are used, such as introducer sheaths, catheters, guidewires, balloons, and stents [**figure 15**].

Figure 16 shows a balloon used to dilate stenoses (narrowing of a canal, orifice, hollow organ, or vessel) within blood vessels. The same procedure is used to dilate the section of the superficial femoral artery shown in the previous images.

Figure 14 Angiography

Figure 15 Examples of angiograms of the left femoral artery

Angiogram of left femoral artery	Dilation with balloon	Dilation with balloon	Final outcome

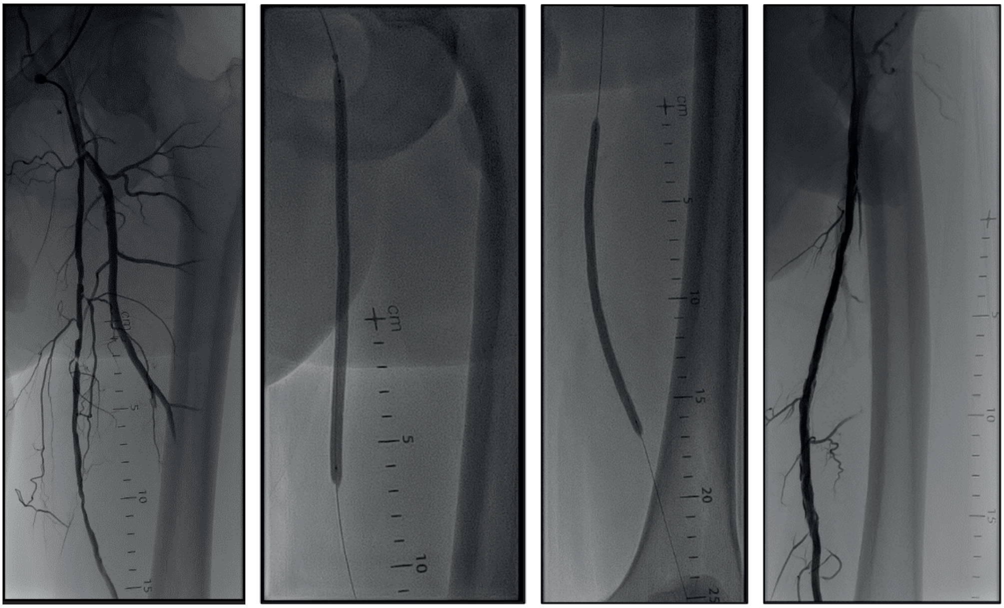


Figure 16 Balloon used during an angiography procedure

◎ COMPUTED AXIAL TOMOGRAPHY (CAT)/COMPUTED TOMOGRAPHY (CT)

CT scans, one of the most important technologies in diagnostic imaging and increasingly widely used at a global level, use ionising radiation, specifically X-rays. This technique was invented by the English engineer Godfrey Hounsfield, who built the first CT equipment in collaboration with the South African physicist Allan Cormack at EMI's Central Research Laboratories in Hayes in the United Kingdom in 1967. Research related to the use of this investigation method earned the two scientists the Nobel Prize for Medicine in 1979, a prize they shared with Allan McLeod Cormack of Tufts University in Massachusetts, who independently proposed a similar technique. The first commercial CT scanner could only be used to study the structures of the skull and was installed at Atkinson Morley Hospital in London in 1971. This diagnostic technique is able to represent the human body in sections along the axial, coronal, and sagittal planes [**figure 17**], enabling the organs and vascular structures to be visualised and examined to detect any anomalies.

The attenuation of the X-ray beam that passes through the patient reveals the difference in the density of the tissues inside the human body, generating digital images through the use of powerful calculating computers. Developments in technology, computers, and engineering have enabled us to achieve digital images and reconstructions of greater quality and complexity. Today, CT scans make it possible to explore the human body in its entirety.

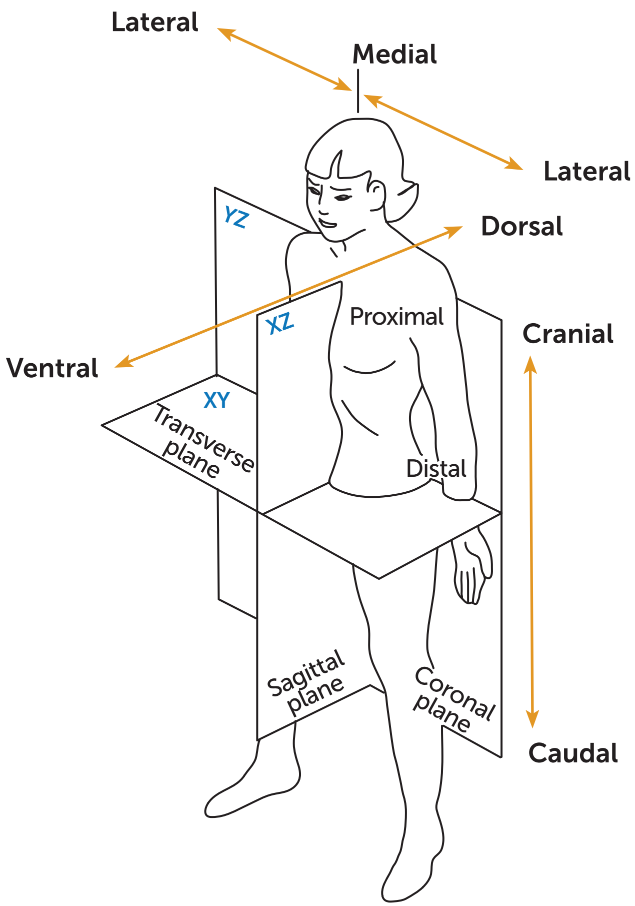
The primary components of a CT scanner are:

- the gantry, a rotating circular structure that contains the X-ray tube and the detector;
- the bed, or scanning table;
- the control console and the calculating computers.

The table where the patient is positioned moves at a constant speed, while the detector tube rotates around it. This means that only the anatomical region of interest is irradiated and the X-rays penetrate it from different angles [**figure 18**].

The detector collects information that is subsequently processed by powerful computers capable of transforming it into images, which are displayed on the

Figure 17 Axes and planes of the human body



monitors located at the control console. It only takes a few seconds from the moment the X-rays are emitted to the moment the images are displayed. The latest generation of CT scanners can produce hundreds of images in a matter of seconds [**figure 19**].

What is the contrast liquid used in CT scans for?

To perform a CT scan, it is sometimes necessary to administer a liquid containing iodine, called iodine **contrast medium**, to make it possible to differentiate between arteries, veins, lymph nodes, and organ

Figure 18 The main components of a CT scanner

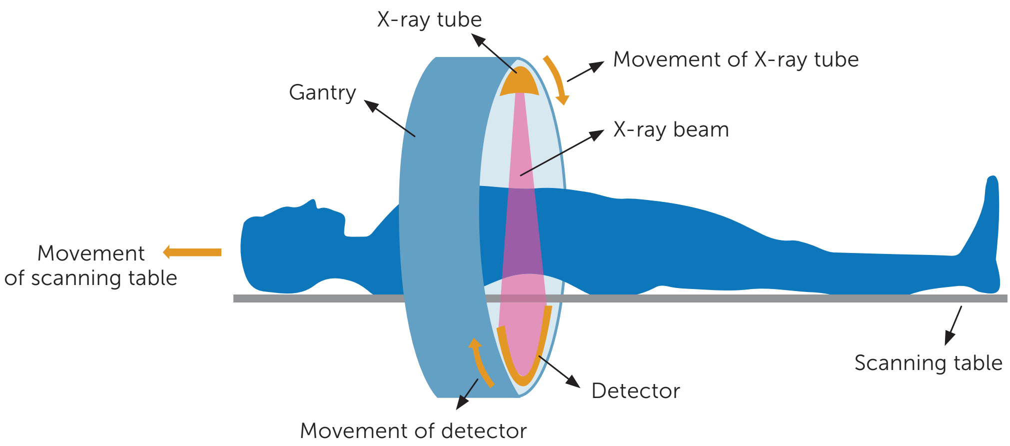
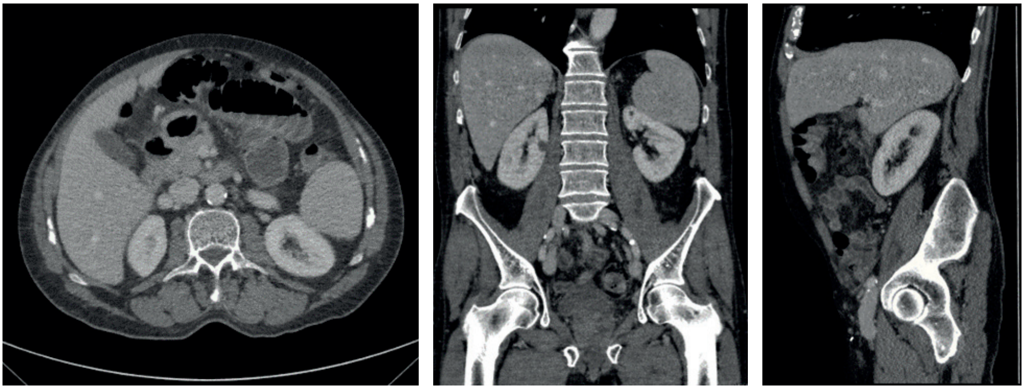


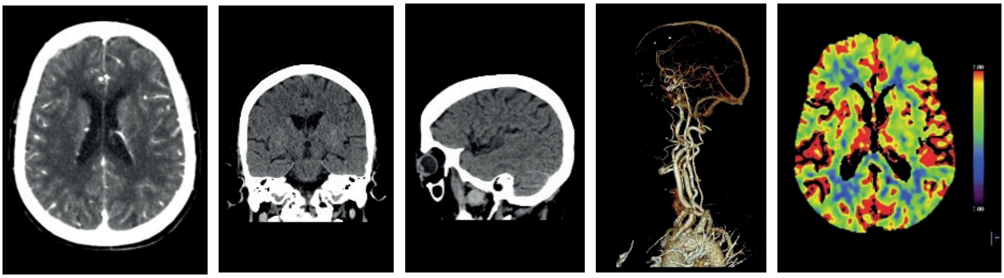
Figure 19 Example of CT scans of the abdomen



Axial plane Coronal plane Sagittal plane

abnormalities in general. Administering the contrast medium also makes it possible to reconstruct the data acquired into three-dimensional images of the irradiated region and, in some cases, to map the functionality of the irradiated organ [**figure 20**].

Figure 20 Example of a CT of the brain with contrast medium



MAMMOGRAPHY

This method, used to generate images of female breasts (and male breast tissue), uses X-rays and is considered a breast x-ray [figure 21]. The first mammograms were introduced in 1930 by an American radiologist working in New York, Stafford L. Warren, who further developed techniques and studies previously carried out by a German surgeon, Albert Salomon. Salomon had begun working on tissue samples obtained from the removal of breasts of women with breast cancer (mastectomies) in 1913.

Figure 21 Mammograms

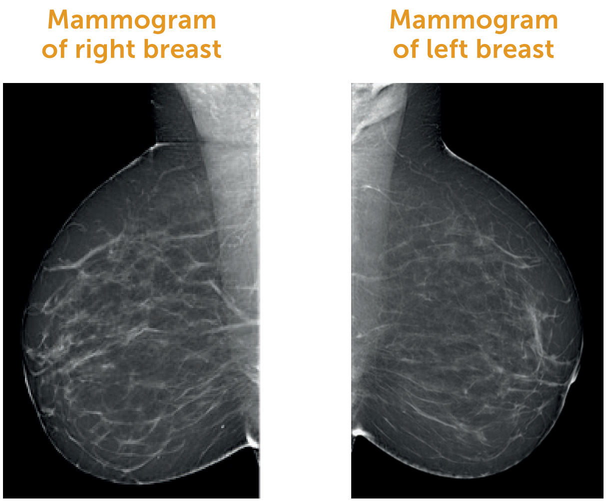


Figure 22 Mammography unit with tomosynthesis

Today, mammography is considered the diagnostic examination par excellence and the first choice for breast cancer research; in some cases, an ultrasound examination is also performed to improve the visualisation of the entire anatomical structure, especially in people with dense breasts.

In recent years, **tomosynthesis** has been introduced, which enables three-dimensional (3D) images of the breast to be obtained and the overlapping effect of tissues typical of x-rays to be reduced and/or eliminated. Generally, it is performed in addition to a standard mammogram [**figure 22**].

DIAGNOSTIC METHODS THAT USE NON-IONISING RADIATION

MAGNETIC RESONANCE IMAGING (MRI)

Magnetic resonance imaging (MRI) is a modern imaging method that produces layered images of all regions of the human body using magnetic fields and radio frequencies. MRI does not have the same effects as ionising radiation, so it falls under non-ionising radiation.

Why is it necessary to not have any metal objects on you when undergoing an MRI?

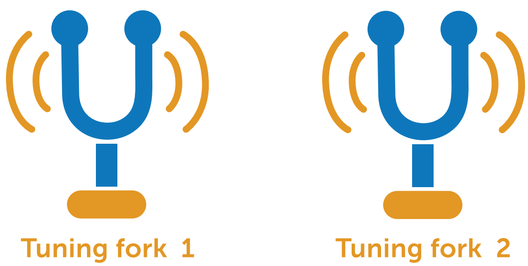
Before undergoing an MRI examination, the patient is asked to fill out a form, which is essential to understand if this scan can be performed. The strong magnetic field present in the MRI machine is able to attract metal objects with specific properties and alter the functionality of some medical devices. Therefore, before a patient enters an MRI machine, information must be collected such as the presence of pacemakers, defibrillators, heart valves, cerebral clips, hearing and dental devices, cochlear implants, tattoos, piercings, and permanent make-up, as well as the presence of diseases such as diabetes or glaucoma. If there is at least one contraindication, the medical technical staff suspends the examination and evaluates the feasibility of carrying out the procedure on the patient on a case-by-case basis in collaboration with other health care workers. Every person who enters the MRI room must complete this form.

The physical and mathematical principles underlying this technique are extremely complex.

Let's start by asking, what is resonance? Resonance is defined as an exchange of energy between two similar systems.

For example, if we take two tuning forks that emit the same note (vibrate at the same frequency) and we set one of the two vibrating (tuning fork 1), the second one will also start vibrating (tuning fork 2). The affinity between the two systems is called the resonant frequency [**figure 23**].

Figure 23 The phenomenon of resonance



The magnetic resonance used for diagnostic imaging works according to the same principle as the tuning fork. In practice, once the patient is positioned inside the machine, the presence of the large magnetic field, a sort of big **magnet**, and the subsequent application of radio frequency pulses produced by antennas called **coils**, enable the diagnostic images to be produced.

MRI uses the body's own magnetic properties to produce detailed images of any part of the body. In particular, it uses hydrogen nuclei (composed of a single proton), which are abundant in water and fat. Hydrogen nuclei are electrically charged particles of matter and their behaviour is determined by their spin, as if they were small magnets; their axes are randomly aligned. If we put the patient's body inside the machine's magnetic field, the hydrogen nuclei align either with or against the direction of the field.

This alignment is stable and if we want to induce a resonance signal, we have to disrupt it. We do this by using an appropriate radio wave to induce a new stable situation until we stop the radio signal. When the signal is interrupted, the hydrogen nuclei re-release the accumulated energy as electromagnetic waves, the characteristics of which depend on the surrounding environment. This results in a returning resonance signal that we can pick up with an antenna. The signal obtained reveals the characteristics of the tissue analysed. Using special mathematical tools and powerful computers, we can now transform the electrical signal into an image [**figure 24**].

Figure 24 Magnetic resonance imaging

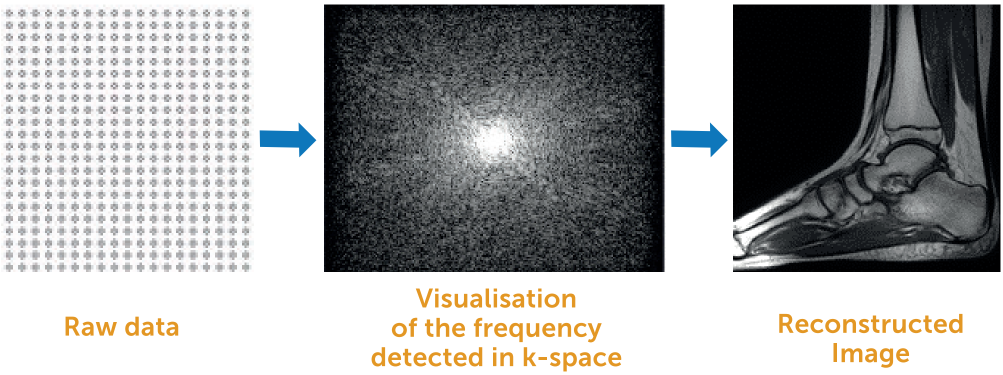
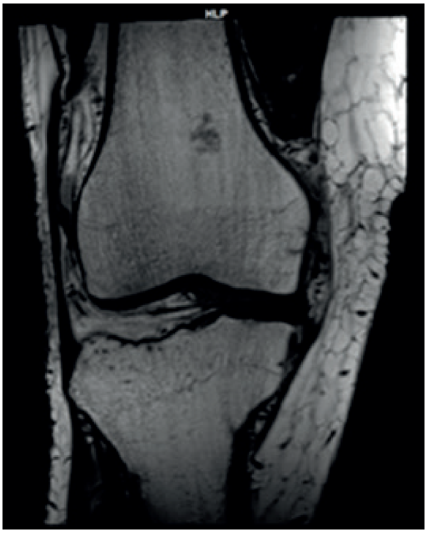


Figure 25 Examples of magnetic resonance images



Magnetic resonance image of the knee, coronal plane

Magnetic resonance image of the lumbar spine, sagittal plane

The combination of the energies produced by the magnetic field and the radio frequency pulses generate the characteristic noise the MRI is known for. This technique is particularly suitable for visualising organs and tissues rich in fluids and is widely used to examine the nervous system (the brain and spinal cord), internal organs, joints, and blood vessels [**figure 25**].

COMPARISON OF MAGNETIC FIELDS

According to the International System of Units (SI), the unit of measurement of magnetic induction, or magnetic flux density, is the **tesla** (T). However, given that this is a very large unit of measurement, useful for indicating huge magnetic fields, such as those of stars, the unit from the old system, the **gauss** (G), is often still used. One tesla is equivalent to 10,000 gauss. **Table 1** shows some values of magnetic fields by way of example.

The Earth's magnetic field varies depending on the location on our planet and is between 0.4 and 0.6 gauss [**figure 26**].

Table 1 Orders of magnitude of some magnetic fields

10^{-9}-10^{-8} gauss	Magnetic field of the human brain
10^{-6}-10^{-3} gauss	Magnetic field of molecular clouds
0.25-0.60 gauss	Magnetic field of the Earth on its surface
25 gauss	Magnetic field of the Earth in its core
50 gauss	Fridge magnet
100 gauss	Iron magnet
1,500 gauss	Inside a sunspot
10,000 to 13,000 gauss	Remanence of a neodymium magnet (NIB)
16,000 to 22,000 gauss	Saturation of high-permeability iron alloys used in transformers
3,000-70,000 gauss	Magnetic resonance imaging apparatus
10^{12}-10^{13} gauss	Surface of a neutron star
4×10^{13} gauss	Limit of quantum electrodynamics
10^{15} gauss	Magnetic field of some newly formed magnetars
10^{17} gauss	Upper limit of magnetism of a neutron star

Generally, the magnetic resonances that are directed at humans use magnetic fields up to 30,000 gauss, which corresponds to 3 tesla.

A magnetic field with a resonance of 3 tesla is about 60,000 times the strength of the Earth's magnetic field. It is precisely because of the strong magnetic field present with this method that any metal objects that would be attracted like bullets inside the machinery must be removed from patients. It is also important to always assess the patient's health by completing a safety questionnaire.

Figure 26 Magnetic fields

ULTRASOUND

Ultrasound (or sonography) is a non-invasive diagnostic technique that uses **high-frequency sound waves** that propagate within the body, instead of ionising radiation. The frequency of these sound waves exceeds 20,000 Hz, so they are not audible to the human ear. Ultrasound works according to the same principle as when you stand at the highest point of a valley and shout loudly towards a rock face and hear an echo: the sound wave you emit is reflected by the rock face itself and bounces back to your ears.

The images are generated using the reflection of sound waves produced by special probes; the probes themselves then detect the echoes of these waves from the area being examined [**figure 27**]. The image formed on the monitor

Figure 27 Operating principle of ultrasound

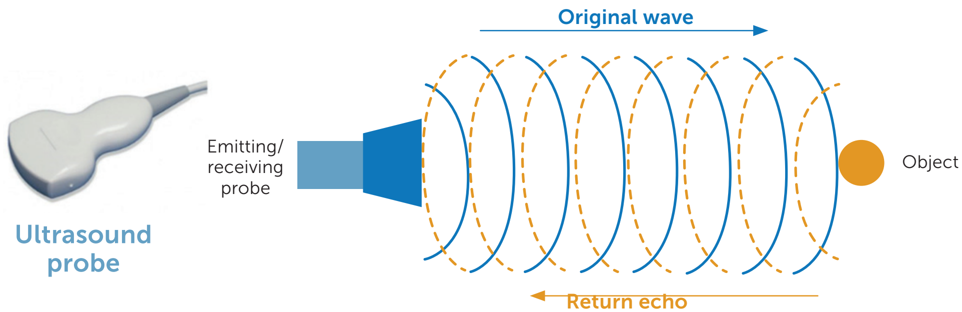


Figure 28 Example of an ultrasound image (or sonogram)

Ultrasound of left kidney

represents a small section of the area of the body on which the probe is resting at that time [**figure 28**].

The use of ultrasound does not involve any kind of risk, so it is a procedure that does not present contraindications. This is why it can be carried out at every stage of a person's life. It is common practice, for example, to perform ultrasounds during pregnancy to monitor the growth of the foetus. In addition, it is also a method that produces real-time images and uses easily portable machines.

> Why is there no contraindication to performing an ultrasound?

The anatomical regions mainly examined using this method are made up of soft tissues:

- the abdomen;
- the urinary tract;
- the thyroid;

- the heart and the blood vessels;
- the tendons, muscles, and joints.

A LOOK AT NUCLEAR MEDICINE

Nuclear medicine is a branch of medicine that uses radioactive substances, called **radiopharmaceuticals**, composed of a radioactive part and a pharmacologically active part. They can be used for both diagnostic and therapeutic purposes.

Specifically, the radiopharmaceutical is composed of a carrier (or vector), i.e. a molecule with biological transport functions, and the radioactive nuclide bound to it. The carrier allows the radionuclide to be conveyed to the organ or structure of interest, while the radioactive nuclide allows us to track the distribution and storage of the radiopharmaceutical in the body using appropriate diagnostic technology.

Specific equipment, such as **positron emission tomography** (PET/CT) is used to produce high-resolution images by merging the molecular images (obtained by PET) with radiological images obtained with the tomography technique (acquired through CT combined with PET) [**figure 29**].

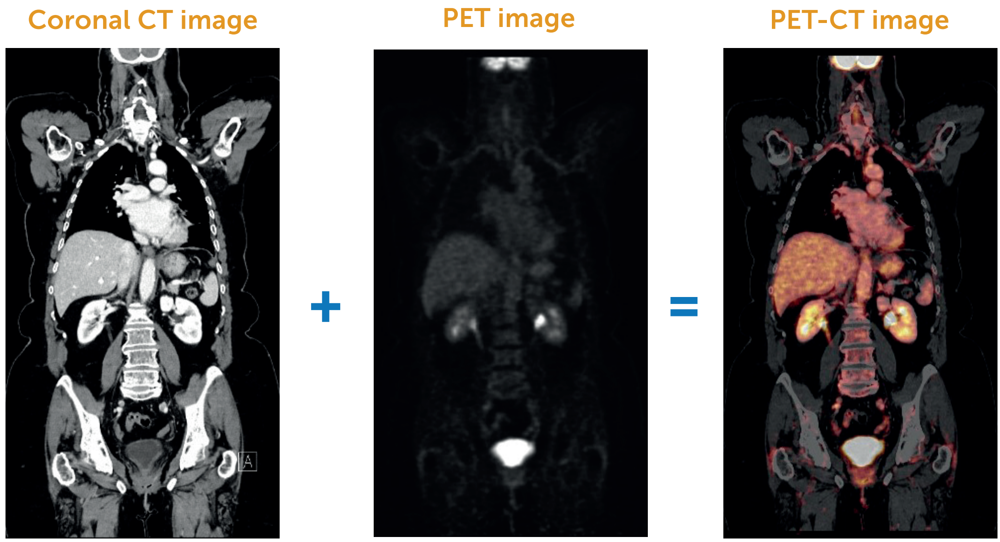
The most widely used radiopharmaceuticals in nuclear medicine are:

- 18F-fluorodeoxyglucose (FDG);
- 18F-PSMA (acronym for "prostate-specific membrane antigen");
- 18F-fluoroethyltyrosine (FET);
- 68Ga peptides (gallium 68).

The main clinical applications are in fields such as oncology, cardiology, neurology, and rheumatology.

In the field of oncology, the technique makes it possible to assess the morphological, structural, and functional characteristics of many types of cancer. In addition, it enables us to evaluate how patients are responding to treatments

Figure 29 CT, PET, and combined PET-CT images obtained after administration of the radiopharmaceutical 18F-fluorodeoxyglucose (FDG)



and obtain information that is useful for the prognosis and for assessing the biological aggressiveness of the tumour.

ANGER CAMERA OR GAMMA CAMERA

The most widespread technology in nuclear medicine is the gamma camera, also called a scintillation camera, or Anger camera. The first prototype was designed by the engineer and biophysicist Hal Oscar Anger in 1957 at the University of California Berkeley laboratories.

It is used to obtain static, dynamic, and tomographic scintigraphic images. By administering the radionuclide internally, representative images of its distribution and storage within the body can be acquired. The gamma camera therefore does not emit radiation, but only detects it. The detection system underlying this technology is able to perform single photon emission tomography (SPECT). The most commonly used radionuclides in medical-nuclear diagnostics are technetium-99m, iodine-123, and indium-111 [figure 30], due to their physical and dosimetric characteristics, as well as because they are easy to obtain and low cost.

Figure 30 Total body bone scintigraphy performed with technetium-99m

CONCLUSIONS AND FUTURE PROSPECTS

We have reached the end of our review of diagnostic imaging in radiology, covering more than a century of developments in technology, computer science, engineering, and biomedicine. We have gotten to grips with the world of diagnostic imaging and the variety of methods that allow us to better evaluate every anatomical structure in the human body. Diagnostic imaging is now a very powerful tool in the hands of doctors and enables them to diagnose, monitor, and treat a large number of diseases in teamwork with radiology technicians, radiologists, various other healthcare workers, and engineers.

We have also seen how both ionising and non-ionising radiation, on which the diagnostic techniques we have covered are based, are present in our environment, both naturally occurring (natural radioactivity, the Earth's magnetic field) and as a result of man-made technologies, such as radio, microwave ovens, lamps, and old cathode-ray tube televisions. When we consider the use of ionising radiation in diagnostics, we must always take into account how risky these techniques are and take the appropriate precautions to be able to exploit their advantages while limiting their undesirable effects.

The continuous development of diagnostic imaging points to a future where new technologies and increasingly advanced analysis systems will be more widespread in the healthcare sector.

Technologies such as **radiomics**, that is, the application of artificial intelligence to diagnostic imaging, represent a new frontier in medicine: here, the images obtained by CT, MRI, and PET are converted into numerical data that are analysed, together with other data, by powerful calculation tools. This gives us useful information for identifying genes that can predispose an individual to develop tumours, information on the aggressiveness of a disease already present, and information on the patient's diagnosis, treatment, prognosis, and responsiveness to treatment.

The development of technology in diagnostic imaging is also due to the work carried out at the best research centres in the world. One example is Medipix technology, developed at CERN in Geneva, which is applied in some CT scanners on the market. This technology enables us to differentiate and classify the biomolecules present within the anatomical region studied, helping healthcare professionals to better understand the structure of any anomalies.

In conclusion, the future challenge in diagnostic imaging is to be able to integrate all patient data, thus providing images into which other information is subsequently fed (anamnesis or medical history, cultural context, laboratory data, etc.), with a view to providing personalised, or precision, medicine.

A fall with a happy ending

PART TWO

TEXTS

By the students of class 3B of the Acquarossa Middle School:

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Clara Beatriz Castè
Chiara Cavargna
Clarissa Degiorgi
Giorgia Delfoc
Samuele Ferrari
Timoteo Lucchini
Valentina Maroni
Clarissa Martinoli
Diana Morosi
Nathan Ochsner
Manuele Oncelli
Bruno Pedretti
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Alessia Poncioni
Vito Ragazzi
Gioele Ratti
Edgard Solari
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Under the coordination of the teachers:

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ILLUSTRATIONS

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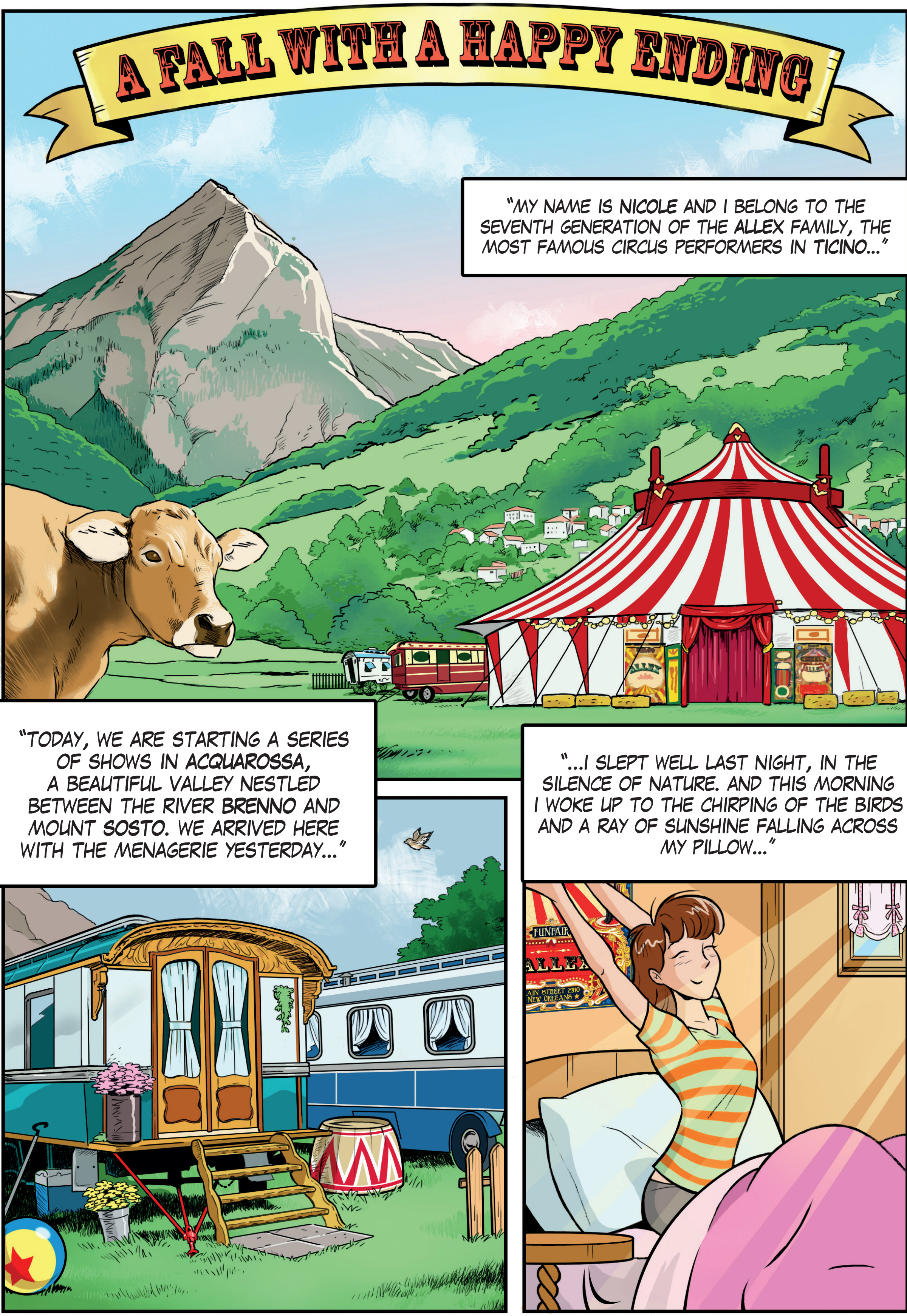
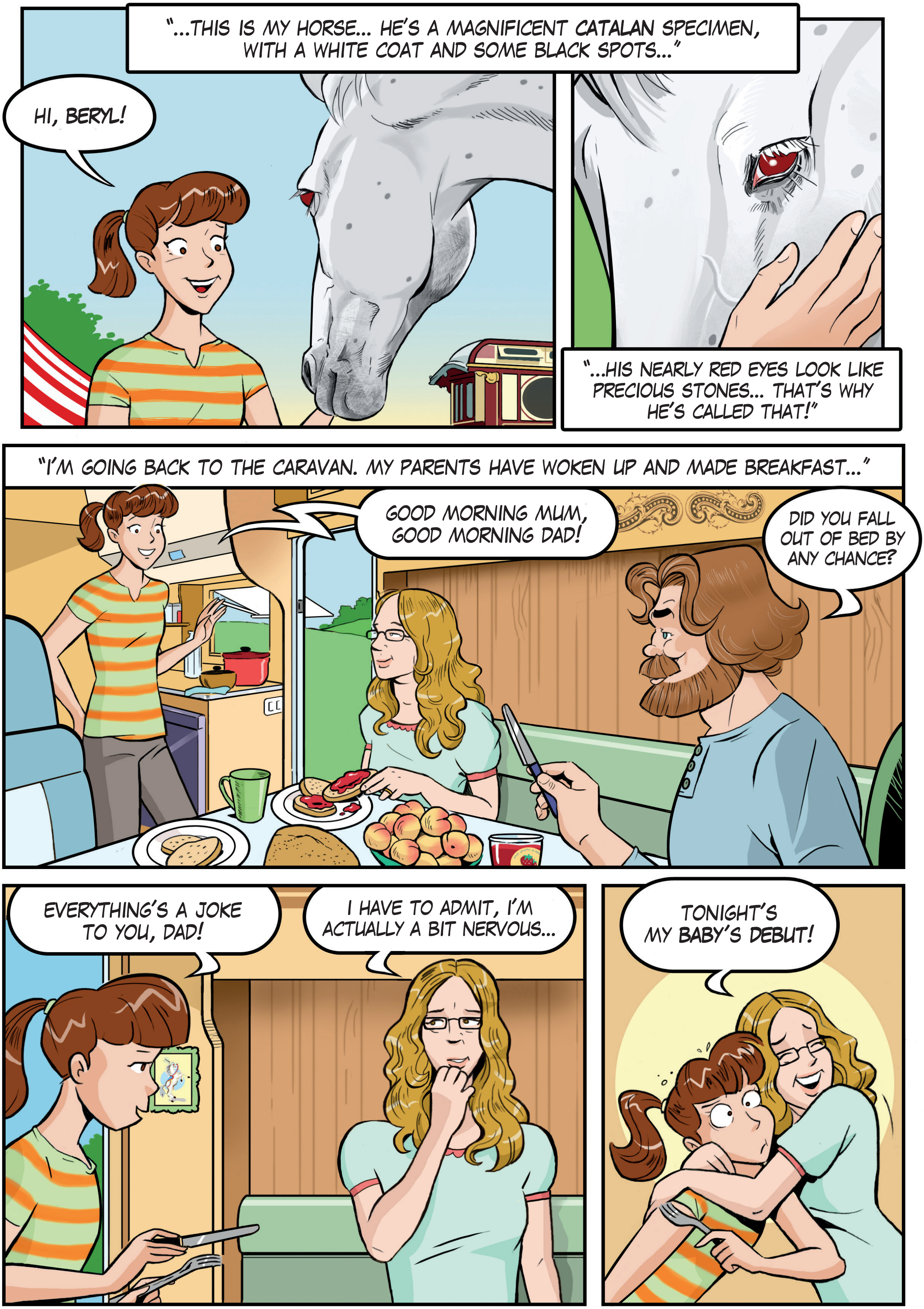
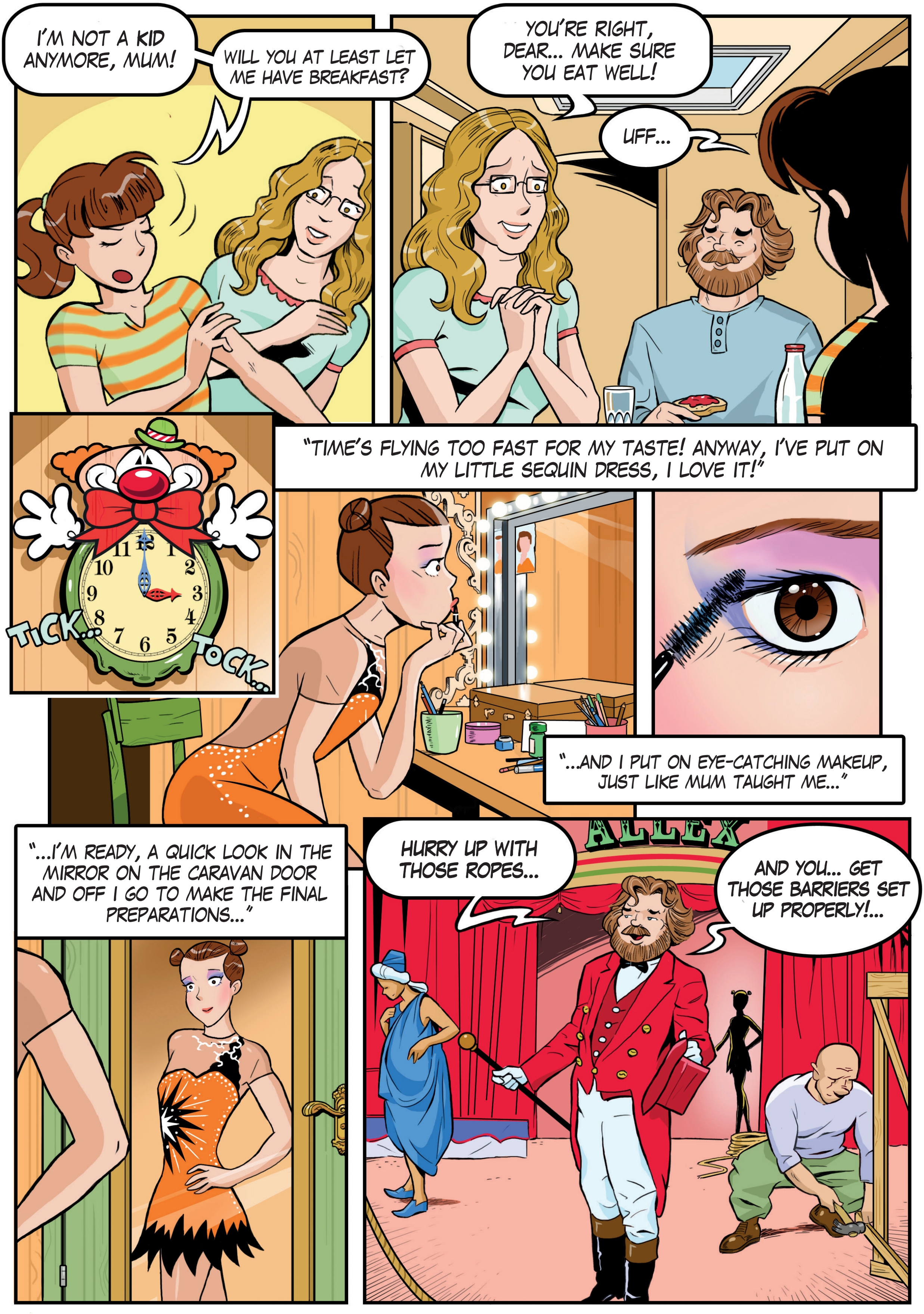

A FALL WITH A HAPPY ENDING
"MY NAME IS NICOLE AND I BELONG TO THE SEVENTH GENERATION OF THE ALLEX FAMILY, THE MOST FAMOUS CIRCUS PERFORMERS IN TICINO..."
"TODAY, WE ARE STARTING A SERIES OF SHOWS IN ACQUAROSSA, A BEAUTIFUL VALLEY NESTLED BETWEEN THE RIVER BRENNO AND MOUNT SOSTO. WE ARRIVED HERE WITH THE MENAGERIE YESTERDAY..."
"...I SLEPT WELL LAST NIGHT, IN THE SILENCE OF NATURE. AND THIS MORNING I WOKE UP TO THE CHIRPING OF THE BIRDS AND A RAY OF SUNSHINE FALLING ACROSS MY PILLOW..."
FUNFAIR
ALLEX
NEW ORLEANS

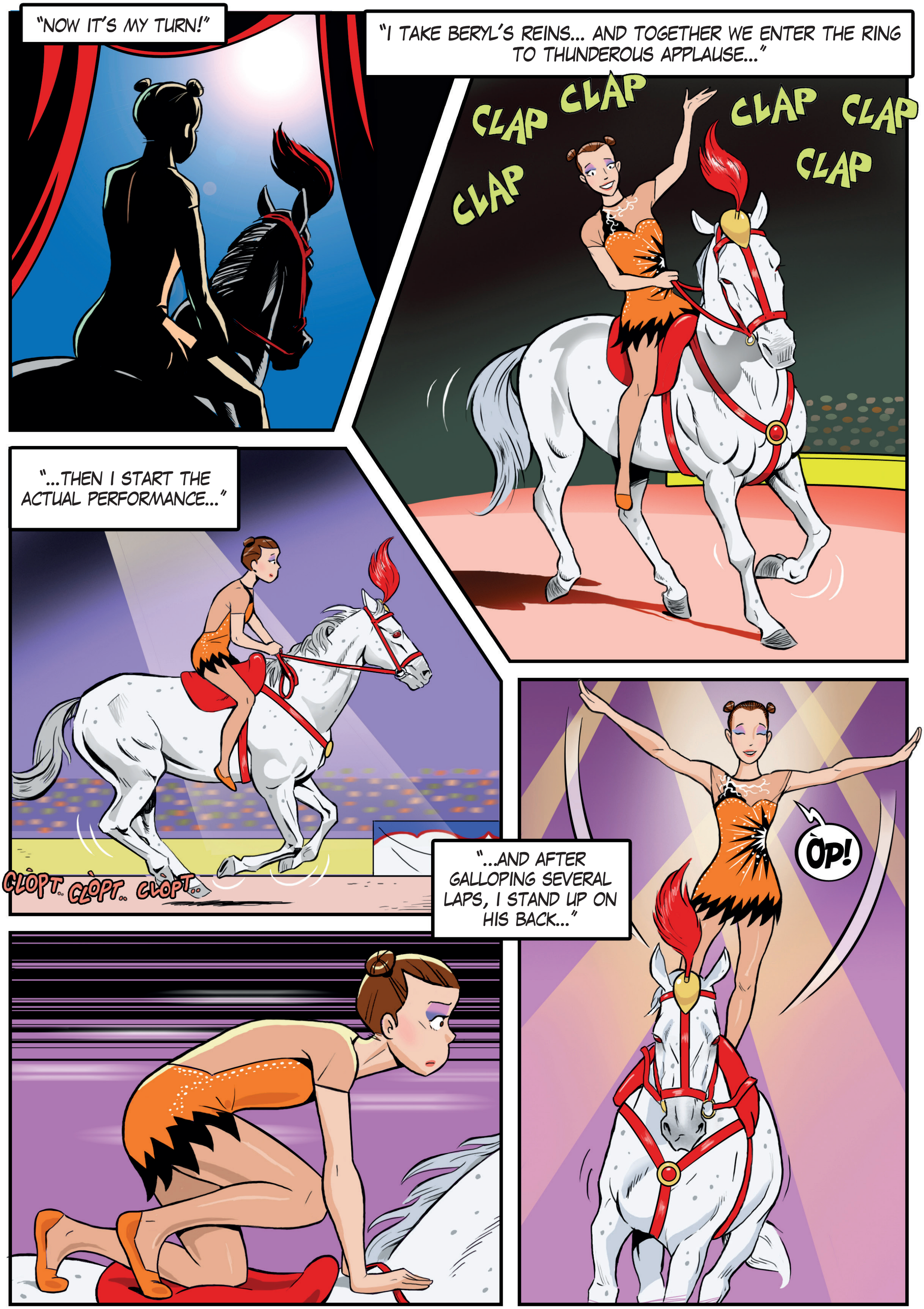

"MY PARENTS ARE STILL ASLEEP, IT'S ACTUALLY STILL VERY EARLY. BUT I FEEL WELL RESTED..."
ALLEY
CIRCUS
"...I WANT TO GO OUTSIDE RIGHT NOW, THE SCENERY HERE IS BEAUTIFUL..."
"...OUR RED AND WHITE STRIPED BIG TOP STANDS OUT AGAINST THE EMERALD GREEN OF THE FIELD, WATCHED OVER BY MOUNT SOSTO, WHICH LOOKS LIKE A KINDLY OLD GRANDFATHER..."
"SO PEACEFUL... EXACTLY WHAT I NEED TODAY!"
HIIII!

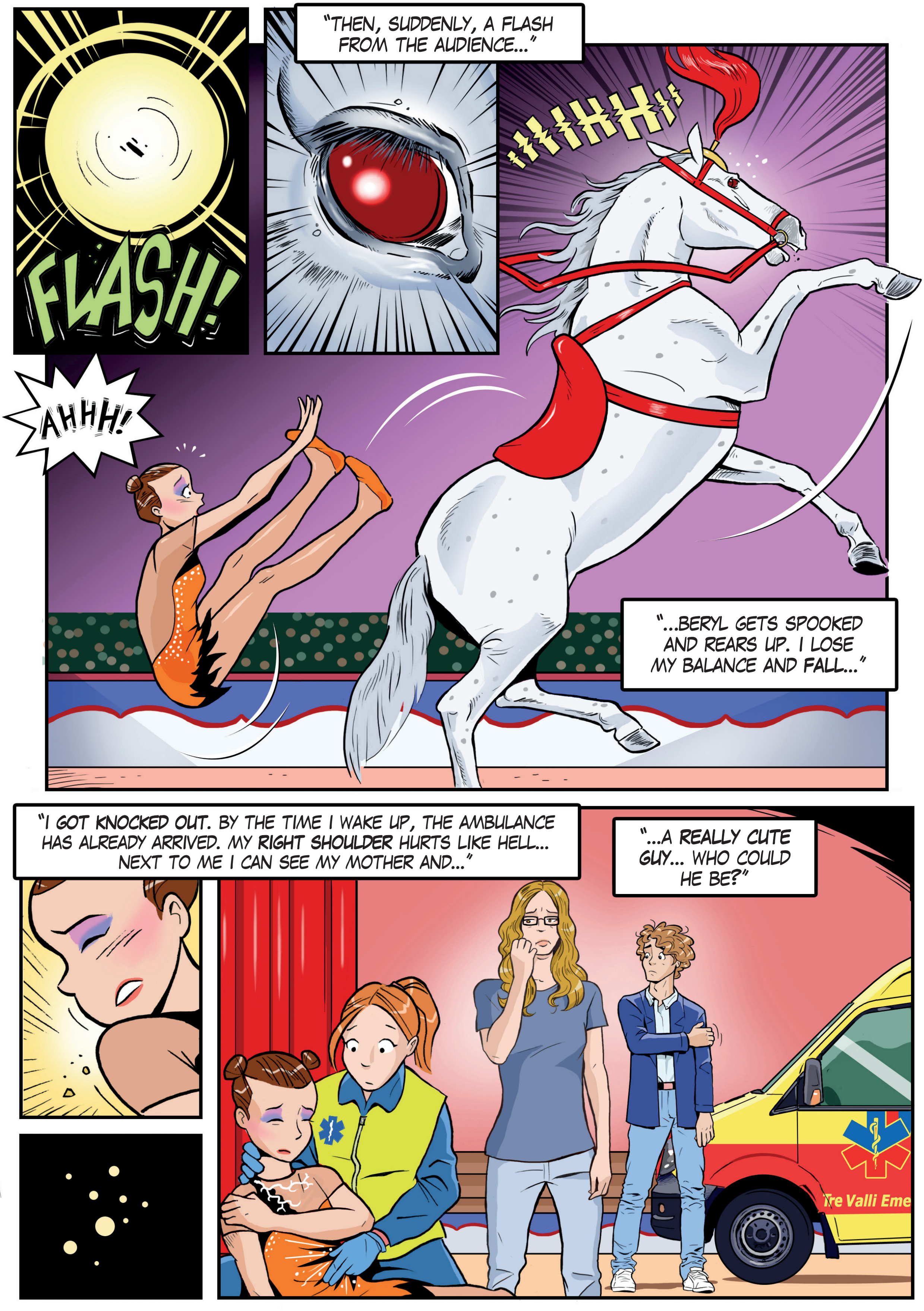

"...THIS IS MY HORSE... HE'S A MAGNIFICENT CATALAN SPECIMEN, WITH A WHITE COAT AND SOME BLACK SPOTS..."
HI, BERYL!
"...HIS NEARLY RED EYES LOOK LIKE PRECIOUS STONES... THAT'S WHY HE'S CALLED THAT!"
"I'M GOING BACK TO THE CARAVAN. MY PARENTS HAVE WOKEN UP AND MADE BREAKFAST..."
GOOD MORNING MUM, GOOD MORNING DAD!
DID YOU FALL OUT OF BED BY ANY CHANCE?
EVERYTHING'S A JOKE TO YOU, DAD!
I HAVE TO ADMIT, I'M ACTUALLY A BIT NERVOUS...
TONIGHT'S MY BABY'S DEBUT!

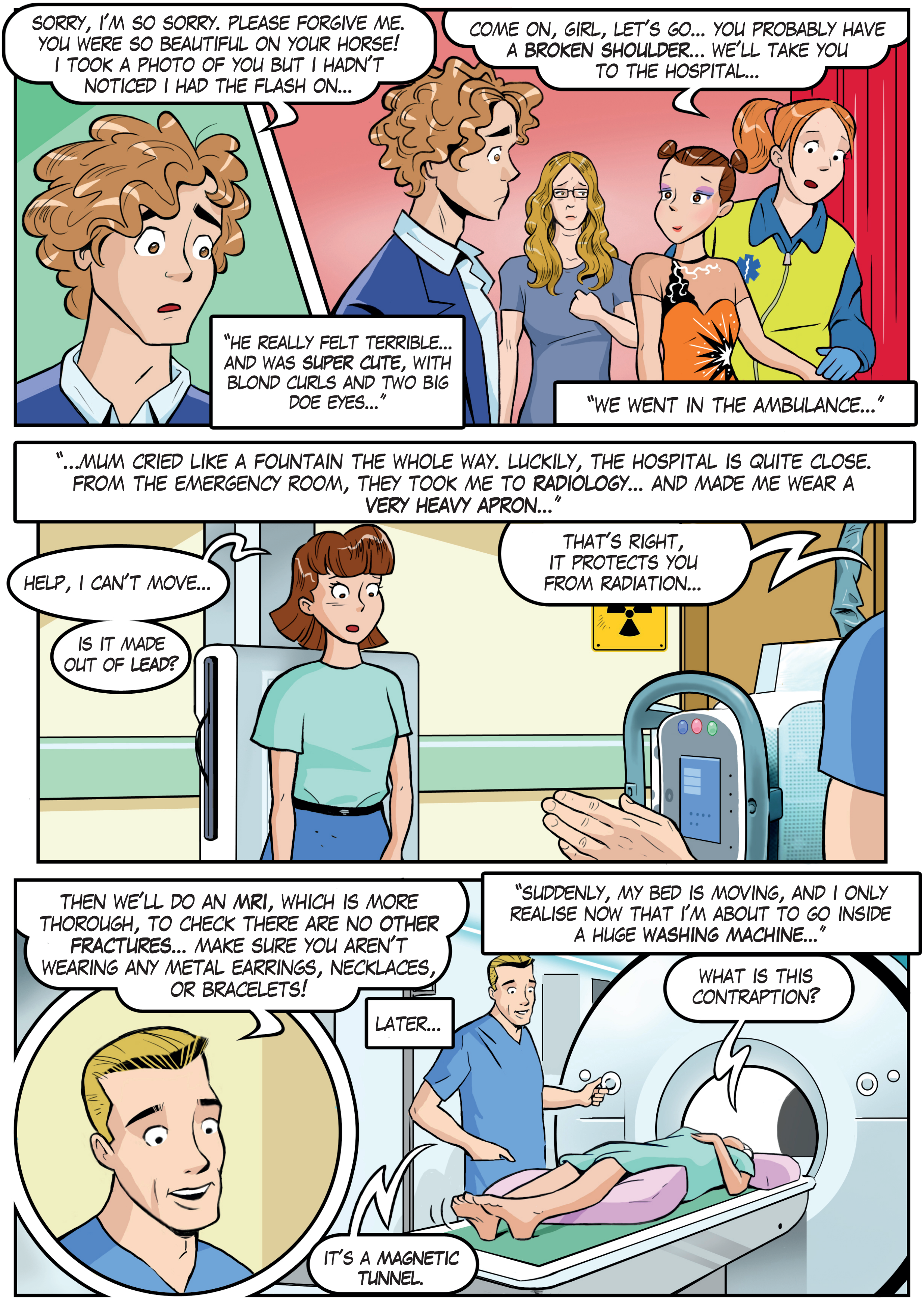

I'M NOT A KID ANYMORE, MUM!
WILL YOU AT LEAST LET ME HAVE BREAKFAST?
YOU'RE RIGHT, DEAR... MAKE SURE YOU EAT WELL!
UFF...
"TIME'S FLYING TOO FAST FOR MY TASTE! ANYWAY, I'VE PUT ON MY LITTLE SEQUIN DRESS, I LOVE IT!"
TICK... TOCK...
"...AND I PUT ON EYE-CATCHING MAKEUP, JUST LIKE MUM TAUGHT ME..."
"...I'M READY, A QUICK LOOK IN THE MIRROR ON THE CARAVAN DOOR AND OFF I GO TO MAKE THE FINAL PREPARATIONS..."
HURRY UP WITH THOSE ROPES...
AND YOU... GET THOSE BARRIERS SET UP PROPERLY!...

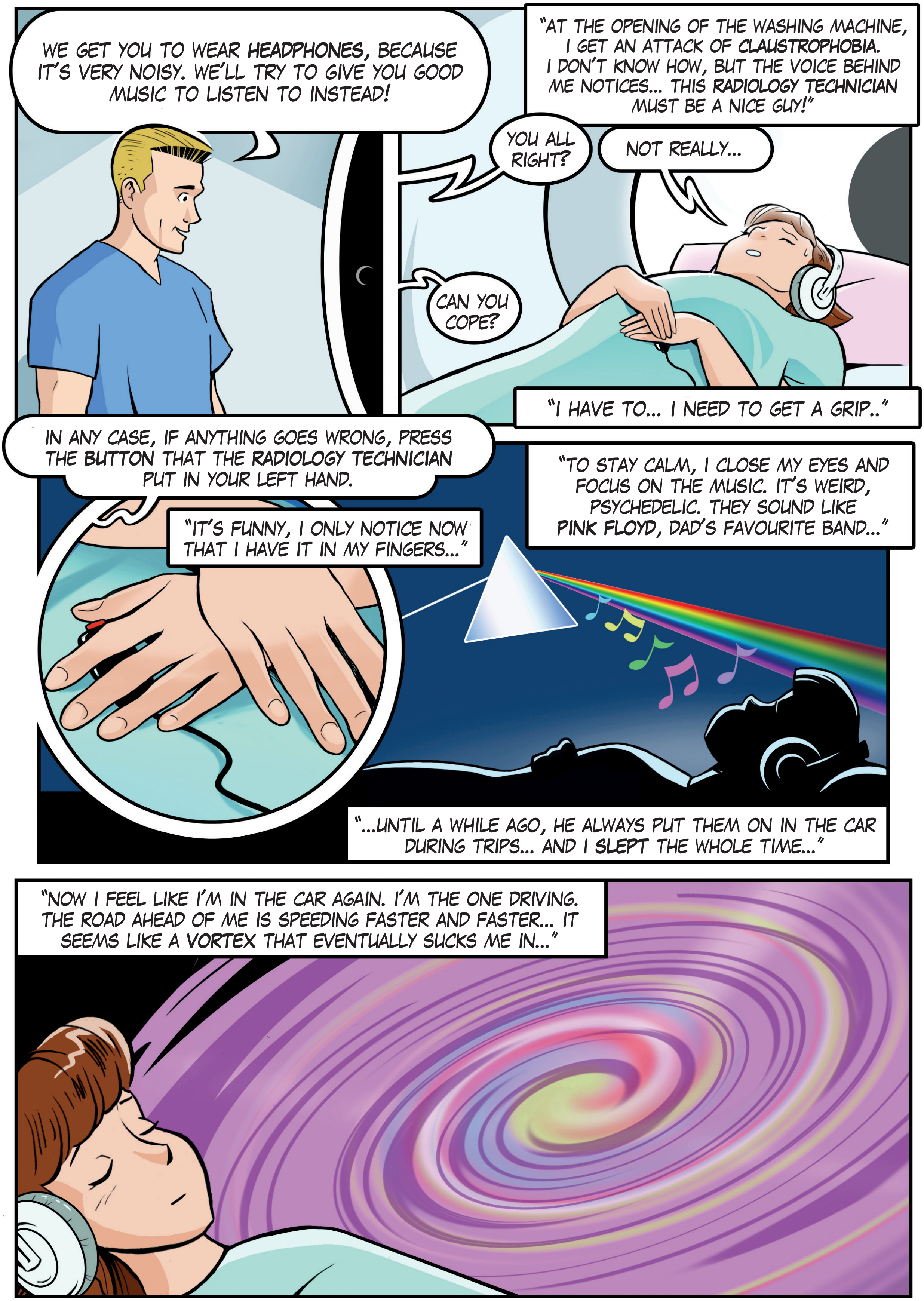

WELL, BERYL IS ALREADY READY...
COME ON, HURRY UP!
EVERYTHING'S READY, WE'RE GOING ON STAGE SOON!
"THERE'S A REALLY LONG LINE OF SPECTATORS OUTSIDE..."
"...MY NERVES ARE ALL OVER THE PLACE..."
THE USE OF FLASH PHOTOGRAPHY IS STRICTLY PROHIBITED
CAROLINA, MY LEGS ARE SHAKING WITH NERVES...

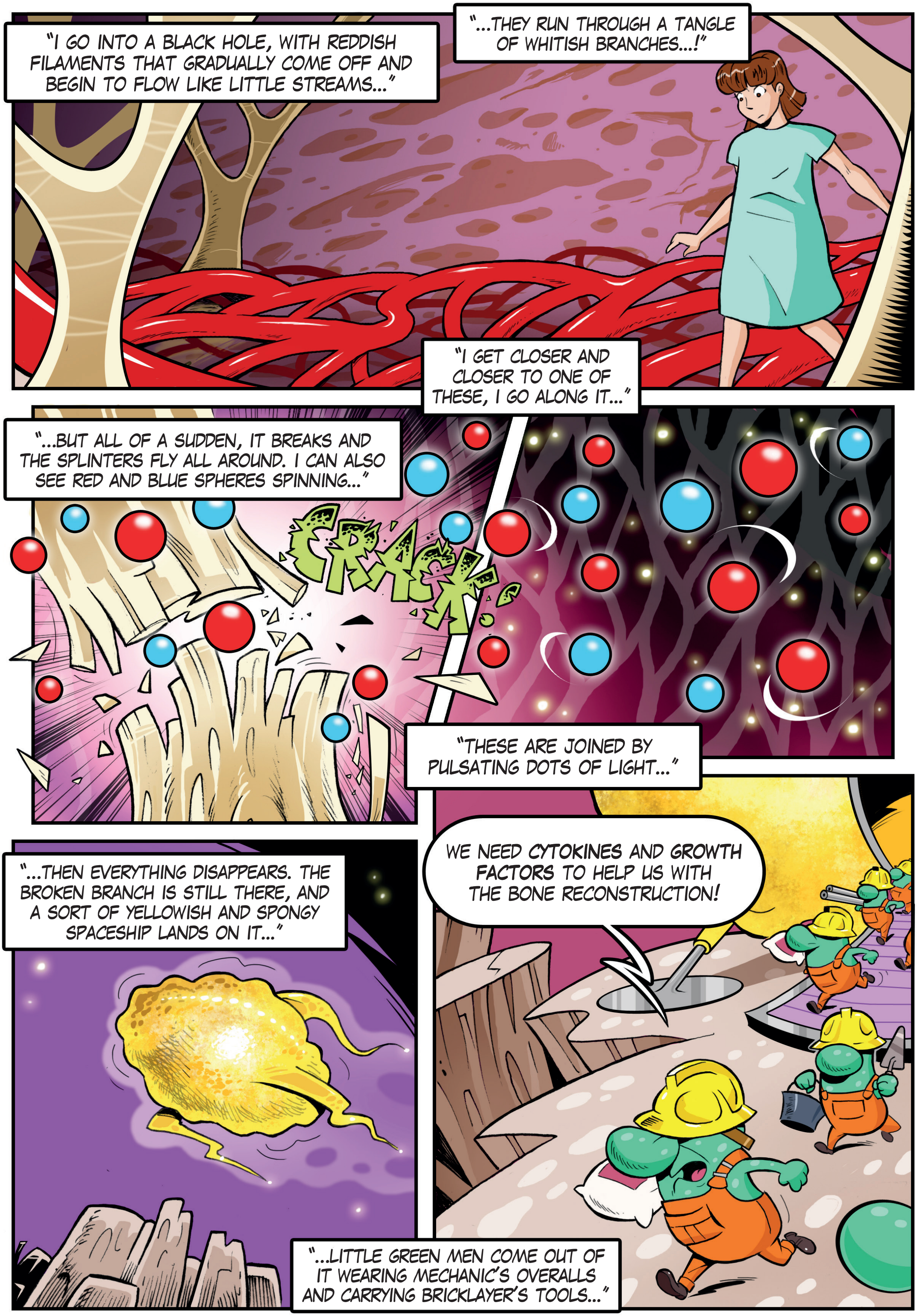

DON'T WORRY... YOU'RE GREAT, EVERYTHING'S GOING TO BE FINE!
YOU'RE RIGHT, I'VE PRACTISED A LOT, THERE'S NOTHING TO WORRY ABOUT...
"THE SHOW GOT OFF TO A GREAT START WITH THE CLOWNS..."
CLAP...
CLAP...
CLAP...
CLAP...
CLAP...
"...THEN THE TRAPEZE ARTISTS..."
"...THE JUGGLERS..."
"...AND CAROLINA AMAZES EVERYONE WITH HER FLEXIBILITY..."

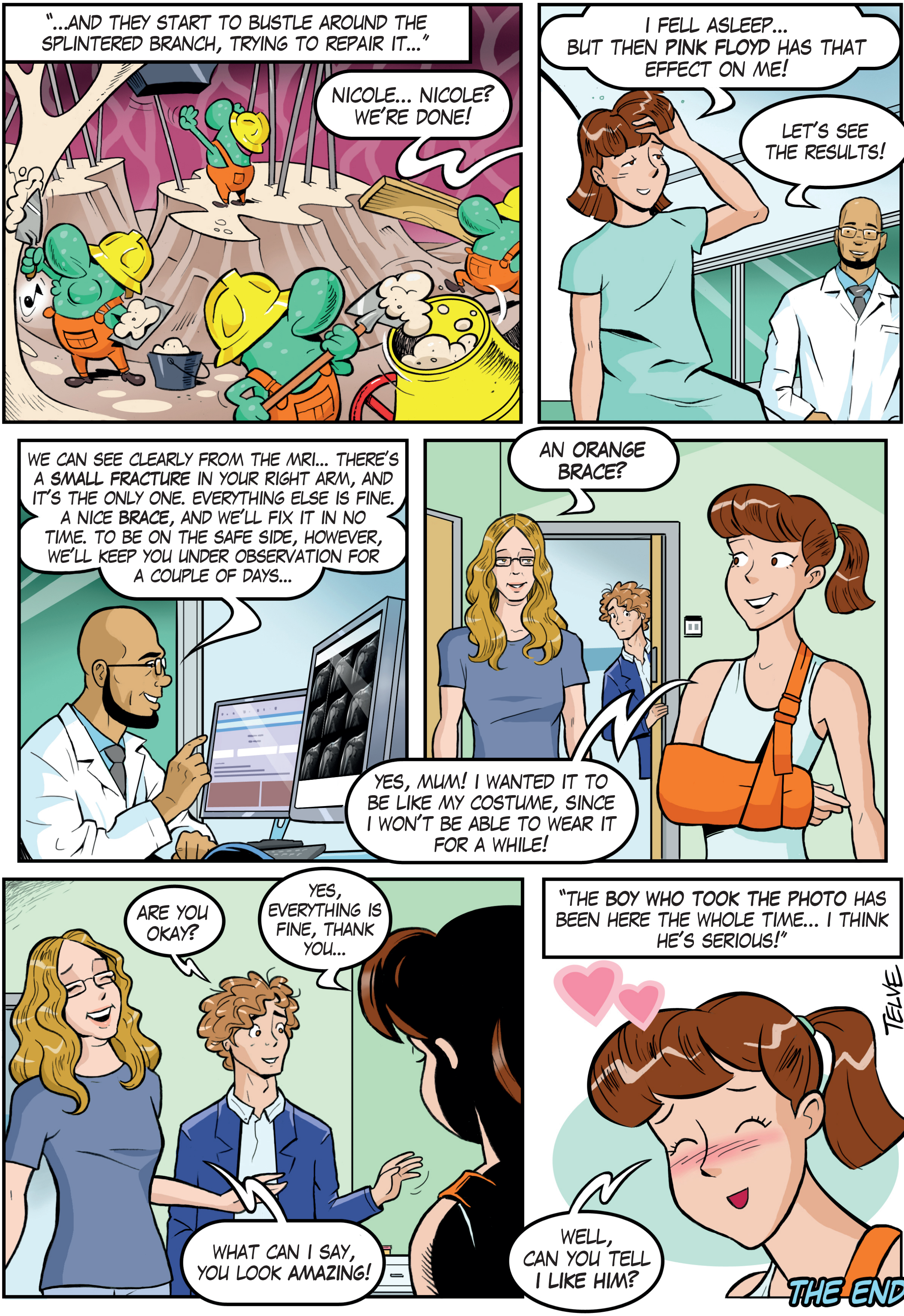

"NOW IT'S MY TURN!"
"I TAKE BERYL'S REINS... AND TOGETHER WE ENTER THE RING TO THUNDEROUS APPLAUSE..."
CLAP CLAP CLAP CLAP CLAP CLAP
"...THEN I START THE ACTUAL PERFORMANCE..."
CLOPT.. CLOPT.. CLOPT..
"...AND AFTER GALLOPING SEVERAL LAPS, I STAND UP ON HIS BACK..."
OP!


FLASH!
"THEN, SUDDENLY, A FLASH FROM THE AUDIENCE..."
HHHHH!!
AHHH!
"...BERYL GETS SPOOKED AND REARS UP. I LOSE MY BALANCE AND FALL..."
"I GOT KNOCKED OUT. BY THE TIME I WAKE UP, THE AMBULANCE HAS ALREADY ARRIVED. MY RIGHT SHOULDER HURTS LIKE HELL... NEXT TO ME I CAN SEE MY MOTHER AND..."
"...A REALLY CUTE GUY... WHO COULD HE BE?"
Tre Valli Eme


SORRY, I'M SO SORRY. PLEASE FORGIVE ME. YOU WERE SO BEAUTIFUL ON YOUR HORSE! I TOOK A PHOTO OF YOU BUT I HADN'T NOTICED I HAD THE FLASH ON...
COME ON, GIRL, LET'S GO... YOU PROBABLY HAVE A **BROKEN SHOULDER**... WE'LL TAKE YOU TO THE HOSPITAL...
"HE REALLY FELT TERRIBLE... AND WAS **SUPER CUTE**, WITH BLOND CURLS AND TWO BIG DOE EYES..."
"WE WENT IN THE AMBULANCE..."
"...MUM CRIED LIKE A FOUNTAIN THE WHOLE WAY. LUCKILY, THE HOSPITAL IS QUITE CLOSE. FROM THE EMERGENCY ROOM, THEY TOOK ME TO **RADIOLOGY**... AND MADE ME WEAR A **VERY HEAVY APRON**..."
HELP, I CAN'T MOVE...
IS IT MADE OUT OF LEAD?
THAT'S RIGHT, IT PROTECTS YOU FROM RADIATION...
THEN WE'LL DO AN **MRI**, WHICH IS MORE THOROUGH, TO CHECK THERE ARE NO OTHER **FRACTURES**... MAKE SURE YOU AREN'T WEARING ANY METAL EARRINGS, NECKLACES, OR BRACELETS!
LATER...
"SUDDENLY, MY BED IS MOVING, AND I ONLY REALISE NOW THAT I'M ABOUT TO GO INSIDE A HUGE WASHING MACHINE..."
WHAT IS THIS CONTRAPTION?
IT'S A MAGNETIC TUNNEL.


WE GET YOU TO WEAR HEADPHONES, BECAUSE IT'S VERY NOISY. WE'LL TRY TO GIVE YOU GOOD MUSIC TO LISTEN TO INSTEAD!
"AT THE OPENING OF THE WASHING MACHINE, I GET AN ATTACK OF CLAUSTROPHOBIA. I DON'T KNOW HOW, BUT THE VOICE BEHIND ME NOTICES... THIS RADIOLOGY TECHNICIAN MUST BE A NICE GUY!"
YOU ALL RIGHT?
NOT REALLY...
CAN YOU COPE?
"I HAVE TO... I NEED TO GET A GRIP.."
IN ANY CASE, IF ANYTHING GOES WRONG, PRESS THE BUTTON THAT THE RADIOLOGY TECHNICIAN PUT IN YOUR LEFT HAND.
"IT'S FUNNY, I ONLY NOTICE NOW THAT I HAVE IT IN MY FINGERS..."
"TO STAY CALM, I CLOSE MY EYES AND FOCUS ON THE MUSIC. IT'S WEIRD, PSYCHEDELIC. THEY SOUND LIKE PINK FLOYD, DAD'S FAVOURITE BAND..."
"...UNTIL A WHILE AGO, HE ALWAYS PUT THEM ON IN THE CAR DURING TRIPS... AND I SLEPT THE WHOLE TIME..."
"NOW I FEEL LIKE I'M IN THE CAR AGAIN. I'M THE ONE DRIVING. THE ROAD AHEAD OF ME IS SPEEDING FASTER AND FASTER... IT SEEMS LIKE A VORTEX THAT EVENTUALLY SUCKS ME IN..."


"I GO INTO A BLACK HOLE, WITH REDDISH FILAMENTS THAT GRADUALLY COME OFF AND BEGIN TO FLOW LIKE LITTLE STREAMS..."
"...THEY RUN THROUGH A TANGLE OF WHITISH BRANCHES...!"
"I GET CLOSER AND CLOSER TO ONE OF THESE, I GO ALONG IT..."
"...BUT ALL OF A SUDDEN, IT BREAKS AND THE SPLINTERS FLY ALL AROUND. I CAN ALSO SEE RED AND BLUE SPHERES SPINNING..."
CRACK!
"THESE ARE JOINED BY PULSATING DOTS OF LIGHT..."
"...THEN EVERYTHING DISAPPEARS. THE BROKEN BRANCH IS STILL THERE, AND A SORT OF YELLOWISH AND SPONGY SPACESHIP LANDS ON IT..."
WE NEED CYTOKINES AND GROWTH FACTORS TO HELP US WITH THE BONE RECONSTRUCTION!
"...LITTLE GREEN MEN COME OUT OF IT WEARING MECHANIC'S OVERALLS AND CARRYING BRICKLAYER'S TOOLS..."


"...AND THEY START TO BUSTLE AROUND THE SPLINTERED BRANCH, TRYING TO REPAIR IT..."
NICOLE... NICOLE? WE'RE DONE!
I FELL ASLEEP... BUT THEN PINK FLOYD HAS THAT EFFECT ON ME!
LET'S SEE THE RESULTS!
WE CAN SEE CLEARLY FROM THE MRI... THERE'S A SMALL FRACTURE IN YOUR RIGHT ARM, AND IT'S THE ONLY ONE. EVERYTHING ELSE IS FINE. A NICE BRACE, AND WE'LL FIX IT IN NO TIME. TO BE ON THE SAFE SIDE, HOWEVER, WE'LL KEEP YOU UNDER OBSERVATION FOR A COUPLE OF DAYS...
AN ORANGE BRACE?
YES, MUM! I WANTED IT TO BE LIKE MY COSTUME, SINCE I WON'T BE ABLE TO WEAR IT FOR A WHILE!
ARE YOU OKAY?
YES, EVERYTHING IS FINE, THANK YOU...
WHAT CAN I SAY, YOU LOOK AMAZING!
"THE BOY WHO TOOK THE PHOTO HAS BEEN HERE THE WHOLE TIME... I THINK HE'S SERIOUS!"
WELL, CAN YOU TELL I LIKE HIM?
TELVE
THE END

GLOSSARY

ALARA (as low as reasonably achievable): The principle according to which a series of procedures are implemented that make it possible to perform examinations using ionising radiation with the intention of reducing the dose that the person receives as much as possible, without impairing the quality of the image produced.

Anger camera (gamma camera): Also known as a scintillation camera, a device used in nuclear medicine to obtain static, dynamic, and tomographic scintigraphic images after administration of a radionuclide.

Angiography: A radiological examination involving the injection of a water-soluble contrast medium that makes it possible to visualise the vessels of the human body for diagnostic purposes.

Apoptosis: Programmed cell death. This is a fundamental mechanism for the maintenance and proper development of the body's cells.

Computed axial tomography (CAT)/computed tomography (CT): Acronym for computed axial tomography (CAT) or computed tomography, CT is a diagnostic method that uses ionising radiation (X-rays) to obtain detailed three-dimensional images of specific anatomical areas of the human body.

Contrast medium: Contrast media or contrast agents are substances that can change the way an analysed region appears in a medical image.

Deoxyribonucleic acid (DNA): Nucleic acid that contains the genetic information necessary for the development and proper functioning of most living organisms.

Deterministic effects of radiation	Deterministic effects generally appear immediately after exposure to ionising radiation. Once the maximum limit has been exceeded, the higher the dose the individual absorbs, the more severe the damage will be.
Dosimeter	A dosimeter monitors the radiation representative of the effective whole-body dose for a given period of time. The effective dose, expressed in sieverts, is an indicator of biological risk.
Electromagnetic field	This consists of the combination of an electric field and a magnetic field and is generated locally by any distribution of an electric charge and an electric current that are variable over time, propagating in space in the form of electromagnetic waves.
Electromagnetic spectrum	The range of frequencies of electromagnetic waves that determine the type of radiation based on their frequency and wavelength.
Fluoroscopy (Radioscopy)	A technique that enables us to obtain real-time images of the internal anatomy of a human being; X-rays are used for this method.
Gauss (G)	A unit of measurement of magnetic induction. It is named after the scientist Karl Friedrich Gauss (1777-1855).
Gray (Gy)	The unit of measurement of the absorbed radiation dose. One Gy corresponds to the absorption of 1 joule of energy by 1 kilogram of matter 1 Gy = 1 J/kg.
Ionising radiation	Electromagnetic or corpuscular radiation with sufficient energy to "ionise" the matter it passes through.
Magnet	A material or object that is able to attract objects of ferromagnetic material due to its own natural magnetism or induced magnetism.
Mammography	A breast X-ray performed in order to detect the presence of potentially tumorous growths.

Mastectomy	Surgical removal of the breast.
Non-ionising radiation	Any type of electromagnetic radiation that does not carry enough energy to ionise the matter it passes through.
Petites Curies	Small cars equipped with mobile radiology devices that were used during the First World War for French soldiers at the front.
Photon	A massless particle with zero electric charge and integer spin; it is a fundamental constituent of electromagnetic radiation. It is also described as a quantum of energy.
Polonium	A chemical element with the atomic number 84 and the symbol Po. It is a rare radioactive semimetal.
Positron emission tomography (PET/CT)	Positron emission tomography (PET) is a medical diagnostic technique in nuclear medicine used for bioimaging.
Radiation protection	A discipline that arose as a field of application of radiobiology and that deals with how to protect individuals, their descendants, the population in general, and the environment against the harmful effects of ionising radiation.
Radioactivity	Radioactivity, or radioactive decay, is a set of physical processes at the nuclear level through which some unstable or radioactive atomic nuclei (radionuclides) decay (or transmute) over a certain period of time, called the decay time.
Radiobiology	This is the branch of biology that deals with the effects of radiation on living matter.
Radio frequency	A radio frequency, also known by the acronym RF, generally refers to a high-frequency electrical signal or electromagnetic wave propagating through space or along a coaxial cable.
Radiology	Medical radiology is the branch of medicine that deals with the production and interpretation of radiological images for diagnostic or therapeutic purposes. It is also called diagnostic radiology or radiodiagnostics.

Radiomics The analysis of medical images with the aim of obtaining quantitative information through appropriate mathematical methods and the use of computers. This information cannot be detected through simple visual observation by the operator.

Radionuclide An unstable nucleus that decays by emitting energy in the form of radiation, hence its name. Radioisotopes are radioactive isotopes, i.e. radionuclides of the same chemical element.

Radiopharmaceutical A radioactive substance consisting of a radioactive part and a pharmacologically active part. Radiopharmaceuticals can be used for both diagnostic and therapeutic purposes.

Radium A chemical element with the atomic number 88 and the symbol Ra. The word radioactivity comes from the name of this element.

Resonance signal The pulses of the radio frequency waves change the alignment of the nuclei, which, when the pulses cease, re-align themselves with the axis of the magnetic field. In doing so, they resonate, that is, they emit a very weak signal called the resonance signal.

Sievert (Sv) The unit of measurement of the equivalent dose and the effective dose of radiation. The sievert (Sv), which is named after the Swedish scientist Rolf Sievert, is a representative measurement of the effects and damage caused to the individual.

Single photon emission tomography (SPECT) Single photon emission tomography, better known by the acronym SPECT, is a medical tomographic imaging technique in nuclear medicine that uses ionising radiation, gamma rays.

Stenosis Pathological narrowing of a canal, orifice, hollow organ, or vessel.

Stochastic effects of radiation The stochastic or probabilistic effects of radiation are due to mutations produced at the cellular level. The higher the dose of ionising radiation to which the individual is exposed during their lifetime, the greater the likelihood is that they will develop cancer or that their offspring will have deformities.

Tesla (T) A unit of measurement in the International System of Units (SI). It is used to measure magnetic induction, i.e. the density of the magnetic flux.

Tomosynthesis A technique that enables three-dimensional (3D) images of the breast to be obtained and the overlapping effect of tissues typical of x-rays to be reduced and/or eliminated. Generally, it is performed in addition to standard mammography.

Ultrasound Mechanical sound waves. Ultrasound frequencies are not audible to the human ear.

Wavelength In physics, the wavelength is represented by the distance between two crests or between two troughs of its waveform; it is commonly indicated by the Greek letter lambda.

X-rays Also called Röntgen rays, X-rays are high-energy electromagnetic radiation. They are mainly used for medical purposes, in biochemical analyses, and to study the structure of materials.

X-ray tube A vacuum glass ampoule, containing a high-voltage cathode and anode. It is used for the production of X-rays.

For many centuries, the only way to observe the inside of the human body was to dissect it and perform an autopsy. Today, with the help of diagnostic imaging, we are able to explore the organs and structures even of living bodies from the outside.

In this booklet, the author takes us on a surprising journey, explaining discoveries, devices, and technologies that have left their mark on and revolutionised the history of medicine.

The booklet thus gives us a picture of the overall complexity of this constantly evolving field, presenting the great variety of methods that allow us to better assess each anatomical structure of the human body and to monitor, and therefore treat, a significant number of diseases.

Francesco Mascaro, Imaging Institute of Southern Switzerland, Canton hospital organisation (EOC), Bellinzona.

Inside the comic:

A fall with a happy ending

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