Mineralogy is the study of chemistry, crystal structure, and physical and optical properties of minerals. Specific studies within mineralogy include the processes of mineral origin and formation, classification of minerals, their geographical distribution, as well as their utilization.
History of mineralogy

1. Europe and the Middle East

**Pliny the Elder**
Pliny (77 AD) describes and discusses mineral’s applications and properties. He laid the basis of **crystallography** by discussing **crystal habit**.

**Georgius Agricola, 'Father of Mineralogy'**
In the early 16th century AD, the writings of the **German** scientist **Georgius Agricola** in 1530 is considered to be the official establishment of mineralogy in the modern sense of its study. For his works, **Agricola is posthumously known as the "Father of Mineralogy"**.
2. China and the Far East

In ancient China, the oldest literary listing of minerals dates back to at least the 4th century BC

3. America

The most influential mineralogy text in the 19th and 20th centuries was the *Manual of Mineralogy* by James Dwight Dana, first published in 1848.

Early writing on mineralogy, especially on gemstones, comes from ancient Babylon, ancient and medieval China, and Sanskrit texts from ancient India and the ancient Islamic World. Systematic scientific studies of minerals and rocks developed in Europe.

The modern study of mineralogy was founded on the principles of crystallography and to the microscopic study of rock sections with the invention of the microscope in the 17th century.
Modern mineralogy

Historically, mineralogy was heavily concerned with taxonomy of the rock-forming minerals; to this end, the International Mineralogical Association is an organization whose members represent mineralogists in individual countries. Its activities include managing the naming of minerals (via the Commission of New Minerals and Mineral Names), location of known minerals, etc. There are over 4,000 species of mineral recognized by the IMA. Of these, perhaps 150 can be called "common," another 50 are "occasional," and the rest are "rare" to "extremely rare."
Physical mineralogy

Physical mineralogy is the specific focus on physical attributes of minerals. Description of physical attributes is the simplest way to identify, classify, and categorize minerals, and they include:

1. crystal structure
2. crystal habit
3. twinning
4. cleavage
5. luster
6. diaphaneity
7. color
8. Streak
9. hardness
10. specific gravity
Chemical mineralogy

Chemical mineralogy focuses on the chemical composition of minerals in order to identify, classify, and categorize them, as well as a means to find beneficial uses from them. There are a few minerals which are classified as whole elements, including sulfur, copper, silver, and gold, yet the vast majority of minerals are chemical compounds.

Biomineralogy

Biomineralogy is a cross-over field between mineralogy, paleontology and biology. It is the study of how plants and animals stabilize minerals under biological control, and the sequencing of mineral replacement of those minerals after deposition. It uses techniques from chemical mineralogy, especially isotopic studies, to determine such things as growth forms in living plants and animals as well as things like the original mineral content of fossils.
Optical mineralogy

Optical mineralogy is a specific focus of mineralogy that applies sources of light as a means to identify and classify minerals. All minerals which are not part of the cubic system are double refracting, where ordinary light passing through them is broken up into two plane polarized rays that travel at different velocities and refracted at different angles. Mineral substances belonging to the cubic system contain only one index of refraction. Hexagonal and tetragonal mineral substances have two indices, while orthorhombic, monoclinic, and triclinic substances have three indices of refraction.

Crystal structure

X-rays are used to determine the atomic arrangements of minerals and to identify and classify them. Some very fine-grained minerals, such as clays, commonly can be identified most readily by their crystal structures. With knowledge of atomic arrangements and compositions, one may deduce why minerals have specific physical properties.
Descriptive mineralogy
Descriptive mineralogy summarizes results of studies performed on mineral substances. It is the scholarly and scientific method of recording the identification, classification, and categorization of minerals, their properties, and their uses. Classifications for descriptive mineralology includes:

1. native elements
2. sulfides
3. oxides and hydroxides
4. halides
5. carbonates, nitrates and borates
6. sulfates, chromates, molybdates and tungstates
7. phosphates, arsenates and vanadates
8. silicates
9. organic minerals
Minerals

Minerals are the building blocks of rocks. A mineral may be defined as any naturally occurring inorganic solid that has a definite chemical composition (that can vary only within specified limits) and possesses a crystalline structure. The study of minerals is known as mineralogy.

Minerals may be characterized by the fundamental patterns of their crystal structures. A crystal structure is commonly identified by its fundamental repeating unit. Crystal structures can be divided into crystal systems, which can be further subdivided into crystal classes—a total of thirty-two crystal classes, which are sometimes referred to as point classes.
1) Definition of Crystal - Classification of crystals into Crystal systems

1.2. Definition of a Mineral

A mineral is a naturally-occurring, homogeneous solid with a chemical composition which is fixed or which varies only within well-defined limits, and an ordered atomic arrangement. It is usually formed by inorganic processes.
Let's look at the five parts of this definition:

1.) "Naturally occurring" "nonsynthetic" means that synthetic compounds not known to occur in nature cannot have a mineral name. This eliminates all unnatural man-made substances like plastic and synthetic compounds.

2.) "Homogeneous solid" (Solid - This eliminates gases and liquids) means that it must be chemically and physically homogeneous down to the basic repeat unit of the atoms. It will then have absolutely predictable physical properties (density, index of refraction, etc.). This means that rocks such as granite or basalt are not minerals because they contain more than one compound.
3.) "Definite, but generally not fixed, composition" means that atoms, or groups of atoms must occur in specific ratios. For ionic crystals (i.e. most minerals) ratios of cations to anions will be constrained by charge balance, however, atoms of similar charge and ionic radius may substitute freely for one another; hence definite, but not fixed. Chemical composition which is fixed or which varies within well-defined limits - "all minerals are characterized by a chemical formula" - Some minerals have chemical substitutions in which ions of similar size and charge freely substitute for each other (such as the plagioclase series).
4.) "Ordered atomic arrangement" means crystalline. Crystalline materials are three-dimensional periodic arrays of precise geometric arrangement of atoms. Glasses such as obsidian, which are disordered solids, liquids (e.g., water, mercury), and gases (e.g., air) are not minerals. The ordered atomic arrangement is reflected in the crystal form and cleavage of the mineral (example - the rhombs of calcite).

5.) "Inorganic processes" means that crystalline organic compounds formed by organisms are generally not considered minerals. However, carbonate shells are minerals because they are identical to compounds formed by purely inorganic processes.

An abbreviated definition of a mineral would be "a natural, crystalline phase".
More commonly, minerals are described or classified on the basis of their chemical composition. Although some minerals, such as graphite or diamond, consist primarily of a single element (in this instance, carbon), most minerals occur as ionic compounds that consist of orderly arrangements of cations and anions and have a specific crystalline structure determined by the sizes and charges of the individual ions.
It has been noted that the chemical composition of minerals could vary within specified limits. This phenomenon is known as **solid solution**. When minerals form, ions of similar size and charge, such as calcium and magnesium ions, can substitute for each other and will be found in the mineral in amounts that depend on the proportions that were present in solution, or in the melt (liquid magma) from which the mineral formed. Thus, many minerals can exist in solid solution.
Because minerals are naturally occurring substances, abundance of minerals tends to reflect abundance of elements as they are found in Earth's crust. Although about 4,000 minerals have been named, there are 40 minerals that are commonly found and these are referred to as the rock-forming minerals.
The most abundant element in Earth's crust is oxygen, which makes up about 45 percent of the crust by mass. The second most abundant element is silicon, which accounts for another 27 percent by mass. The next six most abundant elements, in order of abundance, are aluminum, iron, calcium, magnesium, sodium, and potassium, which collectively comprise about 26 percent, leaving only about 2 percent for all other elements. If one classifies minerals according to the commonly accepted system that is based on their anions, it is not surprising that silicates (having anions that are polyatomic combinations of oxygen and silicon) are the most common mineral group.
1.1. The Science of Mineralogy
The science of mineralogy is the study of the physics and chemistry of natural, solid, crystalline materials.

Unlike fluids, minerals preserve the records of Earth's history. Further minerals contain the wealth of natural resources of the planet. Therefore understanding the physics and chemistry of the solid materials of the planet (mineralogy) is central to much of the Earth Sciences.

Minerals are a critical part of our everyday life. They are used in the construction of our buildings, homes, roads, and machines. They are used to fertilize our crops, produce energy for our homes, add flavor to our foods, and even make many of our medicines. Rocks are aggregates of one or more minerals. Therefore, mineral identification is also a crucial part of rock classification.
III. Physical Properties
A. **Crystal Form** is the shape of a mineral when bounded by smooth, planar surfaces which form regular geometric patterns. The formation of crystal faces requires favorable conditions such as cooling rate, pressure, and available space. Crystal form is often used in determining the amount of symmetry present in the crystalline structure.

B. **Hardness** – it is the measure of the mineral's ability to resist abrasion - Hardness reflects the strength of the bond between atoms within the crystal structure. It is often variable with orientation due to differences in bond strength with changes in crystal orientation.
MOH's Hardness Scale - a relative, not an absolute scale of mineral hardness

1. Talc
2. Gypsum --------------- Fingernail (2.2)
3. Calcite --------------- Copper penny (3.1)
4. Fluorite
5. Apatite --------------- Glass (5.5)
6. Orthoclase ------------ Steel (6.5)
7. Quartz
8. Topaz
9. Corundum
10. Diamond
C. Breakage
1. Cleavage is the tendency of minerals to break along parallel planes of weaknesses (cleavage planes) within the crystal forming parallel planar surfaces along broken fragments - Cleavage results from weaker bond strengths along the certain planar directions within the mineral. *The number of cleavage planes and the angles between the cleavage planes are important characteristics used in identifying minerals (example - micas, excellent cleavage in 1 direction; halite, good cleavage in three directions, each at 90° to each other; and sphalerite, 6 good directions not at 90°).

*Difference between cleavage and crystal form - crystal form is only an external reflection of atomic structure which is lost when the crystal is broken. In contrast, cleavage is related to planes of weakness which are found throughout the mineral. Cleavage planes will form no matter how finely the crystal is broken.
2. Fracture - a lack of cleavage that results in an absence of planar surfaces when the mineral is broken - Minerals that display fracture break like glass (ex. - quartz with conchoidal fracture).

D. Specific Gravity - comparison of a mineral's density with the density of water.
Specific Gravity = density of the mineral / density of equal vol. of water = X / 1 gr./cm³

E. Color - useful for some minerals (ex. olivine is always green), but commonly too variable for most (ex. quartz can be almost any color).

F. Luster - appearance of the mineral in reflected light - Luster is described as metallic or non-metallic. Submetallic is further described as vitreous (glassy) or non-vitreous.

G. Streak - color of the mineral when it is powdered - The streak helps eliminate surface effects such as weathering. A white unglazed porcelain plate is used to powder the mineral.

H. Other Properties - magnetism (magnetite), taste (halite), and fluorescence (some fluorite).