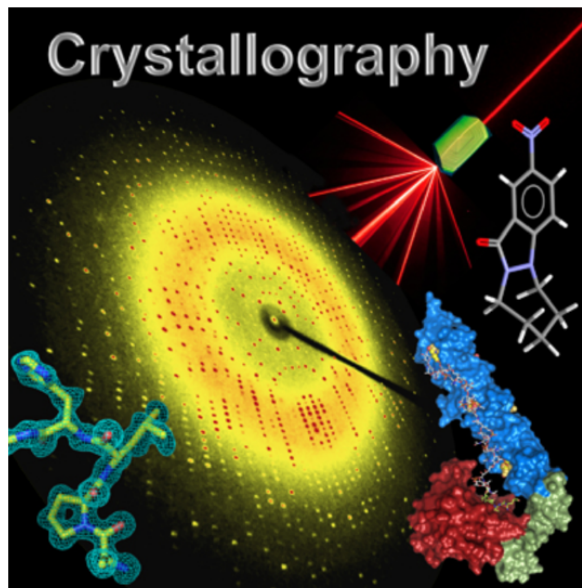


1.0: Introduction



Why water boils at 100°C and methane at -161°C; why blood is red and grass is green; why diamond is hard and wax is soft; why graphite writes on paper and silk is strong; why glaciers flow and iron gets hard when you hammer it; how muscles contract; how sunlight makes plants grow and how living organisms have been able to evolve into ever more complex forms...? The answers to all these problems have come from structural analysis.

Max Perutz, July 1996 (Churchill College, Cambridge)

With the words pronounced by the Nobel laureate **Max Perutz** we open these pages (*), a continuing work in progress, intended to guide the interested reader into the fascinating world of Crystallography, which forms part of the scientific knowledge developed by many scientists over many years. This allows us to explain what crystals are, what molecules, hormones, nucleic acids, enzymes, and proteins are, along with their properties and how can we understand their function in a chemical reaction, in a test tube, or inside a living being.

The discovery of X-rays in the late 19th century completely transformed the old field of Crystallography, which previously studied the morphology of minerals. The interaction of X-rays with crystals, discovered in the early 20th century, showed us that X-rays are electromagnetic waves with a wavelength of about 10^{-10} meters and that the internal structure of crystals was regular, arranged in three-dimensional networks, with separations of that order. Since then, Crystallography has become a basic discipline of many branches of Science and particularly of Physics, Chemistry of condensed matter, Biology and Biomedicine.

Structural knowledge obtained by Crystallography allows us to produce materials with predesigned properties, from catalyst for a chemical reaction of industrial interest, up to toothpaste, vitro ceramic plates, extremely hard materials for surgery use, or certain aircraft components, just to give some examples of small, or medium sized atomic or molecular materials.

Moreover, as biomolecules are the machines of life, like mechanical machines with moving parts, they modify their structure in the course of performing their respective tasks. It would also be extremely illuminating to follow these modifications and see the motion of the moving parts in a movie. To make a film of a moving object, it is necessary to take many snapshots. Faster movement requires a shorter exposure time and a greater number of snapshots to avoid blurring the pictures. This is where the ultrashort duration of the FEL (free electron laser) pulses will ensure sharp, non-blurred pictures of very fast processes (**European XFEL** or **CXFEL**).

We may suggest you to start [getting an overview about Crystallography](#), or looking at [some interesting video clips collected by the International Union of Crystallography](#). Some of them can directly be reached through the following links:

- [Presentation of the International Year of Crystallography](#), 1.30 min video ([International Union of Crystallography](#)). In case of troubles, [use this link](#).

- [Celebrating the centenary of the discovery of X-ray diffraction by crystals](#), 3 min video (The Royal Institution, London). In case of troubles, [use this link](#).
- ["The fascinating world of crystallography"](#), 2.30 min video, prepared by [Quidos](#) for the [International Year of Crystallography](#). In case of troubles, [use this link](#).
- [Georgina Ferry on X-ray crystallography](#), a freelance science writer, editor and broadcaster, discussing the fascinating history and importance of crystallography. This video (7 min) was created as support of an exhibition of the [Wellcome Collection](#). In case of troubles, [use this link](#).
- [The humble Braggs and X-ray crystallography: Solving the patterns of matter](#), 9 min video (The Royal Institution, London). In case of troubles, [use this link](#).
- [A Century of Crystallography: the Braggs Legacy](#), 44 min video (The Royal Institution, London). In case of problems, [use this link](#).
- [Myoglobin: A brief history of structural biology](#), 4 min video (The Royal Institution, London). In case of problems, [use this link](#).
- [Elspeth Garman on the crystallization process](#), 8 min video (The Royal Institution, London). In case of problems, [use this link](#).
- [Stephen Curry explaining from the diffraction phenomena up to the structural resolution](#), 8 min video (The Royal Institution, London).
- [Lecture of Prof. Stephen Curry](#), 1 h video (The Imperial College, London).

In any case, we suggest you to get a previous [overview about the meaning of Crystallography](#), and if you maintain your interest go deeper into the remaining pages that are shown in the menu on the left (if you don't see the left menu, [click here](#)). Enjoy it!

(*) We endeavor to assemble these pages and offer them to the interested reader, but obviously we are not immune to errors, inconsistencies or omissions. We are very grateful to several readers who have helped us to correct some previously undetected small errors or that have improved the wording of certain parts of the text. For anything that needs further attention, please, let us know through [Martín Martínez Ripoll](#).

These pages were [announced by the International Union of Crystallography \(IUCr\)](#), have been selected as [one of the educational web sites and resources of interest to learn crystallography](#), offered as such in the [commemorative web for the International Year of Crystallography](#), and suggested as [the educational website in the brochure prepared by UNESCO](#) for the [crystal growing competition for Associated Schools \(even in subsequent calls of this competition\)](#). The Cambridge Crystallographic Data Centre also offers this website through its Database of Educational Crystallographic Online Resources ([DECOR](#)).

[Martín Martínez Ripoll](#) (1946-) and [Félix Hernández Cano](#) (1941-2005+) were coauthors of a first version of these pages in the early 1990's. Later, in 2002 they produced a PowerPoint presentation dedicated to draw students' attention to the enigmatic beauty of the crystallographic world... This file, called XTAL RUNNER (totally virus free, although in Spanish) can be [obtained through this link](#). If you understand Spanish we also offer you the possibility of reading a short general article of these authors published in 2003, entitled [Cristalografía: Transgrediendo los Límites](#). Today we ask ourselves, [where are those glory days gone?](#)

Some relevant hints:

- This website is designed by combining three visible areas in the same window: a header and a menu on the left (which always remain visible), and a central area with the information obtained. It is what we can call [full-screen mode](#), suitable for desktop computers and tablets.
- The full-screen mode may not be suitable for mobile, in which case we suggest using the [central-screen mode](#), that is, the mode using the central area only, and starting the session with the Table of Contents.
- In both modes, a **small square logo** appears in the upper right corner of the central screen that links to the [Table of Contents](#).
- All the links that appear in the menu on the left (in full screen mode), or in the Table of Contents (in any of the modes) lead to internal pages that are always displayed on the same window. The remaining links, which necessarily refer to external pages, will always be displayed in a "new window". Going back to a previous page can be achieved using the **"Back"** link in the top left of the header (full screen mode), or through the browser's own strategy.

- From time to time we incorporate some novelties or small corrections into these pages, so occasionally we recommended to reload these pages in your browser, or to clear the navigator caché. This will avoid to see the previously existing pages stored on your computer's caché.
- Some companies offer documents directly extracted from these web pages and you have to pay for them. Please, do not participate in this fraud! All the material here presented is freely available to you, although for your personal use only, as it is shown below under the copyright condition.

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