8 ATOMIC PHYSICS IN MEDICAL APPLICATIONS

8.1 ELECTRON MICROSCOPE

In **light microscopes**, this limits the **resolution** to about 200 nm. Because of the wave properties of electrons, it is possible to construct **electron microscopes** with a resolution nearly 1–0.5 nm. It is relatively easy to accelerate electrons in an evacuated chamber to high velocities so that their wavelength is less than 10^{-10} m (1 Å). The direction of motion of the electrons can be altered by electric and magnetic fields. Thus, suitably shaped fields can act as **lenses** for the electrons.

Because electrons are scattered by air, the microscope must be contained in an **evacuated chamber**. The samples under examination must be **dry and thin**. **These conditions, present some limitations in the study of biological materials.**

Therefore, the **biological samples** must be specially prepared for electron microscopic examination.

- **Hard, dry materials** such as bone, wood, dried Insects, seeds or teeth can be examined with little further treatment or directly.
- **Living cells and tissues, soft-bodied organisms** usually require fixation to preserve and stabilize their structure.

Fixation of biological samples is usually performed by incubation in a solution of a buffered chemical fixative or by cryo-fixation. The fixed cell or tissue is then dehydrated or cryo-substituted. The dry specimen is usually mounted on a specimen stub using colloidal silver and sputter coated with gold, carbon or gold/palladium alloy before examination in the microscope.

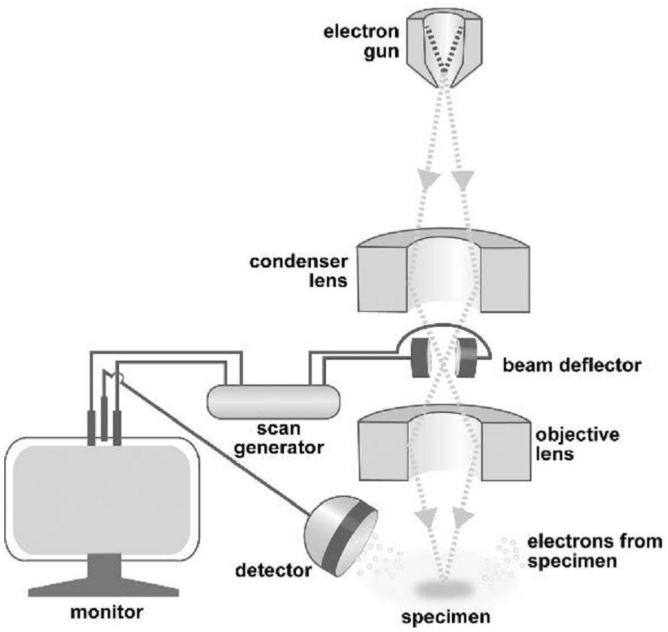

Figure 20: The basic components of a conventional scanning electron microscope.

8.2 RADIOGRAPHY (PLAIN X-RAYS)

Plain film X-rays remain an important tool for the diagnosis of many disorders. In radiography, a beam of X-rays, produced by an X-ray generator, is transmitted through an object, e.g. the part of the body to be scanned. The X-rays are absorbed by the material they **pass through** in differing amounts depending on the density and composition of the material. X-rays that are not absorbed pass through the object and are recorded on X-ray sensitive film (see Figure 20).

While bone **absorbs** X-rays, soft tissue such as muscle fibre **absorbs fewer.** This is because bones have **higher density** than tissues. This results in the familiar **contrast seen in X-ray images**, with bones shown as clearly defined **white areas** and **darker areas of tissue** (see Figure 22). This makes conventional X-rays very suitable for scans of bones and tissue dense in calcium such as in dental images and detection of bone fractures.

X-ray imaging provides fast, high-resolution images and is relatively inexpensive. The average examination for most plain film examinations takes no more than 10–15 minutes and requires no special preparation of the patient. Because movement, e.g. of the lungs and diaphragm, blurs the image, patients are usually asked to hold their breath during the exposure. The X-ray picture is stored on a piece of film called a radiograph. These are interpreted by a physician specially trained to interpret them, known as a **radiologist**.

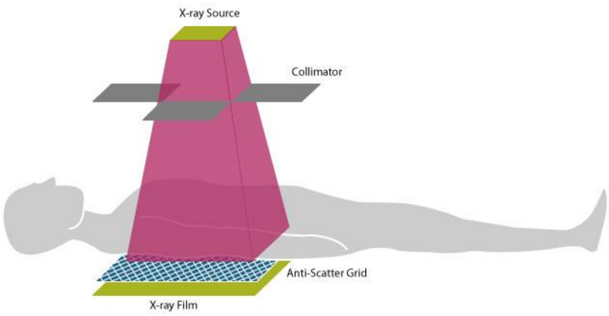

Figure 21: The basic setup for X-ray imaging.

Figure 22: A typical X-ray radiograph of the chest, in which the regions of bone appear white.

8.3 COMPUTED TOMOGRAPHY (CT SCAN)

Computed tomography (CT) scanners have revolutionized medical imaging. These scans are used for different clinical questions in a variety of clinical fields. **In emergencies,** for example, CT is widely used as it delivers detailed information fast, which is essential for **appropriate treatment decisions**. The CT X-ray picture does provide **depth information**.

The most prominent part of a CT scanner is the gantry–a circular, rotating frame with an X-ray tube mounted on one side and a detector on the opposite side. A fan-shaped beam of X-rays is created as the rotating frame spins the X-ray tube and detector around the patient. As the scanner rotates, several thousand sectional views of the patient's body are generated in one rotation, which result in re-constructed cross-sectional images of the body (Figure 23). Using on these data, it is possible to create a **3D visualization and views from different angles**.

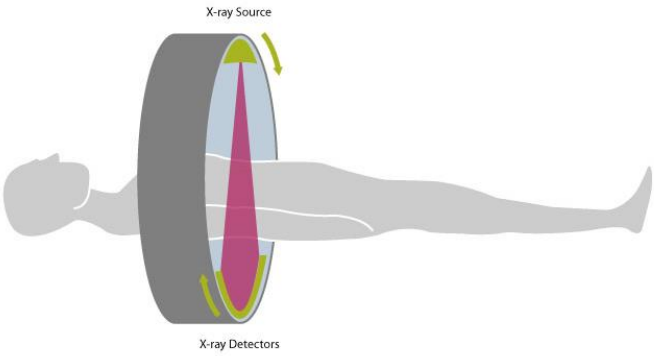

Figure 23: The principle of computed tomography.

8.4 LASERS SURGERY

The technology had to be developed for precise control of **light intensity** and **duration** and for **accurate positioning** of the focal point. Therefore, intense laser light focused onto a small area could burn off and vaporize selected tissue **without** damage to neighbouring areas. Bleeding and pain during such a procedure would be **minimized** because blood vessels are cauterized and nerve endings are sealed. Infections would be **reduced** because the cutting tool is not in physical contact with the tissue.

The positional accuracy of laser tissue-removal is particularly important in neurosurgery and eye surgery. For example, the use of lasers in **the ophthalmological applications** is for:

- **Repair of retinal detachments and retinal tears:** Laser light is focused through the iris onto the boundary of the detached or torn region of the retina. The tissue is burnt and the subsequent scarring "welds" the retina to the underlying tissue.
- **Diabetic retinopathy**: Diabetes often causes **disorders** in blood circulation, including leaks in the retinal blood vessels. Such a condition can cause serious damage to the retina and the optic nerve. Laser light focused on the damaged blood vessel seals the leak and halts further retinal deterioration.

Figure 24: Physician performing laser eye surgery.

8.5 Lasers in Medical Diagnostics

A laser-based **non-invasive diagnostic instrument** is a recently developed optical scanning device designed to detect intracranial bleeding often caused by concussion or hemorrhagic stroke. Failure to detect such bleeding promptly, within an hour or so, can cause irreversible brain damage or death.

A CAT scan is the usual method of diagnosing brain bleeding (hematoma). However, CAT scan instrumentation is **expensive** and is found only at **major medical facilities**. The newly developed device **costs about 1% of a CT** scanner, it is **portable**, about the size of a book, and can perform the diagnosis **in just 2 minutes**. Further, the patient is **not exposed to the high doses of radiation** required to produce a CT image.

The operation of the instrument is based on the difference in the optical properties of blood and brain tissue. Absorption by blood of light in the near infrared region of the spectrum is much greater than absorption of the light by brain tissue. **A comparison of measured light intensities** from different regions of the cranium identifies the presence and location of the hematoma.