A biochemist

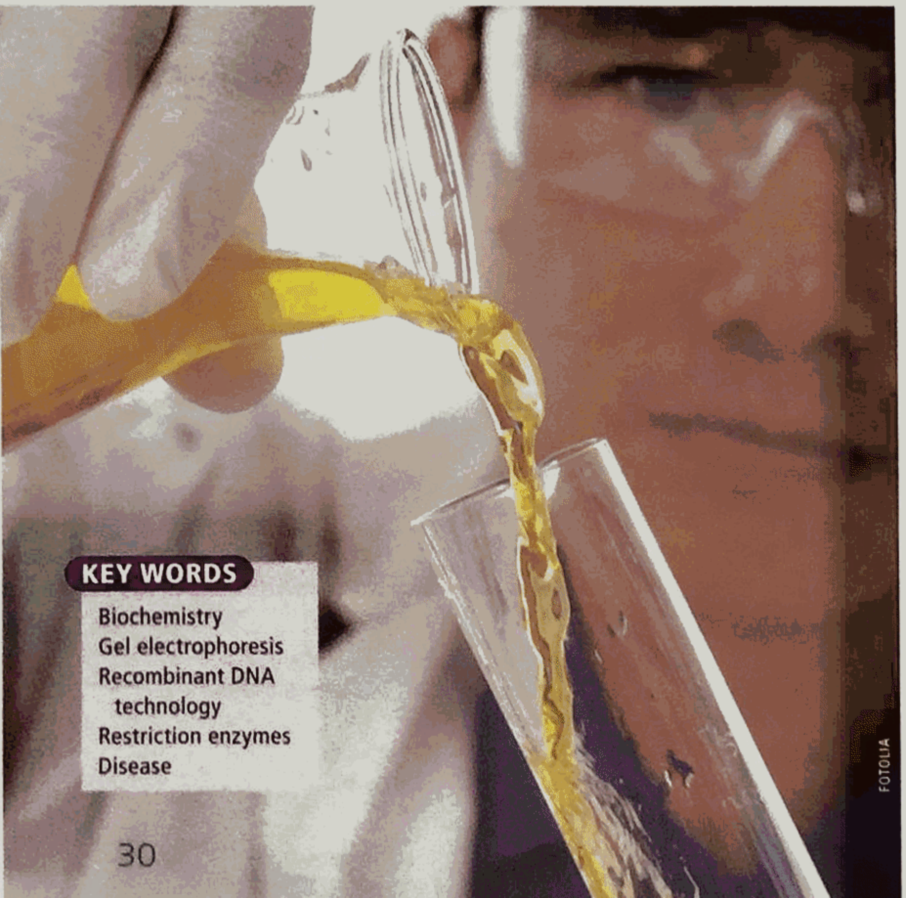
If you are thinking of science as a career and you enjoy discovering how things work on a small scale, then you may want to consider biochemistry as an option.

Biochemists work in a wide range of job sectors. Many apply their scientific knowledge to a particular field of research, selected from a variety of possibilities. The range of options is partly what makes being a biochemist so exciting, but it also makes 'a typical biochemist' difficult to define. So, before attempting to answer 'what is a biochemist?' it is helpful to start by defining what biochemistry actually is.

Biochemistry: the molecular basis of life

Simply put, biochemistry is the study of the chemical substances and processes inside living organisms. In many ways it combines biology and chemistry, by applying chemical knowledge and techniques to biological concepts and problems. However, while other biological science subjects consider parts of organisms, or whole organisms, or even groups of organisms, biochemistry is concerned with how things work on a much smaller scale — at the molecular level.

At the molecular level we can analyse the composition of a cell and explore how its different components (proteins, lipids, nucleic acids etc.) interact to allow the cell to function. This involves studying processes such as metabolic pathways, protein synthesis and DNA replication. Many of these pathways are the same in all organisms — from bacteria to humans (see pp. 2–5). We can also investigate how cells communicate with each other, improving our understanding of complex processes such as homeostasis, development, tissue repair and immunity.



KEY WORDS

- Biochemistry
- Gel electrophoresis
- Recombinant DNA technology
- Restriction enzymes
- Disease

Vital to our understanding of these processes is an appreciation of how the three-dimensional structure and chemical composition of molecules determines their function — for example, how the specific shape and amino acid sequence of an enzyme allow it to act as a catalyst. This information allows us to predict how molecules will function, meaning we can use computers to model how different substances might interact.

Biochemistry also allows us to decode the precise sequence of nucleotides in a molecule of DNA. We can then identify particular genes, the proteins they code for and the functions these proteins perform. This provides a huge amount of genetic and molecular information, which helps to enhance our knowledge of how cells function and how processes are controlled.

As well as revealing what should take place in the cell, biochemistry teaches us what happens when things don't go according to plan — for example, when a DNA mutation leads to the production of a faulty protein. Understanding how and why things go wrong allows us to make informed hypotheses about how to fix them and therefore how to treat or cure disease (see pp. 34–38).

Since biochemistry allows us to study life at the molecular level, it underpins our understanding of a wide range of other scientific disciplines. It provides the foundations of pharmacology, physiology, forensics, genetics, pathology, zoology, microbiology, plant science, and even surgery and anatomy. This breadth makes it difficult to draw a neat border around biochemistry, but also means that it offers the freedom to study the particular aspects of most interest to you.

What do biochemists do?

Biochemists investigate biochemical pathways and molecules using a range of special tools and techniques. You will probably already have heard of some of these, such as restriction enzymes (see Box 1), as part of your studies; others might be less familiar. They include laboratory-based procedures such as gel electrophoresis (see Box 2), the polymerase chain reaction (PCR, see BIOLOGICAL SCIENCES REVIEW, Vol. 24, No. 2, pp. 20–21), DNA sequencing (see pp. 34–38); recombinant DNA technology (see Box 3), cloning, western and Southern blotting, and DNA probes. In addition, the computer-based field of bioinformatics plays an increasingly important role in the advancement of biochemistry.

Research carried out by biochemists can be used for the benefit of medicine, veterinary science, agriculture, environmental science and manufacturing.

Where do biochemists work?

Biochemists can be found in sectors including hospitals and medical research units, food research institutes, forensic crime research, agriculture, academia and industry. Box 4 gives more information about the type of scientific roles they traditionally perform.

Biochemists often work in multi-disciplinary teams, collaborating with professionals from a variety of sectors. These can include chemists, physicists, healthcare professionals, government policy makers, engineers and journalists. This offers great variety and means that good communication skills are important.

Qualifications and salaries

Most biochemists will have a first degree, and often a PhD, in a biochemistry-related subject (although it is possible to enter technician-level roles straight from school). This hard work can certainly pay off, with biochemists earning in the range from £25 000 to £95 000 or more for a consultant scientist.

Alternative jobs for biochemists

The job sectors shown in Box 4 represent some of the traditional roles in which biochemists use their scientific

BOX 1

Restriction enzymes: a biochemical tool

Restriction enzymes recognise particular base sequences in DNA and cut both strands of the double helix at specific sites. Each restriction enzyme recognises a different specific sequence and has its own unique cleavage pattern. Figure 1 shows two examples, EcoRI and HaeIII.

Some restriction enzymes, such as HaeIII, make blunt, even cuts across both DNA strands. Others make staggered cuts and leave a few bases of single-stranded DNA at each end of the cleavage site, for example EcoRI. These single-stranded tails are able to form hydrogen bonds to complementary bases or to the complementary tails of other DNA fragments cut by the same restriction enzyme. They are therefore known as 'sticky ends' and are used in a whole range of techniques such as PCR (see Biological Sciences Review, Vol. 24, No. 2, pp. 20–21) and genetic engineering.

Restriction enzymes are a powerful tool for biochemists. They allow us to sequence long molecules of DNA, isolate genes, compare different mixtures of DNA and create new DNA molecules for cloning using recombinant DNA technology.

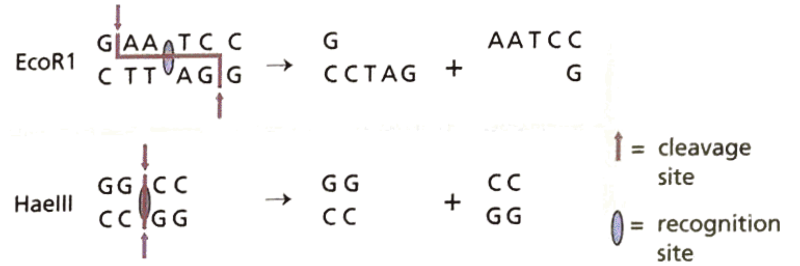


Figure 1 The restriction recognition and cleavage sites of two restriction enzymes: EcoRI (from *Escherichia coli* bacteria) and HaeIII (from *Haemophilus aegyptius* bacteria).

BOX 2

Gel electrophoresis: a biochemical technique

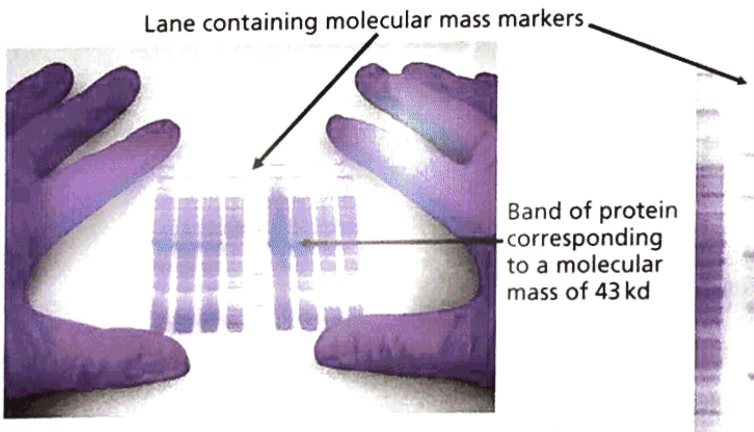
Gel electrophoresis is used to separate pieces of DNA (which may have been sliced into fragments using a restriction enzyme), RNA or protein molecules. The technique uses an electric field applied across a small gelatinous slab called a gel matrix. DNA, RNA and protein molecules all bear a charge. DNA and RNA are negatively charged due to phosphate and carboxyl groups in their sugar–phosphate backbone. Protein molecules can be positive or negative depending on their amino acid composition. When these molecules are placed in an electric field, they move towards the point of opposite charge. For example, negatively charged DNA moves towards the positively charged anode.

The gel matrix contains small pores that allow the molecules to be separated on the basis of their size. Smaller, lighter molecules can move more easily and therefore more quickly through the gel.

Once electrophoresis is complete, the molecules in the gel can be stained with a dye to make them visible. The result is a series of distinct bands, each corresponding to a molecule of a particular size that was present in the original mixture (see Figure 2).

Biochemists often load several different samples into adjacent wells in the gel. These separate samples run in parallel in their individual lanes. Doing this allows biochemists to compare the composition of different mixtures. Bands in different lanes that travel the same distance through the gel contain molecules that moved through the matrix at the same speed. This usually means they are approximately the same size. Molecular mass markers (containing compounds of known molecular mass) are used in one lane to help determine the mass of molecules in each sample.

Gel electrophoresis has a wide range of applications, including DNA fingerprinting, which is used in both forensics and genetics to compare samples of DNA.



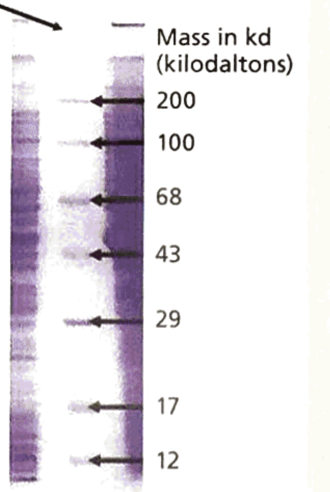


Figure 2 The results of a gel electrophoresis experiment to separate a mixture of proteins. Eight separate protein samples were used (corresponding to the eight lanes). The middle lane shows the molecular mass marker. The bands have been stained with Coomassie blue dye. Darker bands indicate the presence of a higher concentration of protein.

BOX 3

Recombinant DNA technology

Recombinant DNA technology is one example of a biochemical technique. It is used to introduce a new piece of DNA, usually a gene of interest, into an existing DNA molecule to create a hybrid. This can be cloned to generate many copies of the gene which, when expressed, produces its protein product. Figure 3 shows this process in more detail.

The required gene is isolated using a restriction enzyme. The gene is then inserted into a vector (a DNA molecule capable of replicating itself inside a suitable host), such as a bacterial plasmid or viral phage. The vector DNA will have been cut with the same restriction enzyme as the gene, to create complementary 'sticky ends'. The sticky ends from the two DNA molecules form hydrogen bonds between complementary nucleotides, and an enzyme (DNA ligase) covalently joins the inserted gene to the vector DNA.

The resulting hybrid (or recombinant) DNA molecule is then inserted into a host cell such as a yeast, mammalian or bacterial cell. These cells are said to be 'transformed'.

To identify which cells contain the recombinant DNA, the vector usually contains a gene that offers resistance to a particular antibiotic. When placed in a medium containing the antibiotic, transformed cells are able to survive while non-transformed cells die. In this way, biochemists can identify the transformed cells.

Once the transformed cells have been selected, they are cloned in large numbers. The recombinant DNA is replicated by the host cell, then transcribed and translated to synthesise the protein from the original gene of interest.

This technology has had significant effects on biochemistry. It can be used to produce useful proteins for use in medical treatment, to genetically engineer more robust crops, to identify the protein products of isolated genes and to detect genetic diseases and cancers.

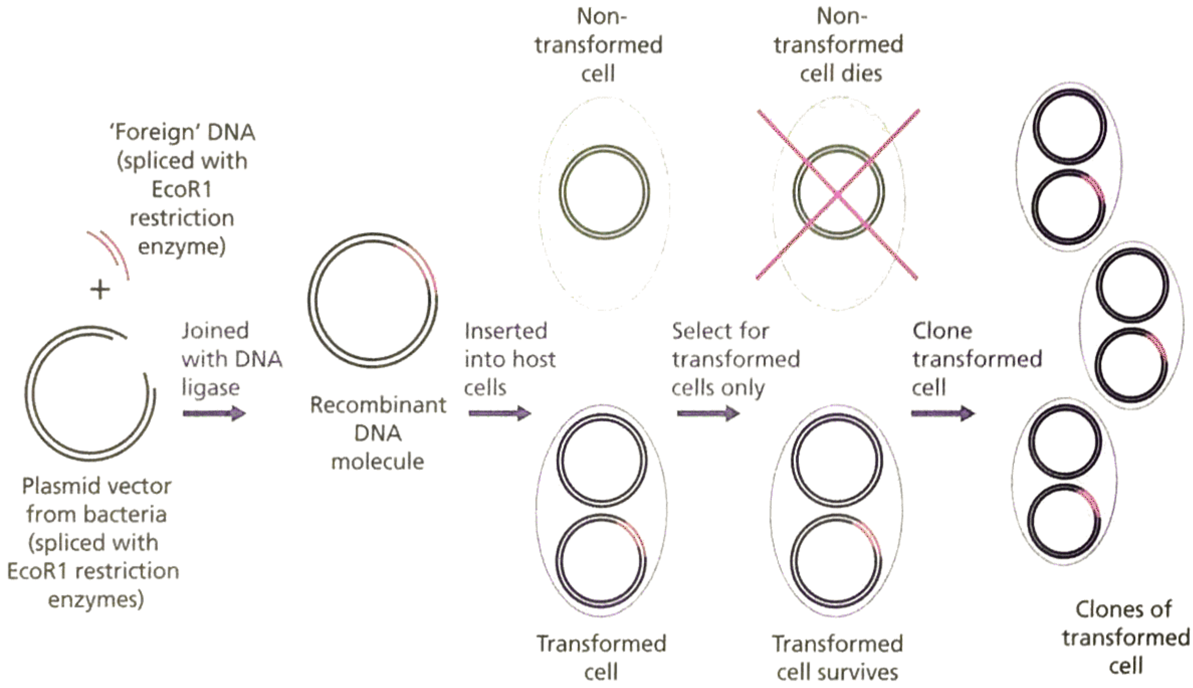


Figure 3 Overview of the production and cloning of a recombinant DNA molecule.

knowledge. However, a qualification in biochemistry opens the door to a wide range of other career opportunities. As well as practical knowledge of the subject, biochemists develop other useful skills such as problem solving, numeracy, communication, creativity, critical thinking, team working, time management and data analysis. These skills are recognised by a huge variety of employers. Therefore some biochemists find jobs that use their scientific knowledge outside a laboratory environment, in anything from science journalism, publishing or consultancy to sales and marketing or patent law. This wide range of options makes biochemistry an exciting, rewarding and flexible career choice.

Biochemical challenges and breakthroughs

Over the past 100 years, biochemists have been responsible for a number of important breakthroughs that have transformed our understanding of the subject. These discoveries have also had a profound influence on other areas of science such as medicine. Significant discoveries include the structure of DNA and RNA and their role in protein synthesis; techniques for determining the three-dimensional structure and activity of many different proteins; key metabolic pathways such as glycolysis and the Krebs cycle; hormones and cell signalling mechanisms; and the structure and functions of membranes.

The Human Genome Project

One of the most exciting ventures has been the Human Genome Project — 'the largest international collaboration ever undertaken in biology'. This and the more recent 1000 Genomes Project (see pp. 34–38) rely heavily on biochemical techniques.

A role in medicine

Biochemistry has allowed us to understand the molecular mechanisms of many diseases, such as sickle-cell anaemia and skin cancer. Techniques for measuring the level of activity of particular enzymes have become important tools in helping to diagnose certain illnesses. DNA probes can be used to detect some genetic disorders and even cancers. Recombinant DNA technology has allowed us to create genetically engineered bacteria capable of producing large

BOX 4

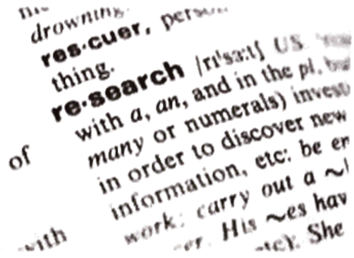
Traditional employment sectors for biochemists

Universities

Biochemists work in research groups in university laboratories, helping to drive the discovery of new ways to use molecular systems and their biological functions. They study the chemical reactions involved in metabolism, growth, reproduction, gene regulation, disease, cell signalling and heredity, helping to expand our knowledge in those areas. This, in turn, improves our understanding of all other aspects of biology. Many will also have teaching or lecturing duties in the university.

Agriculture and the environment

Biochemists help to improve agricultural outputs and to support the environment. For example, they use techniques such as genetic engineering to help develop pest-resistant crops and increase crop yields.



Research institutes

Biochemists may carry out their research in not-for-profit research institutes. They help to solve scientific problems such as curing cancer or other diseases, feeding a growing population and unravelling the human genome.

Forensic science

A range of biochemical techniques are used in forensics to help solve crimes. These include DNA fingerprinting and toxicological analyses. Biochemistry also underpins our understanding of pathology and physiology.

Industry

Biochemists work in industries including pharmaceutical, agrochemical, biotechnology, food and drink, cosmetics and brewing companies, as well as for manufacturers of materials such as polymers and plastics. They help to develop new products (including new medicines and foodstuffs) and processes and test the quality of goods.

Medicine

Working in hospitals, public health laboratories, medical research institutes and the pharmaceutical industry. Clinical biochemists provide a diagnostic service to analyse blood and other bodily fluids to help with the diagnosis and treatment of disease. In universities other biochemists do research into what causes certain diseases in order to help find a cure.

amounts of valuable proteins, such as insulin for use in the treatment of diabetes.

Other burning questions

How do our bodies fight disease? What causes cancer? What is the molecular basis of Alzheimer's disease? How do embryonic stem cells 'know' which body cells they should develop into? How are memories formed? Biochemistry is helping us to answer these and other fascinating and fundamental questions in biology.

With all the advancements biochemistry has provided over the past 100 years, who knows what it might offer us in the future?

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FURTHER READING

Biochemistry information

The Biochemical Society, 'Biochemistry across the school curriculum' booklets:
www.biochemistry.org/biochemistrybooklets

The Biochemical Society, Biochemist e-volution:
www.biochemist.org

Berg, J., Tymoczko, J. L. and Stryer, L. (2006) *Biochemistry*, 6th edn, W. H. Freeman.

Wellcome Trust, The Human Genome:
www.genome.wellcome.ac.uk

Biochemistry and careers

The Biochemical Society careers website:
www.biochemistry.org/careers

Prospects website:
www.prospects.ac.uk/options_biochemistry_job_options.htm