Why are X-rays so Significant in Today's World?

Radioactivity Revealed
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Intermediate



Figure 1. Grid of human anatomy medical X-rays (Centers for Disease Control and Prevention, 2024)

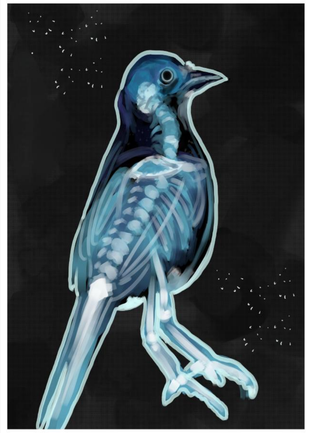


Figure 2. X-ray Drawing of Bird (Pinterest, 2026)

Introduction

X-rays are high-energy, ionizing electromagnetic radiation with extremely short wavelengths (0.03 and 3 nanometers). They are generated when rapidly moving electrons abruptly decelerate, releasing kinetic energy in the form of photons, and because of their high energy, X-rays can penetrate solid matter, creating images that are visible to us based on tissue density.

History

X-rays: accidentally discovered back in 1895, by Wilhelm Conrad Roentgen, a German scientist. At the time, he was testing whether cathode rays could pass through glass, but to his surprise, there was an incandescent green light that managed to escape and projected onto a nearby fluorescent screen, despite his tube being covered in heavy black paper. After a few more experiments, he discovered that this mysterious light was able to pass through most substances but would leave shadows of solid objects. Not knowing what these rays were, he called them 'X', meaning 'unknown,' rays (Columbia University Department of Surgery, 2015).

Not long after, he discovered that X-rays could pass through human tissue, rendering the bones, tissue beneath visible (early x-ray machine shown in figure 4). Within a year, his discovery spread worldwide; doctors in Europe, United States were all using X-rays to locate gun shots, bone fractures, kidney stones, as well as swallowed objects.

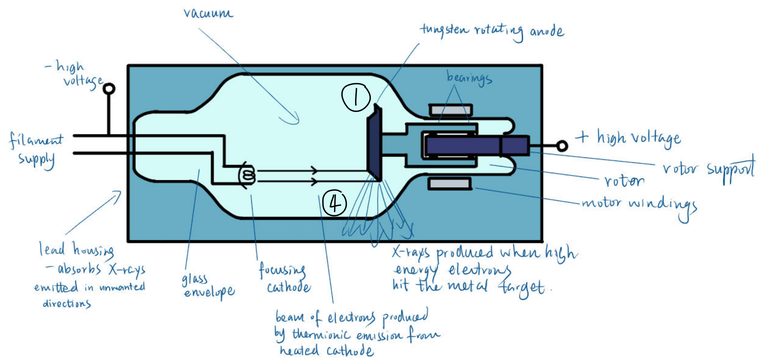
In 1901, Wilhelm Conrad Roentgen soon received the first Nobel Prize in physics.



Explanation of Scientific and Technical Principles

How X-rays Work

Figure 3. Schematic diagram of a rotating anode X-ray tube (drawing) (Micro.org.au, 2020).



Generation: A tungsten cathode filament is heated, causing thermionic emission. A high voltage (kVp) accelerates these electrons into a tungsten anode. <1% of the energy becomes X-rays; the rest: heat.

Emission: Bremsstrahlung ("braking radiation") happens when electrons slow down and deflect around atomic nuclei, producing a continuous range of X-ray energies. Characteristic radiation then occurs when incoming electron knocks out inner-shell electron, an outer electron fills the gap, releasing a photon with fixed energy.

Differential Attenuation: Different materials absorb/scatter X-rays differently. The photoelectric effect (dependent on atomic number) absorbs high-Z materials like bone, making them appear white. Compton scattering (independent of Z) deflects photons, contributing to image noise, allowing low-Z tissues like muscle to appear darker in the scan.

Image Capture: Transmitted photons hit a flat-panel digital detector. Indirect conversion uses a scintillator to turn X-rays into light, then photodiode turns light into charge. Direct conversion uses selenium to turn X-rays directly into charge. The signal is digitised, software assigns white to dense structures, black to air/tissue.

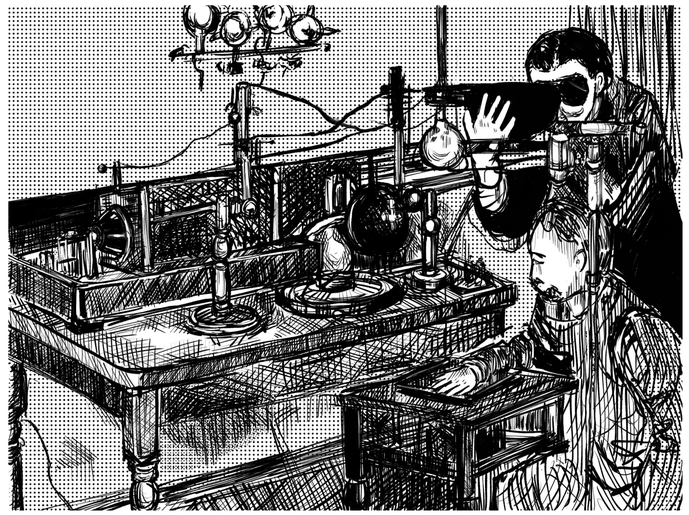


Figure 4. Historical photograph (drawing) demonstrating an early method of testing X-ray output using a fluoroscope (Microscopy Australia, 2020)

Significance and Impact



1. A Revolution in Medicine
X-rays fundamentally changed medical practice by making the invisible visible. Before, doctors could only diagnose many conditions by physical examination or surgery. The X-ray was the first non-invasive way to see inside the living human body, quickly proving essential for:

Diagnosing Bone Fractures and Injuries: First and most impactful uses, as fractures were easily identifiable. The X-ray was less painful than manual manipulation.

Locating Foreign Objects: Finding swallowed items like coins or bullet, became far easier.

Detecting Disease: X-rays are crucial for identifying conditions like pneumonia, lung cancer, and bone tumours.
A special type of X-ray, mammography, is used for breast cancer screening.

Guiding Treatment: From planning surgery to monitoring the effectiveness of treatment, X-rays are an indispensable tool.

2. A Broad Scientific and Cultural Impact
The impact of X-rays was not limited to hospitals.

Scientific Advancement: X-rays became a powerful tool for science, particularly in crystallography. By analysing how X-rays diffract through crystals, scientists were able to reveal the atomic, molecular structure of materials, including complex biological molecules.

Cultural Phenomenon: X-rays captivated the public imagination (figure1,4). People were paying to see the bones of their own hands, a spectacle that was wondrous and unsettling. The idea of seeing through solid matter influenced art, literature, and even spiritualism.

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