

DNA Development in Interdisciplinary Fields

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Abstract

DNA is an essential part of organisms. With the progress of science, many scientists in history have constantly discovered and updated the structure, properties, and functions of DNA. So far, we know that most researchers recognize the reverse double helix structure of DNA. It hasn't been introduced of DNA's structure and function from an interdisciplinary perspective. The mechanism, principles, and application of Bragg's law and XRD will be investigated through the combination of biology, chemistry, and physics. More specifically, this interdisciplinary perspective shed light on the discovery of double helix structure based on XRD and the calculation of DNA radius through Bragg's law. This paper can help understand the issues related to DNA in various aspects in future research and think more comprehensively and concretely.

Keywords

DNA; XRD; Double Helix; Interdisciplinary.

1. Introduction

DNA carries the genetic information necessary for the synthesis of RNA and protein. It is an essential biological macromolecule for biological development and regular operation.

The structure of DNA is the basis of function. It contains many functions, depending on the stability of the structure. The structure is compatible with function and property. Questions regarding the establishment of particular structures will be investigated. This paper will introduce it in the technological order.

2. Organization of the Text

2.1 DNA Discovery History

2.1.1 1869s

Initially, Miescher tried to isolate these cells from lymph nodes for experiments, but it was difficult to purify lymphocytes and obtain sufficient numbers for analysis. According to Hoppe seyley's suggestion, Miescher instead examined leukocytes and obtained experimental cells from pus on fresh surgical bandages. In the pus, he found the ideal basic material for analysis. Because this microscopic material was located in the nucleus, it was called nucleus at that time (Dahm, 2005). The discovery of nucleic acids has laid a foundation for the progress of biology and modern society. For example, in the background of COVID-19, we need to do nucleic acid testing to understand our physical condition.

2.1.2 1919s

Phoebus Levene preliminary determined that DNA consists of nucleotides composed of nitrogen-containing bases, sugars and phosphates. Levene proposed that DNA consists of a nucleotide bound together by phosphate. He was convinced that the long strands of DNA were short and that the bases were repeated in a fixed order.

2.1.3 1943s

Oswald Avery et al. Proved that DNA was: in 1928, British scientist Frederick Griffith (1877- 1941) found that smooth pneumococcus could be transformed into rough homologous bacteria (Lorenz, 1994), and some substances could transfer genetic information from the remains of dead bacteria to organisms (Avery, et al.,2000).

2.1.4 1944s

Erwin Schrödinger asserted that genetic material must be composed of large non repetitive molecules in order to maintain the stability of genetic information (Schrödinger, 1944). This is not only a progress in the discovery of DNA structure, but also can be extended to the stability of all kinds of other organisms from a chemical point of view.

2.1.5 1953s

Alfred Hershey and Martha chase confirmed the role of DNA in heredity through another classic experiment. Finally, the experiment showed that the genetic material of phage T2 was actually DNA, and the protein was synthesized by the command of DNA (Martha, & Chase, 1952).

2.1.6 1958s

Matthew Meselson and frank Stahl conducted a landmark experiment to confirm the DNA replication predicted by the double helix structure recently proposed by Watson and Crick (Meselson & Stahl, 1958). Later, Crick's team showed that the genetic code is composed of bases in a non repetitive way, called codons.

2.2 Methodology of DNA Structure Finding & DNA Function

In the late 1950s and 1960s, only X-ray diffraction once dominated this field, and the importance of electron diffraction combined with high-resolution electron microscope gradually increased. At the same time, the use of computers is also increasing (Lucas, 2008).

2.2.1 Helix Chain & Double

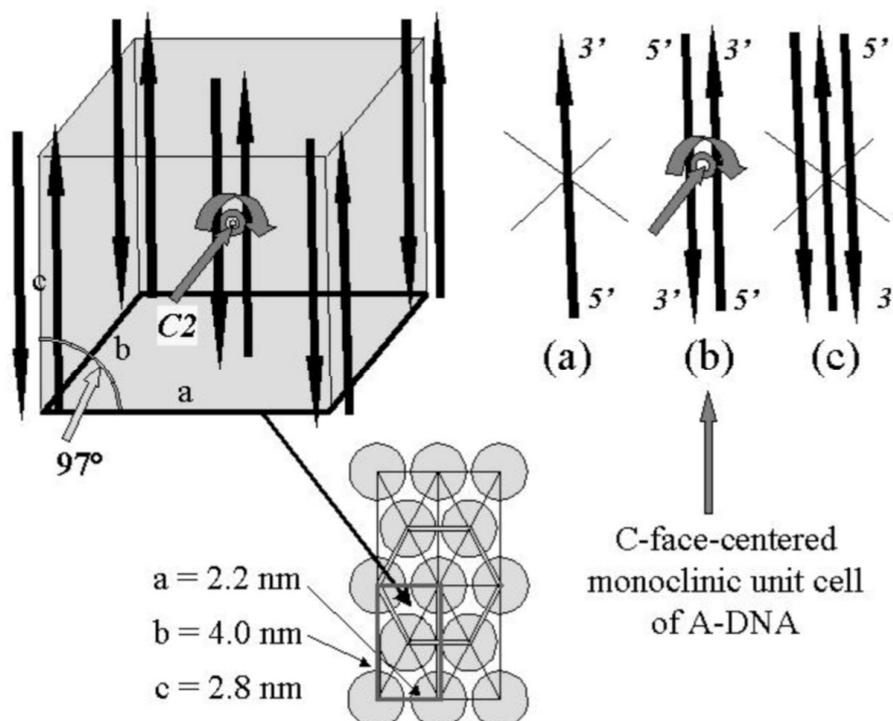


Fig.1 The monoclinic cell is close to the hexagonal structure (a hexagon on the A-B plane is highlighted), and its size is shown in the figure. The C_2 symmetry axis requires that the DNA molecule itself must be dyadic, so it has two antiparallel polar chains (b). The binary structure excludes the possibility of single strand (a) and three strand (c) (Lucas 2008).

First, we need to understand that DNA structure including two different part, helix and double. According to XDR this technology, scientist can use the things in our life like spring to compare with DNA's diffraction pattern. And after many comparison and analysis they find DNA has the same diffraction pattern with other spiral object. So, why DNA are double helix instead of triple or single? In addition, what keeps the two chains connected stable? The most basic structure is phosphate groups stay outside while bases stay inside. The primary reasons would be phosphate groups are more hydrophilic, phosphoric acid groups exist in the form of ions, with strong polarity, strong water polarity and large interaction force, which are easy to attract together and soluble in water, while bases are not so hydrophilic or we can say hydrophobic. The reason why DNA is helical rather than planar is that distance between helix is smaller, making system energy lower. Electrostatic repulsion is smaller in helix. Hydrogen bonds are protected by hydrophilic phosphates. The conclusion that the phosphate group is located outside the structural unit was previously obtained by other reasoning. Two main arguments are cited. The first comes from the work of Gulland and his collaborators. They show that even in aqueous solution, - CO and - NH, the base group is inaccessible and cannot be titrated, while the phosphate group is not titratable fully accessible. The second is based on our own observation of the structure of A and B, which is separated by excessive water. The process is a continuous process, which leads to the formation of gelatin and the formation of solution. It can be assumed that the hygroscopic part of the molecule is located in the phosphoric acid group ((C₂H₅O)₂PO₂Na and (C₃H₇O)₂PO₂Na are highly hygroscopic), and the simplest explanation of the above process is that these groups are located outside the structural unit. In addition, in this way, it can be easily explained that oxygen phosphate groups can be used to interact with proteins at any time (Watson & Crick, 1953).

2.2.2 XRD

All of those important experiments can't leave one technology-XRD, but how's it work? What is the principle of XRD?

First of all, because the crystal can refract light, we can use X-ray to determine that DNA is a crystal before XRD (diffraction of x-rays).

The principle about XRD is when a beam of monochromatic X-ray irradiates the crystal, the electrons around the atoms in the crystal are charged by the periodic change of X-ray.

Each electron becomes a secondary wave source emitting spherical electromagnetic waves. The frequency of the emitted spherical wave is consistent with the incident X-ray. Based on the periodicity of crystal structure, the scattered waves of atoms (electrons on atoms) in the crystal can interfere with each other and superimpose, which is called coherent scattering or diffraction. The diffraction phenomenon of X-ray in crystal is essentially the result of mutual interference of a large number of atomic scattered waves. The diffraction pattern produced by each crystal reflects the atomic distribution law in the crystal.

According to the above principle, there are two main characteristics of the diffraction pattern of a crystal: 1) the distribution law of diffraction rays in space; 2) The intensity of the diffraction harness. Among them, the distribution law of diffraction rays is determined by the size, shape and orientation of crystal cells, and the intensity of diffraction rays depends on the variety of atoms and their position in crystal cells. Therefore, different crystals have different diffraction patterns (Huang, 2012).

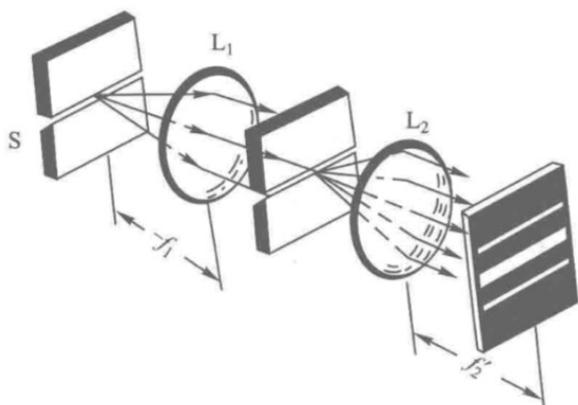


Fig.2 Experimental device



Fig.3 Inverse law of diffraction

However, why we didn't use other radial, that connect with the effect of slit width b on diffraction beam. Half-angular breadth of the central maximum $\Delta\theta$ proportional to the wavelength, and is proportional to the slit, the width b is inversely proportional:

$$\Delta\theta = \lambda/b$$

As the seam widens, λ The ratio of and b decreases (see Fig 3). Stay $b > \lambda$ - the limit case of $\Delta\theta \rightarrow 0$, here, it can be considered that the diffraction pattern is compressed into a bright line. This bright line is exactly the image formed by the light source passing through the lens $L1$, $L2$ without obstacles. It can be seen that the degree to which the light intensity distribution deviates from the geometric optical law can be measured by the half width of the central maximum. Equation shows that only when $b \ll \lambda$. Namely $\lambda/b \ll 1$, the diffraction phenomenon can not be ignored; conversely, the larger λ or the smaller b , the more obvious the diffraction phenomenon is. Because the wavelength of light is very short, in general, when the opening linearity of the slit is much larger than that of the wave, the light can be regarded as propagating along a straight line (Yao, 2019).

To sum up, because the wavelength is similar to the distance between atoms, we choose X- ray.

Also, Bragg's Law is what used to calculate the DNA pitch will be introduced later.

Last in XRD phase analysis with the improvement of XRD standard database, XRD phase analysis becomes more and more simple. At present, the most common operation is to compare the XRD spectrum of the sample with the standard spectrum to determine the phase composition of the sample. The XRD standard database includes JCPDS (i.e. PDF card), ICSD, CCDC, etc. the software for analyzing XRD spectra includes Jade, Xpert Highscore, etc., which will not be explained here.

2.2.3 A-DNA and B-DANN

2.2.4 Bragg's Law

3. Conclusion

The main purpose of this paper is try to provide a more detail interdisciplinary perspective to get the information about DNA. In this area about DNA, Biology, chemistry and physic all provide a very big distribution, they complement each other and each has the extension.

In this review, more detailed information about researching DNA structure and property techniques such as XRD from the interdisciplinary perspective of biochemistry. From this interdisciplinary perspective, our view of DNA related information is no longer one- sided and limited by a single discipline; The understanding of the world is more diversified and three-dimensional.

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