Economic Growth Versus Scientific Advancement of X Rays

S. Narasinga Rao

M.Sc. (Madras), M.Sc. (McMaster), Ph.D. (SUNY, Buffalo)
Sigma Xi Researcher of the year 1990-91
American Association of University Professors Distinguished Scholar of the Year 2001

Dean Emeritus, Dr. Joe C. Jackson College of Graduate Studies and Research,
University of Central Oklahoma, Edmond, OK 73034
Chief Financial Officer, American Crystallographic Association, Inc., Buffalo, NY
Financial Advisor, International Union Of Crystallography, Chester, UK

X-ACTLY SO!

The Roentgen Rays, the Roentgen Rays,
What is this craze?
The town's ablaze
With the new phase
Of X-ray's ways.

I'm full of daze,
Shock and amaze;
For nowadays
I hear they'll gaze
Thro' cloak and gown–and even stays,
These naughty, naughty Roentgen Rays.

–*Wilhelma,* Electrical Review,
April 17, 1896
Assmus p. 21

The New Photography

O, Röntgen, then the news is true,
And not a trick of idle rumour,
That bids us each beware of you,
And of your grim and graveyard humour.

We do not want, like Dr. Swift,
To take our flesh off and to pose in
Our bones, or show each little rift
And joint for you to poke your nose in.

We only crave to contemplate
Each other's usual full-dress photo;
Your worse than "altogether" state
Of portraiture we bar in toto!

The fondest swain would scarcely prize
A picture of his lady's framework;
To gaze on this with yearning eyes
Would probably be voted tame work!

No, keep them for your epitaph,
these tombstone-souvenirs unpleasant;
Or go away and photograph
Mahatmas, spooks, and Mrs. B-s-nt!

—Punch, *January 25, 1896*

Economic Analysis vs. Scientific Analysis of X Rays

What has economics to say about X rays? After all, along with other social sciences, economics has sometimes been regarded with suspicion, even disdain, by the natural sciences. On the one hand, the great mathematician John von Neumann made significant contributions to economic theory without being exiled from the hyper-prestigious Institute for Advanced Study in Princeton. On the other hand, the fourth director of that Institute – the home of, among others, Albert Einstein and J. Robert Oppenheimer – was an economist Carl Kaysen who was nearly run off by a group of mathematicians and physicists who had no respect at all for his judgment and demanded his resignation [1].

Since 1969, economists and natural scientists have had it in common that every year members of their professions are awarded Nobel Prizes. Natural scientists have been receiving the prizes since they were first awarded. For instance, Wilhelm Conrad Röntgen, the discoverer of X rays, received the Nobel Prize for Physics in 1901. It was not until 1969, however, the first economist was granted the Nobel honor. The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1969 was awarded jointly to Ragnar Frisch and Jan Tinbergen *"for having developed and applied dynamic models for the analysis of economic processes"* [2].

Soon after the discovery that crystals produce diffraction patterns when placed in a beam of X rays, father-and-son team William Henry and William Lawrence Bragg formalized the laws of X-ray crystallography (Bragg's Law). In 1915 they won the Nobel Prize in physics for their work – Lawrence, at 25, remaining to this day the youngest winner.

The General Assembly of the United Nations declared that 2014 should be the International Year of Crystallography (IYCr), 100 years since the award of the Nobel Prize to Max von Laue for the discovery of X-ray diffraction by crystals. The IYCr 2014 Opening ceremony took place in Paris at the UNESCO headquarters on January 20-21, 2014 [4]. As part of the celebration of IYCr the Science Museum in London displayed molecular models made using X-ray crystallography in a show titled "Hidden Structures – X-ray Crystallography At 100" [3]. (See http://blog.sciencemuseum.org.uk/x-ray-crystallography-at-100/)

The mayors of the cities of Edmond, Oklahoma and Tempe, Arizona have proclaimed 2014 as International Year of Crystallography in their cities [5]. (See proclamations below.)

Proclamation

City of Edmond
Charles Lamb, Mayor

In Recognition of

International Year of Crystallography

Whereas, American Crystallographic Association, Inc (ACA) was founded in 1949 through a merger of the American Society for X-Ray and Electron Diffraction (ASXRED) and the Crystallographic Society of America (CSA) and is headquartered in Buffalo, NY; and

Whereas, American Crystallographic Association, Inc is a Regional Affiliate of the International Union of Crystallography (IUCr) founded in 1946 that is headquartered in Chester, UK; and

Whereas, 2014 is recognized as the International Year of Crystallography (IYCr) by the General Assembly of the United Nations through a resolution adopted in July 2012 at Morocco; and

Whereas, International Union of Crystallography along with their country regional affiliates celebrates the International Year of Crystallography – 2014 all across the world and the Opening Ceremony is in the UNESCO Building in Place de Fontenoy, Paris on January 20-21, 2014; and

Whereas, Crystallography has become the very core of structural science, showing the structure of DNA, allowing to understand and fabricate computer memories, showing how proteins are created in cells, and helping to design powerful new materials and drugs; and

Whereas, S. Narasinga Rao worked on the X-Ray Crystallography of Human Albumin and Porcine Pepsinogen at the Oklahoma Medical Research Foundation, Oklahoma City; and

Whereas, S. Narasinga Rao started the X-Ray Crystallography Laboratory at the University of Central Oklahoma in Edmond, Oklahoma; initiated and taught courses on X-Ray Crystallography to Kerr-McGee technicians and guided students at the University of Central Oklahoma; and

Whereas, Nobel Prize winners in X-Ray Crystallography – Drs. Jerome Karle, Herbert Hauptman and Johann Deisenhofer visited the University of Central Oklahoma on several occasions at the invitation of Narasinga Rao to spread the message of Crystallography; and

Whereas, S. Narasinga Rao, long time resident of Edmond is the Chief Financial Officer of the American Crystallographic Association, Inc (ACA), is a Fellow of ACA and has served the ACA for 25 years, is a recipient of the Service Award by ACA and is the Investment Counselor for IUCR; and

Now, Therefore, I, Charles Lamb, Mayor of the City of Edmond, Oklahoma, on behalf of the Edmond City Council do hereby proclaim 2014 as the "*International Year of Crystallography*" in Edmond, Oklahoma and request all citizens to participate in the celebrations of American Crystallographic Association, Inc and the International Union of Crystallography during the year 2014.

Given under my hand and seal of the City of Edmond, Oklahoma this [illegible] day of August [illegible]

Mayor

Attest:

City Clerk

Proclamation

WHEREAS, American Crystallographic Association, Inc. (ACA), a merger of the American Society for X-Ray and Electron Diffraction (ASXRED) and the Crystallographic Society of America (CSA) was founded in 1949; and,

WHEREAS, ACA is a Regional Affiliate of the International Union of Crystallography (IUCr) that was founded in 1946 and headquartered in Chester, UK; and,

WHEREAS, 2014 is recognized as the International Year of Crystallography (IYCr) by the General Assembly of the United Nations through a resolution adopted in July 2012 at Morocco; and,

WHEREAS, International Union of Crystallography along with their country regional affiliates celebrates the International Year of Crystallography – 2014 all across the world; and,

WHEREAS, Crystallography has become the core of structural science, showing the structure of DNA, and allowing us to understand and fabricate computer memories, and has helped design powerful new materials and drugs; and,

WHEREAS, John Spence is Regent's Professor of Physics at Arizona State University, Tempe and received the Buerger Award in 2012 by the ACA; and,

WHEREAS, S.Narasinga Rao, a resident of Tempe is the Chief Financial Officer of the ACA and has served the ACA for 25 years; and,

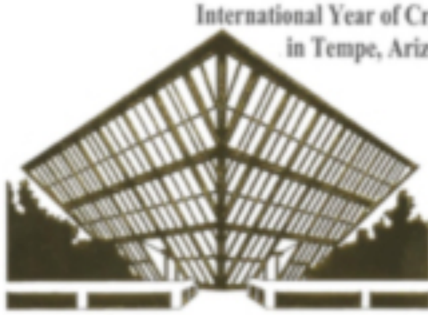
WHEREAS, Over the course of the Noble Prize's history, many awards have been made for scientific achievements related to or involving the use of crystallographic methods and techniques.

NOW, THEREFORE, I, Mark W. Mitchell, Mayor of the City of Tempe, Arizona do hereby declare:

2014

as

International Year of Crystallography
in Tempe, Arizona



IN WITNESS WHEREOF,
I hereunto set my hand
this 12th day of August
Two Thousand and Thirteen

Mark W. Mitchell
Mayor Mark W. Mitchell

City of Tempe

This paper tries to use this commonality of awards to effect a credible transition from the realm of natural sciences to the realm of social sciences. The economic analyses of X rays are based upon the models and methodologies of Nobel Prize winning economists.

X Rays

As 1985 opened, the world of physics was in a rather quiet state. Mechanics was a long-established part of the discipline, the laws of thermodynamics were being reworked in terms of statistical mechanics, electricity and magnetism had been unified and optics had been shown to be an electromagnetic phenomenon. It had been said that all the laws of physics were known. Into this simple state of affairs, in November of that year, was introduced a very puzzling phenomenon. A German Physicist, Wilhelm Conrad Röntgen, at the University of Würzburg observed in his laboratory a mysterious fluorescence near his ongoing experiment on cathode rays. He called the new rays X rays. In this Bavarian city, dominated by ecclesiastical and secular intellects, Roentgen took a quantum leap forward and began a cultural revolution. He announced his discovery in the *Sitzungsberichte*, a publication for local scientists in Würzburg. As the phenomenon of X rays became understood, it became clear that they were electromagnetic in origin, and yet did not fully obey the classical laws of electricity and magnetism.

Just about everyone comes to have some acquaintance with the phenomenon of X rays. Such widespread familiarity distinguishes X rays from more arcane subjects in the province of scientists like, for instance, quasars. Those celestial phenomena are supremely interesting but not, after all, of much day-to-day utility. Of course, the scientific study of quasars has some day-to-day economic impact through purchases of laboratory equipment and payment of scientists' salaries to do quasar research. To the extent that X rays have remained merely objects of refined scientific study, they have a similarly small economic impact.

At the same time, though, X rays also have much wider economic impacts. This is because, in the one hundred years after W.C. Röntgen's discovery, the use of X rays became commonplace. They were put to use – to an increasing number of uses – not just in laboratories but medical facilities, manufacturing installations, transport enterprises, and numerous other applications. This amount of activity has at least four kinds of economic impacts:

1. Development of a technological basis for economic growth
2. Creation of a stock capital for future productivity
3. Consumption of goods and services
4. Services that are beneficial in themselves and also confer economic savings on society

Some of these impacts are hard to measure. For instance, statistics are not readily available on the number and uses of every unit of X-ray machinery in all industries. The most usable statistics on the manufacture of X-ray films and plates lump X rays together with non-X-ray photographic equipment. Likewise, uses in engineering laboratories are lumped with many other kinds of labs; and medical X-ray labs are lumped with veterinarian clinics. Because of these data limitations, this paper does not attempt an estimate of the grand total economic impact of X rays. Rather, this paper concerns itself with the impacts of X rays in certain important economic sectors, especially materials inspection and medical diagnostic imaging.

Impact of X rays on Economic Growth

Probably the most popular conception of the impact of science on the economy is the one that associates scientific advances with economic growth. From this viewpoint, scientific progress implies economic progress. As the realm of scientific knowledge expands, we enjoy greater prosperity and well being. In the particular case of X rays, X-ray equipment and procedures embody scientific progress and so must lead to economic progress.

The economic growth impact of X rays can be examined with the help of 1987 Nobel Prize winner Robert Solow [6]. His empirical analysis led him to infer that economic growth was not entirely accounted for by the growth in inputs to production such as capital and labor. Some of it instead seemed to be due to the growth in human ingenuity, that is, technology.

Solow soon followed that paper with another pioneering article, “Technical Change and the Aggregate Production Function.” Before it was published, economists had believed that capital and labor were the main causes of economic growth. But Solow showed that half of economic growth couldn’t be accounted for by increases in capital and labor. This unaccounted-for portion of economic growth – now called the “Solow residual” – he attributed to technological INNOVATION. His article originated “sources-of-growth accounting,” which economists use to estimate the separate effects on economic growth of labor, capital, and technological change. Solow also was the first to develop a growth model with different vintages of capital. The idea was that because capital is produced based on known technology, and because technology is improving, new capital is more valuable than old capital.

The reasoning here is that scientific progress leads to economic growth if and when science increases the ability of the economy to produce more goods and services without requiring that more inputs be used in production. If, for any set amounts of labor, machinery, and natural resources, a scientific advance causes an increased amount of output to be produced.

Driven by continued digitization of X-ray systems and increasing healthcare investments in emerging regions, the global market for X-ray equipment reached 7.5 billion euros ($10 billion) in revenue in 2012 and is expected to increase by 18% to reach 9 billion euros ($12 billion) in 2017, according to market research firm IMS Integrated Medical Services Research (AuntMinnie.com staff writers). The global X-ray systems market, which was valued at $3.67 billion in 2008, is forecast to reach $3.79 billion by the end of 2009. The market grew by 3.6% between 2001 and 2008 and is expected to grow by 4.5% between 2008 and 2015 to reach $5 billion by 2015. (Global Data’s “Global X-ray Systems Market: Strategic Market Analysis and Insight to 2015” report is an essential source of data and analysis on the global X-ray systems market across 12 countries.) [7].

Key drivers of the X-ray systems market include advances in digital technology, superior image quality, speed and improved flexibility, an aging population, and rising expectations for quality of care. The X-ray market continues to experience a sustained demand, due to the requirement for X rays to diagnose internal injuries and to detect breast cancer. The use of digital X rays allows X-ray modalities to find problem sites more quickly and with great levels of accuracy. These factors are pushing many hospitals worldwide to make a transition from X-ray films to filmless X-ray systems.

While shipments of flat-panel detector and retrofit flat-panel detector DR systems produced an estimated 15% of annual general radiography shipments in 2012, that figure is expected to reach 25% in 2017, IMS said.

IMS noted the mammography market is already dominated by flat-panel detector-based full-field digital mammography systems, led by adoption in mature regions. Purchasing in emerging regions is relatively low, however, with not much demand for breast screening, and few healthcare providers are able to purchase the costly equipment, according to the company.

Interventional and mobile C-arm equipment sales are benefitting from a growing trend toward minimally invasive surgery, according to IMS. Advanced systems with digital technology and advanced navigation software are driving growth in mobile C-arm X-ray equipment, while interventional X-ray treatment is already dominated by digital technology and is being spurred on by new installations of hybrid operating rooms that combine multiple imaging modalities and full surgical equipment in one room, the company said.

Furthermore, hospitals are becoming more receptive to new procedures like transcatheter aortic valve implantation (TAVI) as an alternative to open-heart surgery. These procedures are performed using high-end mobile C-arm equipment with flat-panel detector technology, IMS said.

Outside of radiology, IMS said that veterinary X-ray equipment is also seeing a transition to flat-panel detector technology in developed regions, with existing analog systems now being replaced by computed radiography and flat-panel detector X-ray equipment. Wireless flat-panel detector usage is increasing in the equine veterinary market, and fixed equipment is increasingly used in smaller animal practices, the company said.

While the dental X-ray imaging segment is currently dominated by analog film, a major shift to digital sensors and photostimulable phosphor imaging is underway, according to the firm. In addition, extraoral imaging is increasing in popularity, with more use of flat-panel detectors based on complementary metal-oxide-semiconductor (CMOS) technology.

Overall, challenging global economic conditions have significantly affected the X-ray market, IMS said. While delayed purchasing and slower demand are predicted to continue in the short term, these hard times are also creating an opportunity for lower-cost digital packages such as retrofit flat-panel detector panels/kits, IMS said.
The global X-ray market is expected to recover over the longer term, however. The main market drivers will be emerging regions, particularly in China, India, Latin America, and parts of Southeast Asia, IMS said. Flat-panel detectors also will become the most common technology type, owing to its increased efficiency, image quality, and lower lifetime cost of ownership, according to the firm.

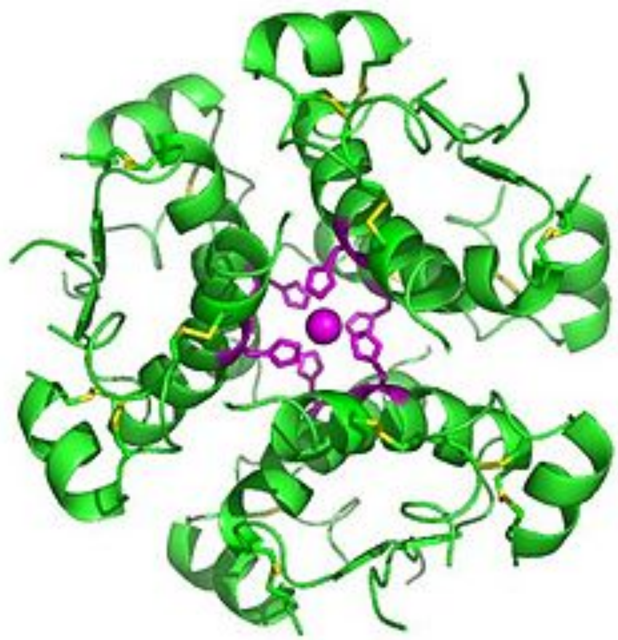
According to a new market report published by Transparency Market Research "Medical Imaging Equipment Market (X-ray, Ultrasound, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Nuclear Imaging Equipment) – Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 - 2019" in 2012, the global medical imaging equipment market was valued at USD 24.39 billion and is expected to grow at a compound annual growth rate (CAGR) of 5.4% during the forecast period of 2013 to 2019 to reach a market value of USD 35.35 billion by 2019.

Medical imaging equipment helps in diagnosing various complex diseases such as chromosomal abnormalities, atherosclerosis and Parkinson's disease. This equipment utilizes energy waves to produce 2-D and 3-D images of human organs. With rise in incidences of various diseases such as cardiovascular diseases (CVD), brain disorders, oral conditions such as gingivitis, and lung disorders, the market is expected to grow at a CAGR of 5.4% during the forecast period of 2013 to 2019.

According to an estimate of the World Health Organization (WHO), around 8.7 million people suffered from tuberculosis (TB) in 2011 worldwide and around 23.3 million people will die due to CVDs. Growth of this market will also be supported by the increasing geriatric population worldwide because elderly people are highly susceptible to various diseases such as osteoporosis, stroke and CVDs. Equipment such as nuclear imaging devices and computed tomography (CT) scanners help in diagnosing these diseases precisely within a short span of time. Moreover, introduction of various technologically advanced products such as handheld X-ray machines and upright MRI scanners will also augment growth (Medical Imaging Equipment Market – Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 – 2019).

Insulin and Diabetes

When control of insulin levels fails, diabetes mellitus can result. As a consequence, insulin is used medically to treat some forms of diabetes mellitus. Patients with type 1 diabetes depend on external insulin (most commonly injected subcutaneously) for their survival because the hormone is no longer produced internally. Patients with type 2 diabetes are often insulin resistant and, because of such resistance, may suffer from a "relative" insulin deficiency. Some patients with type 2 diabetes may eventually require insulin if other medications fail to control blood glucose levels adequately. Over 40% of those with Type 2 diabetes require insulin as part of their diabetes management plan.



High-resolution model of six insulin molecules assembled in a hexamer, determined by X-ray diffraction. The zinc ion (pink sphere) holds the molecules together by binding to the histidine residues from the insulin molecules (pink sticks). This hexamer is the inactive storage form; the active form is the monomer. (https://en.wikipedia.org/wiki/Insulin#/media/File:InsulinHexamer.jpg)

Nearly 26 million people in the United States have diabetes, equal to 8.3 percent of the total population. According to the Centers for Disease Control and Prevention (CDC), about 1.9 million people aged 20 years or older were newly diagnosed with diabetes in 2010 in the United States. The CDC data report released in June 2008 confirmed that diabetes is the largest and fastest-growing chronic disease in the nation

Economic Costs of Diabetes in the United States

The estimated total cost of diabetes in 2007 was $174 billion:

- Includes $116 billion in excess medical expenditures and $58 billion in reduced national productivity
- $27 billion for care to directly treat diabetes
- $58 billion to treat the portion of diabetes-related chronic complications that are attributed to diabetes
- $31 billion in excess general medical costs

A study commissioned by the National Changing Diabetes Program added to the existing estimate the costs for undiagnosed diabetes, pre-diabetes and gestational diabetes to bring the total to $218 billion in 2007. Furthermore, by 2025, the number of people with diabetes is expected to double, placing increased demands on the healthcare system and creating opportunities for more integrated and innovative disease management. For more information about state and CDC diabetes funding, visit NCSL's Diabetes in State Budgets: A 50-State Survey for fiscal year 2011.

Diabetes continues to be a critical health issue, both medically and financially. Its incidence in the United States has grown significantly, rising in tandem with the increase in the obesity rate (CDC 2010, Flegel 2010). Currently, almost 18 million people have diabetes in the USA. Of these, 90 to 95 percent have type 2 (CDC 2010, American Diabetes Association 2010). As a result, diabetes is a major contributor to morbidity and mortality, driving increased use of a wide variety of medical services. The annual direct medical and pharmacy costs of diabetes estimated at $116 billion in 2007 are substantial and are expected to continue to rise as the population of patients with diabetes expands (CDC 2010 and American Diabetes Association 2010). These costs are largely borne by payers, private carriers, employers, federal and state governments.

Nobel Prizes for Insulin Discoveries

The Nobel Prize committee in 1923 credited the practical extraction of insulin to a team at the University of Toronto and awarded the Nobel Prize to two men: Frederick Banting and J.J.R. Macleod. They were awarded the Nobel Prize in Physiology or Medicine in 1923 for the discovery of insulin. Banting, insulted that Charles Best was not mentioned, shared his prize with him, and Macleod immediately shared his with James Collip. The patent for insulin was sold to the University of Toronto for one half-dollar.

The primary structure of insulin was determined by British molecular biologist Frederick Sanger. It was the first protein to have its sequence be determined. He was awarded the 1958 Nobel Prize in Chemistry for this work.

In 1969, after decades of work, Dorothy Hodgkin determined the spatial conformation of the molecule, the so-called tertiary structure, by means of X-ray diffraction studies. She had been awarded a Nobel Prize in Chemistry in 1964 for the development of crystallography.

Rosalyn Sussman Yalow received the 1977 Nobel Prize in Medicine for the development of the radioimmunoassay for insulin. George Minot, co-recipient of the 1934 Nobel Prize for the development of the first effective treatment for pernicious anemia, had diabetes mellitus. Dr. William Castle observed that the 1921 discovery of insulin, arriving in time to keep Minot alive, was therefore also responsible for the discovery of a cure for pernicious anemia.

DNA

https://ghr.nlm.nih.gov/primer/basics/dna

DNA, or deoxyribonucleic acid, is the hereditary material in humans and almost all other organisms. Nearly every cell in a person's body has the same DNA. Most DNA is located in the cell nucleus (where it is called nuclear DNA), but a small amount of DNA can also be found in the mitochondria (where it is called mitochondrial DNA or mtDNA).

DNA dodecamer structure determined by X-ray crystallography. The helical sugar-phosphate backbone strands are colored red and yellow; the bases are depicted as rectangles (G•••C base pair green, A•••T base pair red). (DOI: 10.2210/pdb1bna/pdb)

The information in DNA is stored as a code made up of four chemical bases: adenine (A), guanine (G), cytosine (C), and thymine (T). Human DNA consists of about 3 billion bases, and more than 99 percent of those bases are the same in all people. The order, or sequence, of these bases determines the information available for building and maintaining an organism, similar to the way in which letters of the alphabet appear in a certain order to form words and sentences.

DNA bases pair up with each other, A with T and C with G, to form units called base pairs. Each base is also attached to a sugar molecule and a phosphate molecule. Together, a base, sugar, and phosphate are called a nucleotide. Nucleotides are arranged in two long strands that form a spiral called a double helix. The structure of the double helix is somewhat like a ladder, with the base pairs forming the ladder's rungs and the sugar and phosphate molecules forming the vertical sidepieces of the ladder. An important property of DNA is that it can replicate, or make copies of itself. Each strand of DNA in the double helix can serve as a pattern for duplicating the sequence of bases. This is critical when cells divide because each new cell needs to have an exact copy of the DNA present in the old cell.

What Is DNA?

https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

We all know that elephants only give birth to little elephants, giraffes to giraffes, dogs to dogs and so on for every type of living creature. But why is this so?

The answer lies in a molecule called deoxyribonucleic acid (DNA), which contains the biological instructions that make each species unique. DNA, along with the instructions it contains, is passed from adult organisms to their offspring during reproduction.

Where Is DNA Found?

https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

DNA is found inside a special area of the cell called the nucleus. Because the cell is very small, and because organisms have many DNA molecules per cell, each DNA molecule must be tightly packaged. This packaged form of the DNA is called a chromosome.

During DNA replication, DNA unwinds so it can be copied. At other times in the cell cycle, DNA also unwinds so that its instructions can be used to make proteins and for other biological processes. But during cell division, DNA is in its compact chromosome form to enable transfer to new cells.

Researchers refer to DNA found in the cell's nucleus as nuclear DNA. An organism's complete set of nuclear DNA is called its genome.

Besides the DNA located in the nucleus, humans and other complex organisms also have a small amount of DNA in cell structures known as mitochondria. Mitochondria generate the energy the cell needs to function properly.

In sexual reproduction, organisms inherit half of their nuclear DNA from the male parent and half from the female parent. However, organisms inherit all of their mitochondrial DNA from the female parent. This occurs because only egg cells, and not sperm cells, keep their mitochondria during fertilization.

What Is DNA Made Of?

https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

DNA is made of chemical building blocks called nucleotides. These building blocks are made of three parts: a phosphate group, a sugar group and one of four types of nitrogen bases. To form a strand of DNA, nucleotides are linked into chains, with the phosphate and sugar groups alternating.

The four types of nitrogen bases found in nucleotides are: adenine (A), , thymine (T), guanine (G) and cytosine (C). The order, or sequence, of these bases determines what biological instructions are contained in a strand of DNA. For example, the sequence ATCGTT might instruct for blue eyes, while ATCGCT might instruct for brown.
Each DNA sequence that contains instructions to make a protein is known as a gene. The size of a gene may vary greatly, ranging from about 1,000 bases to 1 million bases in humans.

The complete DNA instruction book, or genome, for a human contains about 3 billion bases and about 20,000 genes on 23 pairs of chromosomes.

What Does DNA Do?

https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

DNA contains the instructions needed for an organism to develop, survive and reproduce. To carry out these functions, DNA sequences must be converted into messages that can be used to produce proteins, which are the complex molecules that do most of the work in our bodies.

How Are DNA Sequences Used to Make Proteins?

https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

DNA's instructions are used to make proteins in a two-step process. First, enzymes read the information in a DNA molecule and transcribe it into an intermediary molecule called messenger ribonucleic acid, or mRNA.

Next, the information contained in the mRNA molecule is translated into the "language" of amino acids, which are the building blocks of proteins. This language tells the cell's protein-making machinery the precise order in which to link the amino acids to produce a specific protein. This is a major task because there are 20 types of amino acids, which can be placed in many different orders to form a wide variety of proteins.

Who Discovered DNA?

https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

The German biochemist Friederich Miescher first observed DNA in the late 1800s. But nearly a century passed from that discovery until researchers unraveled the structure of the DNA molecule and realized its central importance to biology.

For many years, scientists debated which molecule carried life's biological instructions. Most thought that DNA was too simple a molecule to play such a critical role. Instead, they argued that proteins were more likely to carry out this vital function because of their greater complexity and wider variety of forms.

The importance of DNA became clear in 1953 thanks to the work of James Watson, Francis Crick, Maurice Wilkins and Rosalind Franklin. By studying X-ray diffraction patterns and building models, the scientists figured out the double helix structure of DNA – a structure that enables it to carry biological information from one generation to the next.

What Is the DNA Double Helix?

https://www.genome.gov/25520880/deoxyribonucleic-acid-dna-fact-sheet/

Scientist use the term "double helix" to describe DNA's winding, two-stranded chemical structure. This shape – which looks much like a twisted ladder – gives DNA the power to pass along biological instructions with great precision.

To understand DNA's double helix from a chemical standpoint, picture the sides of the ladder as strands of alternating sugar and phosphate groups – strands that run in opposite directions. Each "rung" of the ladder is made up of two nitrogen bases, paired together by hydrogen bonds. Because of the highly specific nature of this type of chemical pairing, base A always pairs with base T, and likewise C with G. So, if you know the sequence of the bases on one strand of a DNA double helix, it is a simple matter to figure out the sequence of bases on the other strand.

DNA's unique structure enables the molecule to copy itself during cell division. When a cell prepares to divide, the DNA helix splits down the middle and becomes two single strands. These single strands serve as templates for building two new, double-stranded DNA molecules – each a replica of the original DNA molecule. In this process, an A base is added wherever there is a T, a C where there is a G, and so on until all of the bases once again have partners.

In addition, when proteins are being made, the double helix unwinds to allow a single strand of DNA to serve as a template. This template strand is then transcribed into mRNA, which is a molecule that conveys vital instructions to the cell's protein-making machinery.

The Uses of DNA Fingerprinting

There are several uses of DNA fingerprinting. It is not just used for personal identification by a crime investigator but it is also used for paternity and maternity tests. DNA fingerprinting may also be used as a system of personal identification as well as used for medical purposes in detecting and curing genetic diseases.

Personal Identification

This would be the idea of keeping everyone's DNA on a computer as a bar code. This idea has been discussed and has been decided to be impractical and very expensive. It is very unlikely to become a system to be used. Picture identification cards and social security numbers are much more efficient and not likely to change.

Diagnosis and Cures for Inherited Diseases

DNA fingerprinting can also be used to detect and cure genetically inherited diseases. Using a DNA fingerprinting, one can detect genetic diseases like cystic fibrosis, hemophilia, Huntington's disease and many others. If the disease is detected at an early age it can be treated and there is a greater chance that it can be defeated. Some couples who are carriers of a disease seek out genetic counselors who can use a DNA fingerprint to help them understand the risks of their having an affected child and give them information to help them out. The fingerprints can be used by researchers to look for patterns that specific diseases have and try to figure out ways that they can cure them.

Paternity and Maternity

This is also a well known use for DNA fingerprinting. This is the test used to find out who is the father of a baby or children. Every individual has a variable number tandem repeat (VNTR) pattern which is inherited from their parents. The pattern in every individual is different but it is similar enough to reconstruct the parents' VTNR. This can also be used to determine the real biological parents of an adopted child. This test can also be used to determine legal nationality. An individual should be careful when using a test like this because it can cause surprise and that may hurt some individuals.

Criminal Identification and Forensics

This is a very famous method of DNA fingerprinting. This method has become so popular and well known because of the hit TV series CSI (Crime Scene Investigation).

This is a very important use of DNA fingerprinting because it can prove an individual's innocence or guilt of committing a crime. To be used a sample of DNA has to be obtained from the scene of the crime and matched with the suspect in question. The two pieces of DNA are then compared through VNTR patterns.

Backscatter X-ray is an advanced X-ray imaging technology. Traditional X-ray machines detect hard and soft materials by the variation in transmission through the target. In contrast, backscatter X-ray detects the radiation that reflects from the target. It has potential applications where less-destructive examination is required, and can be used if only one side of the target is available for examination.

Backscatter X-ray airport screening devices.
https://en.wikipedia.org/wiki/File:Next_Generation_Backscatter_Device.jpg
https://en.wikipedia.org/wiki/File:Backscatter_large.jpg

The technology is one of two types of whole body imaging technologies being used to perform full-body scans of airline passengers to detect hidden weapons, tools, liquids, narcotics, currency, and other contraband. A competing technology is millimeter wave scanner. These airport security machines are also referred to as "body scanner", "whole body imager (WBI)", "security scanner", and "naked scanner".

Recombinant DNA

Genetic engineering has resulted in a series of medical products. The first two commercially prepared products from recombinant DNA technology were insulin and human growth hormone, both of which were cultured in *E. coli* bacteria.

Twentieth Century Medical and Engineering Achievements from X-ray Diffraction

1. Imaging and treatment of diseases – lung X-ray images, CAT scans, and mammograms in medicine

2. Determination of crystal structures of minerals and biological molecules.

3. Understanding drug mechanisms and design of new drugs for pharmaceutical industry

4. Understanding of sickle cell anemia, thyroid gland diseases, stomach ulcer, phobias, diabetes, hypertension and genetic diseases

5. Scanning of freight cargo containers and detection of flaws in metals in airline industry

6. Scanning both checked and carryon luggage and airport security to prevent terrorism

7. Identification of minerals in the oil exploration industry

Nobel Prize Winning Discoveries in 20th Century: Saving Human Lives

*1895: Discovery of X rays by Wilhelm Conrad Röntgen. *Nobel Prize 1901*.

*1946: Pepsin: Effective medicine for digestive disorders and stomach ulcer. *Nobel Prize to John H. Northrop*.

*1954: Father of Molecular Biology; alpha-helical structure of proteins; nature of chemical bonds. *Nobel Prize to Linus Pauling*.

1959: Myoglobin is the primary oxygen-carrying pigment of muscle tissues; structure determined by John Kendrew and Max Perutz.

*1962: Hemoglobin is the oxygen-transport protein in most vertebrates – structure led to understanding of sickle cell anemia (a single amino acid substitution). *Nobel Prize to John Kendrew and Max Perutz*.

*1962: DNA: Double helical structure changed medicine; opened doors for Human Genome Project; led to discovery of genes or chromosome regions associated with phobias, diabetes, hypertension, etc., and cure for genetic diseases. Fingerprinting used in criminalist investigations by FBI. *Nobel Prize to Francis Crick, James Watson and Maurice Wilkins*.

*1964: Insulin: Treatment for Diabetes. Beta cells in the pancreas release insulin, a hormone that moves sugar from blood into cells where it is used as the body's main fuel. Dorothy Hodgkin solved the structures of cholesterol (1937), penicillin (1946) and vitamin B12 (1956), for which she was awarded the *Nobel Prize in Chemistry in 1964*. In 1969, she succeeded in solving the structure of insulin.

1998**:** Researchers at the Dana-Farber institute and Columbia University made a major breakthrough in Human Immunodeficiency Virus (HIV) research. Dr. Peter Kim was able to determine the structure of a key protein responsible for the HIV infection process.

*2009**:** Another molecular machine of profound importance – the ribosome. Not only did the fearsome structure of this gargantuan assembly of proteins and RNA yield to crystallography but it also validated one of the most startling and significant observations in the history of biochemistry – the ribosome is a ribozyme. *Nobel Prize to Venki Ramakrishnan, Thomas Steitz and Ada Yonath*.

**X-ray crystallography is the single field that has been awarded the most number of Nobel Prizes.*

<u>References</u>

1. Franklin M. Fisher, "Carl Kaysen". In Proceedings of the American Philosophical Society, Vol. 156, No. 3, September 2012.
2. "All Prizes in Economic Sciences". https://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/
3. Science Museum, Exhibition Road, South Kensington, London SW72DD. http://www.iycr2014.org
4. Personal Communications: Mayors of City of Edmond, Oklahoma and City of Tempe, Arizona.
5. The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1987: Robert M. Solow. https://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/1987/
6. Robert Merton Solow, In The Concise Encyclopedia of Economics; http://www.econlib.org/library/Enc/bios/Solow.html.
7. Global X-ray Systems Market, Strategic Market Analysis and Insight to 2015.