Ilya Obodovskiy

From Radio-phobia to Radio-euphoria

Low Radiation Doses: Safe, Useful, and Necessary

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Springer Praxis Books
ISSN 2626-6113 ISSN 2626-6121 (electronic)
Popular Science
ISBN 978-3-031-42644-5 ISBN 978-3-031-42645-2 (eBook)
https://doi.org/10.1007/978-3-031-42645-2

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

I conceived and partly wrote this book in a relatively peaceful time. But while I was working, war broke out in Europe. A war unleashed by a nuclear state whose politicians and propagandists constantly threaten to use nuclear weapons or destroy the reactors of Ukrainian nuclear power plants. In both cases, radioactive contamination of vast territories and a sharp increase in the radiation background worldwide are possible. Before this war, interest in radiation and its effects on health may have been a mere curiosity. But in the conditions of possible nuclear explosions, this issue is moving into the area of as close attention as the weather forecast.

Most of the world's population rightly believes that large doses of ionizing radiation are dangerous. Unfortunately, these concerns apply to any, including small, doses. This condition is called radiophobia. Using a vast amount of research, I will explain to the readers of this book that small doses are safe, beneficial, and at some level even necessary.

There is nothing unusual in the statement about the usefulness of small doses with the danger of large ones. The book contains a large number of various examples confirming this idea. We will point out one here: a temperature of 20 °C (68 °F) is comfortable, and, for example, 100 °C (212 °F) is a burn. In degrees of temperature, all people understand from school age when to wear a thin shirt and when a sheepskin coat. The book will help readers navigate a new sphere in radiation doses and imagine the border between dangerous and safe values.

It will allow one to avoid dangerous zones, if necessary—to take appropriate measures and not to be afraid of zones, although with an increased background, but safe.

San Diego, CA   Ilya Obodovskiy

About Mathematics, Formulas, Numbers, Graphs, and Terminology

One of the greatest scientists of the end of the XIX century, William Thomson, better known in the world as Lord Kelvin, it was in his honor that the unit of absolute temperature was named, wrote: "If you can measure and express what you are talking about in numbers, you know something about it, but if you can't, your knowledge is poor and unsatisfactory." The ability to calculate allows you to move from accumulating knowledge to acquiring skills, from "know-what" to "know-how."

However, it is clear that the abundant use of mathematics will make the book difficult to understand for a wide range of readers. Another major physicist of our time, Stephen Hawking, in the preface to his book "A Brief History of Time" about mathematics in a popular book, said: "I was told that each formula included in the book would halve the number of buyers." Hawking managed with just one formula. There will be no formulas at all in this book.

And yet, mathematics is indispensable. There are no formulas, but mathematics breaks through in the form of numbers and graphs.

In the scientific papers on which the author wrote this book, doses are given in sieverts, grays, roentgens, rads, rems, or other units used at different times. The author tried, wherever possible, to transfer the doses to the same system. But this is not always possible, for such a translation there may not be enough information. In addition, it must be understood that effective and equivalent doses, expressed in sieverts, apply only to the human body and for stochastic effects, i.e., mainly for radiation carcinogenesis.

Units of measurement of source activity and doses, which are unfamiliar to the general public, are actually easy to understand. This is no more difficult than comparing prices for different goods, for example, in dollars and euros. Moreover, the ratio of the dollar and the euro can change daily, and the ratio, for example, of roentgen and gray, is established unambiguously once and for all. One of the objectives of the book is to help interested readers in this matter.

A summary of the units of measure and their ratios is given in the Appendix.

To facilitate a comparison of the numerical values given in the book for activity, dose, and dose rate, lists of typical and official values are given in the last tables in the Appendix.

Another slightly less obvious manifestation of the influence of mathematics is the presentation of measurement results in the form of graphs. We hope that this moment will not cause serious difficulties. Currently, many media provide information on price dynamics, exchange rates, election results, etc., in the form of graphs.

It is known that scientists speak their own language, often obscure to the general public. Technical terminology and jargon also penetrate into non-fiction books, making them hard to read. In the 1930s, the future Nobel laureate physicist Max Delbrück became interested in genetics. At first, listening to speeches or stories of geneticists, he was perplexed: "Why did they need to invent a special gibberish language so that their criminal intentions are not clear to others" (quoted from the book by M.D. Frank-Kamenetskii "Unraveling DNA: The Most Important Molecule of Life"). The peculiarity of genetics was demonstrated by the famous phrase: "A recessive allele affects the phenotype only if the genotype is homozygous." But really this phrase accurately conveys the meaning, and it is perhaps difficult to say otherwise.

In our opinion, the majority of readers prefer to obtain a more or less clear and, if possible, simple picture of the complex phenomena being described. It is clear that such an approach leads to certain losses. On the other hand, simplifying complex phenomena is an extremely fruitful way of solving complex problems. We illustrate this statement with two examples.

The movement of electrons, i.e. electric current in matter is an extremely complex process. Electrons pass through potential barriers and potential wells, collide with inhomogeneities of the crystal lattice and impurity atoms, change the direction of movement, give, and receive energy, etc. However, it turns out that all this complexity can be forgotten if you enter a single parameter—resistance. For this simplification, the name of the author who formulated the corresponding law, Georg Ohm, was honored to become the name of the unit of electrical resistance.

In the 1930s, a young man, Pavel Cherenkov, discovered a new, previously unknown glow, now in all languages, called Cherenkov radiation. Cherenkov observed this glow in various complex substances, solutions, and mixtures. Neither he nor his scientific supervisor, academician Sergei Vavilov could understand the origin of this glow. The famous Soviet scientists Igor Tamm and Ilya Frank explained this phenomenon by replacing all the complexities of substances with a single parameter—the refractive index. For this simplification, they were awarded (together with Cherenkov) the Nobel Prize.

The so-called Central Dogma of Molecular Biology, simplifying the real picture, also played a positive role in biology. Recently, prominent American experts Douglas Hanahan and Robert Weinberg wrote in an article in the journal Cell: "We foresee cancer research developing into a logical science, where the complexities of the disease, described in the laboratory and clinic, will become understandable in terms of a small number of underlying principles." As you can see, biologists also strive for simplifications.

So, reader, in this book, you will get a simplified picture of the complex processes of the effects of ionizing radiation on health.

The reader will find in the book a list of popular books that will expand and deepen the understanding of the problem.

Introduction

There is no doubt that at present, a significant part of the population, at least in civilized countries, suffers from radio-phobia. Although, the verb "suffers" in this case should be used with caution. I remember an anecdote. Doctor: "So, patient, you are suffering from alcoholism." Patient: "No, doctor, what are you? I don't suffer from it, I enjoy it." It is unlikely that anyone enjoys radio-phobia, but people, without a doubt, have a certain craving for the mysteriously frightening.

This craving appeared, most likely, in ancient times, and even Homer, indulging the tastes of the ancient Greek public, composed the horrors that Odysseus encountered in his wanderings. Closer to our time, the so-called Gothic novel appeared, relishing the pleasant feeling of nightmares, and then the "black novel" with elements of the supernatural and mysterious. Crowds of ghosts, vampires, monsters, and aliens from the other world wandered through literary works and later the stage and movies. The famous German storyteller Ernst Theodor Amadeus Hoffmann and the great American writer Edgar Allan Poe paid tribute to the mysteriously frightening theme. Mary Shelley's Frankenstein or the Modern Prometheus and Bram Stoker's Dracula were milestones in following the painful needs of the population. In Russia, N.V. Gogol, for example, was noted on this path with the story "Viy." Nowadays, readers are reading horror novels by Stephen King.

A deafening impression was once made on the public by Edvard Munch's painting "The Scream" (Fig. 1a). The artist used the frightening impression of this painting in a modification of the radiation hazard sign (Fig. 1c), which enhances its intimidating effect.

It is generally accepted that in fact we love disasters. Don't feed us with bread—let us fight some huge threat, whether it is global inequality, global

Fig. 1 (**a**) One of the variants of the most famous work of E. Munch "The Scream," (**b**) a standard sign of radiation hazard, (**c**) a sign of radiation hazard, stylized as a painting by Munch. Figure from The Scream, Wikipedia—https://en.wikipedia.org/wiki/The_Scream. Public domain

warming, a pandemic, world terrorism, the onset of an era of lack of spirituality, fascism raising its head, the collapse of the great Western civilization, etc. Today, we have an apocalypse for every taste and color.

So, people feel the need for horror stories. And nuclear radiation is perfect for this purpose. Invisible and inaudible, without color, smell, and taste, they already arouse concern with their mysteriousness alone. The invisible enemy is the most terrible; terrible properties are unwittingly attributed to him, which in fact may not exist. If there were no nuclear radiation, they would have to be invented, on purpose, as the most potent tool for tickling nerves.

It is interesting to note that the emergence of household electricity was also met with caution. Fear was caused by numerous cases of instant electric shock, leaving no traces. Confirmation of the dangerous nature of electricity was the emergence of a new type of execution in the electric chair. The first murderer was executed in this way in 1890. One of the frightening properties of electricity, as well as radiation, was its invisibility. There were wires here, but it wasn't easy to imagine what moved along them. Electricity caused fears soon after its appearance, but then people got used to it; as we see with radiation, the opposite is true.

Invisible radio waves caused fears and continue to cause them. The possible impact of mobile phone radiation on the ears and brain is being seriously studied in many laboratories worldwide; many ordinary people suspect the harmfulness of products from microwave ovens. This variant of radio-phobia has not yet reached its point in the list of phobias, but, as they say, it is not over yet.

Since the emergence of life on Earth, i.e., almost 4 billion years, all life has been immersed in an ocean of ionizing radiation. For the first 3.5 billion years, living organisms lived in water, where radiation doses are noticeably lower than on land. And only then did life get out onto land and, having apparently found the larger doses it needed, reached its amazing diversity and perfection. Homo sapiens, which arose from evolution about 200 thousand years ago, although he is considered a reasonable person, did not know about the existence of radiation penetrating him for a long time.

Radiation was discovered in a historical perspective quite recently. At the end of 1895, the German scientist V.K. Roentgen discovered a new, previously unknown, radiation. A little later, in the spring of 1896, the French scientist A. Becquerel discovered the radioactive radiation of atoms. And humankind has discovered that in nature, there is well-penetrating radiation.

All the time of acquaintance of people with radiation can be clearly divided into two periods. The first period, the period of delight and fascination with new phenomena, was called the period of radio-euphoria and X-ray mania. This period continued until about the middle of the twentieth century. And then, the population's mood changed quite dramatically, and fears and horrors replaced the enthusiasm.

The period of radio-phobia has come.

I want to remind you that in Greek, "phobia" simply means fear. But in modern use, this concept has a specific semantic connotation. A phobia is not just fear but unreasonable, unjustified fear. As a suffix attached to other words, it means various types of phobias. Specialists currently count a vast number of different phobias—many hundreds. In the lists of phobias, you can find well-known ones, for example, claustrophobia; there are also quite exotic ones, for example, "Paraskavedekatriaphobia"—the fear of Friday the 13th.

However, this phobia seemed eccentric only out of ignorance. A closer examination of the subject showed that, according to Wikipedia, in today's society with a developed economy, the problem of Friday the 13th has turned from mystical into quite tangible economic. People who are more or less prone to "paraskavedekatriaphobia" try to reduce their activity as much as possible on such days, which, according to some estimates, in the US economy alone leads to a loss of 800–900 million dollars each day. (In 2023, Friday the 13th will be two times, in January and October, in 2024—in September and December, in 2025—only in June and in 2026—only in February).

You can imagine what problems radio-phobia creates for people and what losses are in the economy.

Radio-phobia is one of a long list of several hundred different phobias. One of this book's objectives is to help get rid of it or at least weaken its influence.

In this book, the author will try to popularly explain in what cases, under what conditions, radiation is scary, and in which, on the contrary, it is safe and even useful, whether there is reason to consider radio-phobia as a really unreasonable fear.

So, is nuclear radiation dangerous? Yes, large doses are dangerous; the out-of-control radiation that creates them is hazardous. Radiation is dangerous, as wild animals are dangerous in the wild and even in a zoo if they break out of their cages, as dangerous as playing with matches at a gas station, as dangerous as drunk bus drivers or inept airliner pilots. But if appropriate safety measures are taken and observed, the danger of exposure to large doses is very unlikely. Whether people can comply with these measures is a question that the author will try to discuss in this book, but to which he does not have a definitive answer.

But if a meeting with large doses of radiation is very unlikely for the vast majority of readers, then all of us, without exception, regardless of gender, age, place of residence, specialty, type of occupation, financial situation, etc. are continuously exposed to low doses.

Large doses of radiation are a formidable and dangerous animal, and small ones are affectionate and gentle. In this book, in chapters 7-10, we will discuss in detail the three main features of the effects on the body of small doses:

- safety,
- usefulness,
- necessity.

The boundary between dangerous and safe doses and the certainty of this boundary will also be discussed there.

It is well known that radiation is not only inherently useful in small doses but also harmful or even dangerous in large doses. Overeating is harmful, sugar, salt and many other components of our diet are harmful in large quantities. It is clear that, within reasonable limits, these components are absolutely necessary. The book contains many similar analogies and explanations that illustrate this seemingly paradoxical fact. However, as we know, an analogy is not proof. To substantiate the fact of the safety of small doses with the obvious danger of large doses and with the obvious primary damaging effect of nuclear radiation, no analogies and reasoning are required, but experimental or observational data. And it is on such data that the author relies in this book.

Radio-phobia arose after the Second World War. The sight of the devastated Japanese cities of Hiroshima and Nagasaki as a result of the nuclear bombing aroused fear in the world of the colossal destructive power of atomic energy. This fear was automatically transferred to the product of the implementation of atomic energy—to radiation. However, in fact, the role of radiation in the death of people both at the time of the explosions and for a long time after them turned out to be insignificant, much weaker than is often written about. This statement will be substantiated in more detail in Chap. 7. Apparently, the main event that led to the spread of the fear of radiation, radio-phobia around the globe was the episode with the Japanese tuna Fukuryu-Maru, which fell under radioactive fallout after the thermonuclear explosion "Bravo" on Bikini Atoll on March 1, 1954. The veil of secrecy collapsed; the whole world learned about the dangers posed precisely by radiation and was frightened.

Accidents at nuclear installations served as another breeding ground for radio-phobia. There were quite a few minor accidents, but their consequences were minimal. The strongest fuel for radio-phobia was the result of accidents that can safely be called disasters, first at the weapons-grade plutonium production complex in Windscale, UK in 1957, then at the Three Mile Island nuclear power plants in the USA in 1979, at Chernobyl in the former USSR in 1986 and in Fukushima, Japan in 2011.

So, the danger of thermonuclear conflicts and catastrophes at nuclear facilities forms the basis of the negative background that feeds radio-phobia.

With all the further content of the book, the author will try to show that radio-phobia is indeed an unjustified fear. Nevertheless, I want to make a paradoxical assumption here. There may be a fear of ionizing radiation, although it is not justified, but it previously played some positive role.

During the Cold War, when there was a very significant danger of a thermonuclear conflict and subsequent extensive contamination of the globe with radioactive substances, radio-phobia of the population could be a deterrent. It is difficult to say to what extent radio-phobic sentiments influenced the decisions of the leaders of the opposing countries, but perhaps they somehow influenced, and perhaps these sentiments extended to themselves and their families. They are people too. Anyway, despite the fundamental ideological differences, the leaders of the USSR and the USA managed to move away, or rather crawl away, from the edge of the abyss.

During humankind's acquaintance with radiation, the danger of the military use of atomic weapons arose, disappeared, and again matured. There may continue to be periods of weakening and growth of tension in relations between world powers, but it is important that nuclear weapons, figuratively speaking, hang on the wall, and there is always a danger that in the next act of the world play this gun hanging over the world will fire and this act may be the last for human civilization. So, it would seem that there is something to be afraid of.

In addition to military applications, possible accidents at nuclear installations also pose a danger. And even if Japan, a technologically highly developed country, failed to foresee measures that now seem quite obvious, turned out to be helpless in the face of the challenge of the elements, then it would seem, what can we say about other, less advanced countries.

The cautious attitude of people to any sources of radiation was associated, in particular, with the expectation of possible nuclear terrorism. Any action by the authorities had to take into account the danger of panic.

Therefore, the question arises whether it is proper, when such dangers exist, to call for an exit from the stage of pathological radio-phobia. Is it ethical in principle to start the fight against radio-phobia?

There is another reason to doubt the ethics of this struggle. Many thousands of people who took part in the liquidation of the consequences of the nuclear disasters in Chernobyl and Fukushima, evacuated from their homes, sick, suffering, and losing their loved ones, people who believe that they performed a feat and received significant doses of radiation, real or imaginary, categorically disagree with scientific assessments, are offended and outraged when they talk about the safety or even usefulness of radiation. We are witnessing a profound difference between the real facts and the ideas of the affected people and public opinion about the real role of radiation in people's lives.

The population's fears, especially of the liquidators and evacuees, are understandable. Indeed, everyone knows that large doses are dangerous; this circumstance is not in doubt. Affected people are usually incredulous, but perhaps they can believe that small doses are safe. But the vast majority of the population does not know where the border between dangerous and safe doses is, how clear it is, and how to determine it. These questions are discussed in this book.

But already here, it is useful to note that the greatest harm to the victims of the accidents in Chernobyl and Fukushima was brought not by the radiation itself, but by the psychological aspects of the accident and the post-accident situation, a significant change in living conditions. Forced evacuation, restrictions in the usual activities, conflicting information about the possible consequences of the accident, and a radical change in the way of life of these people led to psychological discomfort and significantly affected their health, regardless of the effect of radiation. The atmosphere of secrecy, silence, and outright deceit had an extremely bad effect on the mood of the people.

After reviewing the secret materials of the meetings of the Politburo of the Central Committee of the CPSU, the highest authority in the USSR, the well-known Ukrainian politician and journalist Alla Yaroshinskaya, characterizes her attitude to the events in Chernobyl, or rather, to the actions of the authorities with the following words: "The main lethal isotope that flew out of the Chernobyl reactor was not cesium-137, but deception-86."

So, is it ethical to raise the issue of combating radio-phobia? Understanding humankind's need for horror stories, is it worth it, it would seem from noble motives, to deprive readers of one of the phobias? Isn't it as shameful as depriving a child of his favorite toy?

The answer seems pretty clear to me.

First, there are enough nightmares without radio-phobia. "Nuclear winter," "Ozone hole," "Global warming," "Reversal of the Earth's poles," the regularly expected "Doomsday," pandemics, epidemics, Ebola, bird flu, and many other things. The closest example is the coronavirus.

But most importantly, radio-phobia is very expensive for humanity.

After Chernobyl, up to 200,000 pregnant women in Europe had an abortion, fearing the occurrence of congenital deformities in future children. Measurements carried out in many countries over the past years have shown that the additional dose due to the Chernobyl fallout of radioactive substances turned out to be extremely insignificant, it could not affect the health of the fetus. But hundreds of thousands of desired children were not born due to radio-phobia.

It is known that tens of thousands of women refuse regular mammography, fearing these studies cause breast cancer. Note that the fear of radiation is stronger than the fear of missing out on the early stages of cancer when a cure is likely.

Well, radio-phobia also leads to a restriction and sometimes to a complete cessation of the use of nuclear energy. Some countries of Western Europe, such as Sweden, Germany, Spain, Belgium, and Holland, under pressure from a frightened population, legally abandoned their plans. Following the

Fukushima accident due to the Greens' anti-nuclear activity on May 30, 2011, Germany formally announced its plans to phase out nuclear power over the next 11 years completely. Eight nuclear power plants were shut down immediately, and it was promised that the remaining ones would be turned off in the near future. On December 31, 2021, Berlin closed three of the six remaining nuclear power plants in the country. The remaining three are scheduled to close by the end of the next year. Before the Fukushima accident, Germany produced about a quarter of its electricity from nuclear fuel. According to political scientists, a sharp rejection of nuclear energy could play a fatal role in the German economy. It is unlikely that the so-called renewable sources can compensate for such a sharp loss of generating capacity.

In October 2022, the Chancellor decided that Germany's three remaining nuclear power reactors would keep operating until mid-April 2023 to offset the reduced gas supply from Russia. In mid-April, they really were stopped.

Adopted on the wave of radio-phobia, excessively strict radiation safety standards significantly complicate the use of radiation technologies and reduce their economic efficiency.

Radio-phobia is harmful to health. Like many other phobias, radio-phobia is a pathological fear with an inadequate response. It is also called obsessive fear. Experts point out that phobias can provoke little pleasant symptoms: heart palpitations, increased sweating, weakness, fainting, nausea, and even a feeling of suffocation. Radio-phobia certainly complicates life, especially for people with high emotional sensitivity. Any phobia is stress, upset nerves, a bad mood, and radio-phobia is no exception.

And finally, the validity of the fight against radio-phobia is confirmed by the fact that the safety of small doses of radiation corresponds to objective reality. The possibility of influencing the mood of the population on the decisions of the authorities is doubtful, I don't see any other benefit from radio-phobia, and the damage caused by radio-phobia is absolutely real and, as we have seen, very significant.

That is why the author believes it would be good for readers to understand the real situation with nuclear radiation on planet Earth, and it is better to do without radio-phobia.

The safety of low doses of radiation is an objective reality. Therefore, there is no need to be afraid of what you cannot be afraid of, but what you really need to be afraid of is fear itself.

Contents

1

The World in the Era of Great Discoveries: X-rays and Radioactivity

There is no need to prove that modern science is of undoubted interest to society. Messages even about minor events in the world of science are constantly published. On television, there are not only special programs but also entire scientific channels that transmit information about scientific achievements around the clock.

However, this was not always the case. At the end of the XIX century, there was no radio, no television, and even less the Internet; the population received the main information about events around them from newspapers. However, most of the population of many countries of the world was illiterate. Therefore, newspaper reports were available to a narrow circle of educated people. In those days, the general public fed mainly on rumors and, as a rule, knew nothing about the work of scientists, engineers, and inventors until their work gave some result that directly affected people's lives: a steam engine, a locomotive, a telephone, an electric light bulb.

Though, several discoveries in the history of science were made at the very end of the XIX century and immediately or rather quickly aroused unprecedented public interest. This refers to the discovery of previously unknown rays. At the end of 1895, the German scientist W.C. Röntgen (Fig. 1.1a) discovered radiation that penetrates well through opaque barriers, which in Germany and Russia began to be called Röntgen rays, and in the rest of the world, as Röntgen himself called it, X-rays. A few months later, the French scientist A.H. Becquerel (Fig. 1.1b) discovered the radiation of uranium. For some time after its discovery, this radiation was called Becquerel rays or uranium rays. Even before the end of the century, the Curies discovered that in addition to uranium, thorium also has the same property, which they called

I. Obodovskiy, *From Radio-phobia to Radio-euphoria*, Springer Praxis Books,
https://doi.org/10.1007/978-3-031-42645-2_1

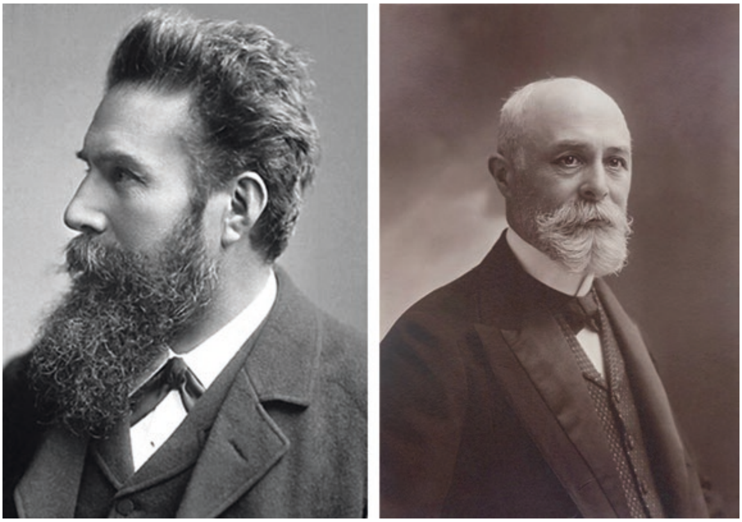

Fig. 1.1 Wilhelm Conrad Röntgen 1900—left, and Antoine *Henri Becquerel, 1905*—right. (**a**) Röntgen. Figure from X-ray, Wikipedia—https://en.wikipedia.org/wiki/X-ray. Public domain. (**b**) Becquerel. Figure from *Henri Becquerel,* Wikipedia—https://en.wikipedia.org/wiki/Henri_Becquerel. Public domain

radioactivity, and when a new radioactive element, radium, was discovered, a million times more active than uranium, the surge of interest in this discovery was reminiscent of the same violent reaction that accompanied the discovery of Röntgen.

In addition to the works of Röntgen, which instantly caused a stir, the invention of the radio must also be mentioned, which also immediately aroused great interest. The announcement of the possibility of telegraphing without wires appeared only a year after the amazing news about X-rays, and it was radiation again, this time "electric beams."

The discoveries of new radiations have stunned the world. The reaction to Röntgen's discovery was instantaneous; it gave rise to a state of society that can be called X-ray mania. The manifestations of X-ray mania are described in Chap. 2. The amazing properties of the radioactive emissions of uranium and, mainly, radium became known to society with some delay. Still, they made an equally strong impression and gave rise to a state that can be called radio-euphoria. How this condition arose and manifested itself is described in detail in Chap. 3.

Both discoveries were made by accident, but the logic of the development of science, the state of the industry, and society shows that if Röntgen and Becquerel had not stumbled upon these radiations, then the discoveries would still have taken place a little later, by themselves or by other scientists, but soon enough. It is known that the famous scientists William Crookes, Nikola Tesla, Philip Lenard, and, less known the Ukrainian Ivan Pulyui, who worked in Vienna, and even Heinrich Hertz himself, observed X-rays before Röntgen. Still, it did not occur to them that they were dealing with a new phenomenon, and the same thing happened with many other discoveries and inventions. There were a lot of scientists and inventors who aimed at the new. Various sources give different names of the inventors of the telegraph, telephone, light bulb, radio, airplane, and many other significant achievements of the human mind. By this time, the pressure of religious dogmas had been overcome. The researchers acknowledged that humanity still does not know much. Human curiosity and the needs of society have contributed to the development of science and technology.

What was this special state of society that gave rise to these great discoveries?

Historians of science are trying to explain why after the fires of the Inquisition, after the plague that devastated Europe, after centuries of religious wars in Europe religious dope was thrown off very quickly in a historical perspective, and great science and advanced technologies arose. Why was such a breakthrough in economic success made in an extremely short time? At the same time, historians are trying to understand why the previously prosperous Chinese, Indian, and Arab civilizations did not make such a breakthrough, why the perfected and aesthetically impeccable ways of expression ceased to satisfy poets, artists, and composers. Different answers to these questions can be found in the book of the historian Yuval Noah Harari "Sapiens. A Brief History of Humankind," in the book of science journalist Nicholas Wade "Inconvenient Legacy," in the book of sociologist and political scientist Jack Goldstone "Why Europe? The Rise of the West in world history. 1500-1850." Well-known American author Jared Diamond in the book "Guns, Germs, and Steel: The Fates of Human Society" tried to find an answer, and so on. Inquisitive readers will find answers to some of their questions in these books. Here I present only a brief picture of the world at the turn of the century.

The end of the XIX and the beginning of the XX centuries were relatively favorable for humankind. The great wars of the XIX century have died down, and people have not yet guessed about the world wars of the XX century. True, there have apparently never been entirely peaceful years on Earth, and now, the Anglo-Boer War was going on in South Africa (1899–1902), and in the Far East, shots were fired in the American-Philippine war (1899–1902), but all this happened on the periphery of the civilized world, and in Europe and the United States, it was relatively calm.

Western civilization, after the gloomy millennium of the Middle Ages, having gone through the periods of the Renaissance and Enlightenment, has created a very attractive world. The scientific and technical achievements of European civilization and its incarnation in North America determined the further development of all mankind for many decades.

The time of the late XIX—early XX centuries in Europe was deservedly called "Belle Époque." In the United States, after the Civil War, a period of rapid economic and population growth began, called the "Gilded Age" (1876–1914), and in the art of Russia, the period at the turn of the century was called the "silver age," it would, of course, also be called the golden age, but the definition of "golden age" was already taken by the Pushkin period. Stefan Zweig in the book "Yesterday's World. Memoirs of a European" calls the era before the First World War (before 1914) "the golden age of reliability."

Europe slowly overcame the consequences of the Middle Ages, until suddenly, in the XVIII century, an explosive industrial development began, called the Industrial Revolution. Historians divide this revolution into two stages: the first industrial revolution, characterized mainly by the appearance of steam engines (James Watt, first patent 1775). This led to a massive transition from manual to machine labor, from manufactory to factory.

The second stage is called the technological revolution, it covers the second half of the XIX—early XX centuries. The industry introduced new conveyor production, electricity played an increasingly important role, and the production of steel and various chemicals was mastered. Most of these technical advances have been based primarily on scientific research and discoveries.

At the end of the XIX and the beginning of the XX century, revolutionary changes took place in transportation methods. For thousands of years, people overcame any distance on land, either on foot or on horses, bulls, elephants, and camels. More recently, in 1812, the French army crossed Europe, reached Moscow, and then back mostly on foot. The cavalry, including the baggage trains, comprised almost a fifth of Napoleon's army.

The beginning of the technological revolution is attributed to the opening in 1869 of a transcontinental railroad that linked the Atlantic and Pacific coasts of the United States. A little later, the Trans-Siberian Railway was completed in Russia, which made it possible to close the connection between the same oceans, but through the Eurasian continent.

In 1885, the first car with a four-stroke gasoline engine, built by the German inventor Karl Benz, drove through the streets of Mannheim, Germany (Fig. 1.2a).

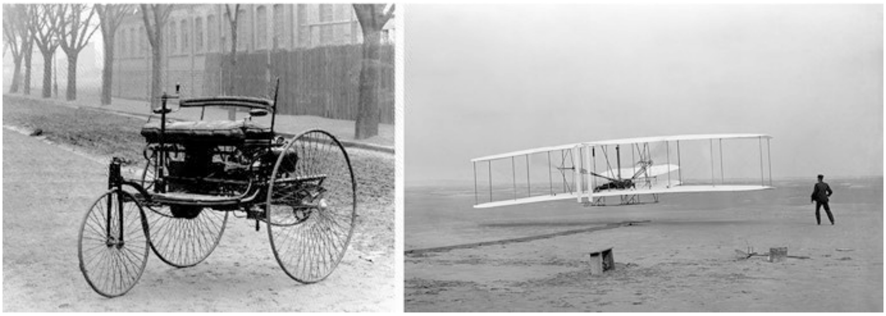

Fig. 1.2 The first car of Karl Benz, 1885 (left). The first flight of the Wright Flyer, December 17, 1903, Orville piloting, Wilbur running at wingtip (right). (**a**) The first car. Figure from Carl Benz, Wikipedia—https://en.wikipedia.org/wiki/Carl_Benz. Public domain. (**b**) The first airplane. Figure from Wright brothers, Wikipedia—https://en.wikipedia.org/wiki/Wright_brothers. Public domain

It took quite a bit of time, and in 1903 a stable, controlled horizontal flight in Kitty Hook Valley, North Carolina, USA, was made. It was the first flight of the "Flyer-1" aircraft, built by the brothers Orville and Wilbur Wright (Fig. 1.2b).

Revolutions in industry, transport, and science and a radical change in socio-economic conditions were accompanied by a revolution in art. Having supplanted the classics in the last decade of the XIX—early XX centuries, a new artistic direction spread throughout the world, capturing all types of art, music, literature, architecture, decorative and applied and fine arts. The general name of the new direction is "modern." In different countries, in relation to different types of art, the names differed, the most famous is "Art nouveau" or "Fin de siècle" in France and "Jugendstil" in Germany.

During the time that a modern observer can capture, say, from the time of Ancient Greece, many artistic trends have changed in art. Art critics call Romanesque and Gothic styles Baroque, Classicism, Sentimentalism, Romanticism, Realism, Symbolism, etc, but in all styles in literature, the word was a word that carried a specific meaning, in music, there was harmony, and in painting and sculpture, the house was a house, a tree was a tree, and a person was a person. And suddenly, in the XIX century, the old forms ceased to satisfy artists, and a large number of new artistic trends appeared: impressionism, and then post-impressionism, surrealism, symbolism, acmeism, futurism, cubism, suprematism, abstractionism, and others. Artists and poets, in their manifestos, explained in detail why they considered it necessary to move further and further away from traditional realism and why new forms of expression were needed.

The result of the revolution in painting is visible in Fig. 1.3. On the left is a reproduction of the famous painting of the Russian artist Ilya Repin "Reply of the Zaporozhian Cossacks," and on the right is an abstract composition by Wassily Kandinsky, created already in the XX century, in 1910, but clearly showing the direction of the revolution in painting.

At the turn of the century in the musical capital of the world, in Vienna, the era of the waltz king Johann Strauss ended, and the era of the operetta king Imre Kalman began. Strauss waltzes still continued to circle Europe, and the Argentine tango was already seeping from the streets and taverns of Buenos Aires into restaurants and dance halls in Europe and the USA.

In the United States, at the end of the XIX century, new musical styles appeared due to the fusion of African rhythms and European harmony—blues, ragtime, and, finally, jazz.

On December 28, 1895, a historical event influenced the cultural life of all subsequent times. On this day in Paris, on the Boulevard des Capucines, the first film screening was held in one of the halls of the Grand Cafe. Cinema has begun its triumphal march across the planet.

Only enthusiasts were engaged in science in the XIX century. At that time, scientific activity was not the main source of material support for most scientists. As a rule, scientific research was carried out at universities, and scientists earned their living by teaching, and the main characters of our subsequent narrative were engaged in research in the interval between lectures, laboratory, and seminar classes. Specialized scientific institutes have just begun to appear.

Beginning in the middle of the XVIII century, a few scientific enthusiasts studied electricity, but the general public knew nothing about the laws of C.-A. Coulomb or A.-M. Ampère nor about the work of A. Volta or

Fig. 1.3 Classical painting (Ilya Repin, Reply of the Zaporozhian Cossacks) and the first abstract watercolor (W. Kandinsky, 1910). (**a**) Ilja Repin. Figure from Ilya Repin—https://en.wikipedia.org/wiki/Ilya_Repin. Public domain. (**b**) Kandinsky. Figure from Wassily Kandinsky—https://en.wikipedia.org/wiki/Wassily_Kandinsky. Public domain