Nobel Lectures

Chemistry

2006 – 2010

Nobel Lectures

Including Presentation Speeches
and Laureates' Biographies

CHEMISTRY

2006 – 2010

Editor

Bengt Nordén

Chalmers University of Technology, Sweden

World Scientific

NEW JERSEY • LONDON • SINGAPORE • BEIJING • SHANGHAI • HONG KONG • TAIPEI • CHENNAI

Published by

World Scientific Publishing Co. Pte. Ltd.
5 Toh Tuck Link, Singapore 596224
USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

NOBEL LECTURES IN CHEMISTRY (2006–2010)

ISBN 978-981-4630-16-0
ISBN 978-981-4630-17-7 (pbk)

Printed in Singapore by Mainland Press Pte Ltd.

NOBEL LECTURES

CHEMISTRY

2006 – 2010

NOBEL LECTURES

INCLUDING PRESENTATION SPEECHES AND LAUREATES' BIOGRAPHIES

PHYSICS

CHEMISTRY

PHYSIOLOGY OR MEDICINE

LITERATURE

ECONOMIC SCIENCES

PREFACE

On 27th November 1895, Alfred Nobel signed his last will and testament, giving the largest share of his fortune to five prizes, the Nobel Prizes for those who confer the "greatest benefit on mankind" in *physics, chemistry, peace, physiology or medicine,* and *literature.* As described in Nobel's will one part was dedicated to "the person who shall have made the most important chemical discovery or improvement". "Chemical discovery or improvement" contrasts the criterion for the physics prize: "discovery or invention within the field of physics" of which the difference may reflect Alfred Nobel's view that chemistry, more than physics, is subject to incremental development. Whether discovery or improvement, the most deserving person for the Nobel Prize is not awarded for a lifetime achievement but for having published (a publication is thus a requirement!) some distinct result that has substantially changed our views or provided radically new methodology.

The *Nobel Laureates* in chemistry are selected by a committee that consists of five members elected by the *Royal Swedish Academy of Sciences.* In its first stage, several thousand people are invited to nominate candidates. Note that invitations as well as nominations are kept secret (for at least 50 years). The nominations are screened by the committee, and a list of approximately three hundred preliminary candidates is produced. A selected number is then scrutinized by experts invited to review and evaluate the value and consequences of each achievement. The list is typically then reduced to approximately 50 names. The committee submits a report with recommendations to the appropriate institution which, in the case of Chemistry, is the "Fourth Class" (Chemistry) of the Royal Swedish Academy of Sciences. It confirms or modifies the proposed name(s) to be awarded. Thereafter the whole Academy in Plenum is presented the suggestion and decides after voting. Then at a Press Conference, the Prize is made public. This slow and thorough process of scrutiny is arguably one component that gives the prize its unique value. A prize amount may be equally divided between two works, each of which is considered to merit a prize. If a work that is being rewarded has been produced by two or three persons, the prize shall be awarded to them jointly. In no case may a prize amount be divided among more than three persons. A majority of the Chemistry Nobel Prizes have been given to one Laureate (63 persons), while 23 to two and 19 to three persons.

The award in chemistry requires the significance of achievements being "tested by time." In practice this means that the investigations have proven beyond doubt that the people identified are the true discoverers as well as time has shown the impact of their achievements. This means that there is a lag between the discovery (improvement) and the award by typically the order of 10 years and sometimes much longer. As a downside of this approach, not all scientists live long enough for their work to be recognized. Some important scientific discoveries are never even considered for a Prize as the discoverers may have died by the time the impact of their work is realized.

Here we can enjoy reading about the Nobel Prizes in Chemistry awarded during 2006–2010, and the presentations given by the Nobel Laureates who are spanning a very wide range of fields, from discoveries related to molecular function in biology and medicine, to new ways of putting molecules together, a field that is mainly organic chemistry and which has dominated the Nobel Prizes in Chemistry over the years.

The Nobel Prize in Chemistry for 2006 was awarded to **Roger Kornberg** "for his studies of the molecular basis of eukaryotic transcription". This prize is an example of the centre-stage role chemistry has in providing mechanistic understanding of complex biological processes — in this case explaining transcription, the copying of the genetic code for instruction of how proteins are to be constructed. What Roger Kornberg himself has done is to describe how the genetic information is copied from DNA into what is called messenger-RNA. The messenger-RNA carries the information out of the cell nucleus so that it can be used to construct the proteins in the various cells. There it is used as an instruction for protein production — it is the proteins that in their turn actually run the organism and its function. Transcription is necessary for all life. This makes the detailed description of the mechanism that Roger Kornberg provides exactly the kind of "most important chemical discovery" referred to by Nobel in his will.

The Nobel Prize in Chemistry for 2007 was awarded to **Gerhard Ertl** for groundbreaking studies in surface chemistry. This science is important for the chemical industry and can help us to understand such varied processes as why iron rusts, how fuel cells function and how the catalysts in our cars work. Chemical reactions on catalytic surfaces play a vital role in many industrial operations, such as the production of artificial fertilizers. Surface chemistry can even explain the destruction of the ozone layer, as vital steps in the reaction actually take place on the surfaces of small crystals of ice in the stratosphere. The semiconductor industry is yet another area that depends on knowledge of surface chemistry. It was thanks to processes developed in the semiconductor industry that the modern science of surface chemistry began to emerge in the 1960s. Ertl was one of the first to see the potential of these new techniques. Step by step he has created a methodology for surface chemistry by demonstrating how different experimental procedures can be used to provide a complete picture of a surface reaction.

In 2008 the Nobel Prize in Chemistry was shared among three scientists whose achievements together form a chain of discoveries and improvements which at the end provides a novel tool by which bio-molecular function may be visualized in the cell with unique precision. **Osamu Shimomura** was the first to isolate a protein from a jellyfish and he discovered that this protein glowed bright green under ultraviolet light — it is called Green Fluorescent Protein (GFP). **Martin Chalfie** then demonstrated the value of GFP as a luminous genetic tag for various biological phenomena. **Roger Tsien** contributed by explaining the mechnism why GFP fluoresces and extended this knowledge to synthesize a colour palette beyond green allowing researchers to give various proteins and cells different colours. This enables scientists to follow several different biological processes at the same time. With the aid of GFP, researchers have developed ways to watch processes that were previously invisible, such as the development of nerve cells in the brain or how cancer cells spread.

The Nobel Prize in Chemistry for 2009 awards studies of one of life's core processes: the ribosome's translation of DNA information into life. Ribosomes are machines that produce proteins, who in turn control the chemistry in all living organisms. As ribosomes are crucial to life, they are also a major target for new antibiotics. However, the ribosomes are huge, very complex and therefore hard to approach with standard structure-analytical tools. The Nobel Prize awards **Venkatraman Ramakrishnan**, **Thomas Steitz** and **Ada Yonath** for having shown what the ribosome really looks like and also how it functions at the atomic level. All three have used a method called X-ray crystallography to map the position for each and every one of the hundreds of thousands of atoms that make up the ribosome. The Laureates have generated 3D models that also show how different antibiotics may bind to the ribosome. These models are now used by scientists in order to develop new antibiotics, directly assisting the saving of lives and decreasing humanity's suffering.

The 2010 Nobel Prize in Chemistry was in Organic Chemistry and awarded to **Richard Heck**, **Ei-ichi Negishi** and **Akira Suzuki** for their development of novel methods to synthesize carbon-based molecules. Carbon-based (organic) chemistry is the basis of life and is responsible for numerous fascinating natural phenomena: colour in flowers, snake poison and bacteria-killing substances such as penicillin. Organic chemistry has allowed man to build on nature's chemistry, making use of carbon's ability to provide a stable skeleton for functional molecules. This has given us new medicines and new materials such as plastics. In order to create these complex chemicals, chemists need to be able to join carbon atoms together. However, carbon is stable and carbon atoms do not easily react with one another. The first methods used by chemists to bind carbon atoms together were therefore based upon various techniques for rendering carbon more reactive. Such methods worked when creating simple molecules, but when synthesizing more complex molecules chemists ended up with too many unwanted by-products in their test tubes. The particular techniques that the three scientists developed, so called palladium-catalyzed cross coupling, were very selective and could be used to synthesize molecules as complex as those created by nature itself.

This book should give a vivid picture of what is really going on at the various molecular research frontiers, as represented by the scientists and their works that have been awarded by the Nobel Prizes in Chemistry during 2006–2010. It should illustrate the wealth of the world of molecules and the impact molecular sciences has in widely different contexts which are important to us. I wish the reader an enjoyable and inspiring reading.

Bengt Nordén
Editor

CONTENTS

Chemistry 2006

Roger D. Kornberg

"for his studies of the molecular basis of eukaryotic transcription"

THE NOBEL PRIZE IN CHEMISTRY

Speech by Professor Lars Thelander of the Royal Swedish Academy of Sciences. Translation of the Swedish text.

Your Majesties, Your Royal Highnesses, Ladies and Gentlemen,

This year's Nobel Laureate in Chemistry is receiving the award because he succeeded in creating a molecular model of the apparatus in our cells that copies information in the genes to enable its use as a blueprint to create the proteins that perform all the functions in the cells and form the body.

The genetic information that we inherit from our parents is stored inside the nucleus of our cells in the form of DNA. This information is encoded in an alphabet consisting of four letters and for some years now we have known the sequence of the 3 billion characters that describe the genetic information in a human cell. The nucleus of a cell is a very secure repository that could be compared to a safe, but stored inside it the information is passive and of no benefit to the cell. To regulate the processes in the cell the information has to be extracted from the DNA and activated, and this occurs when selected sections are copied into a new type of molecule called RNA. In the form of RNA, the information can then be transferred from the nucleus to regulate the synthesis of proteins and other important reactions in the cell.

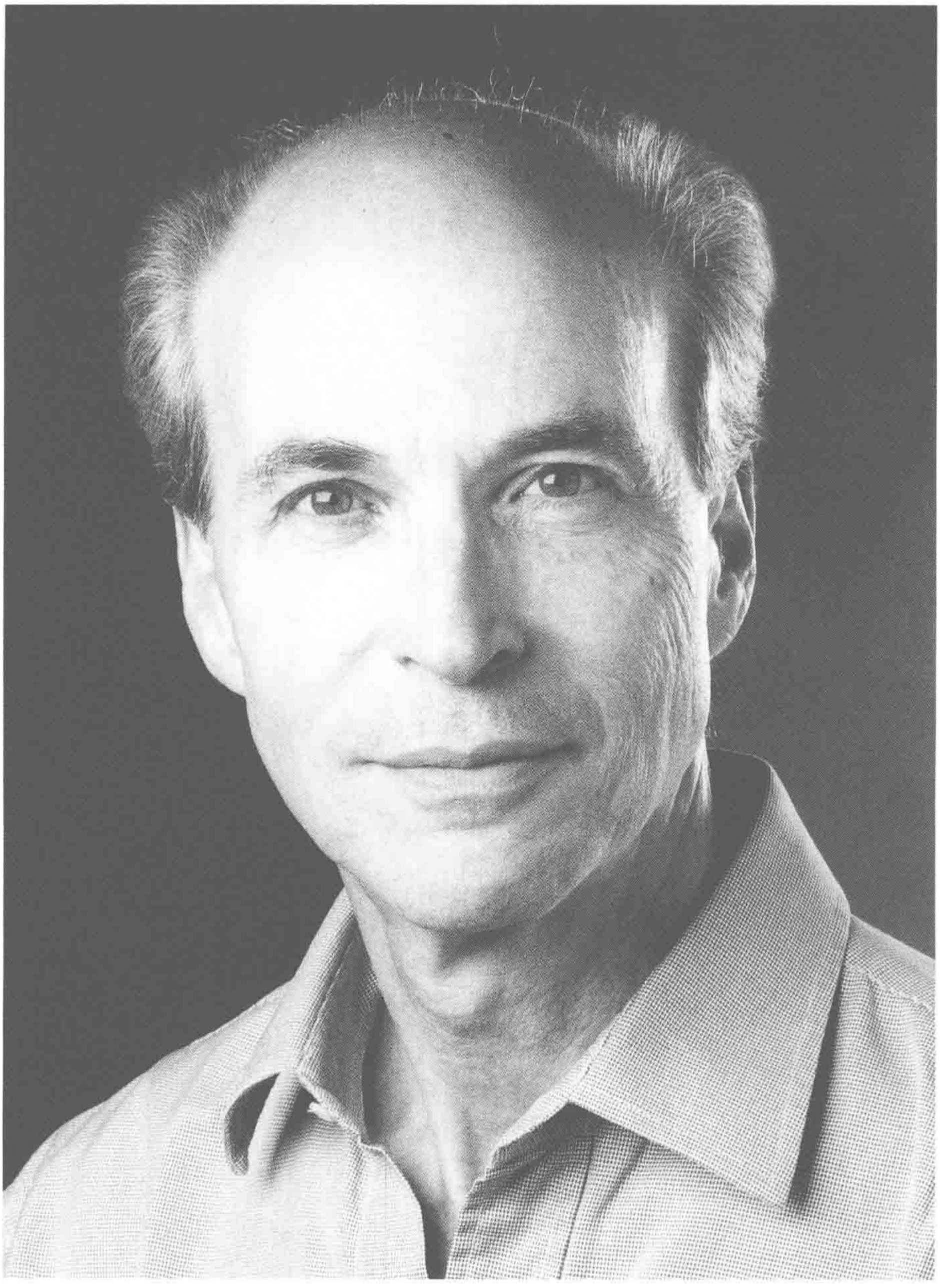
Copying the information from DNA to RNA is called transcription. This takes place continually in living cells and is absolutely essential for life. Transcription has to fulfil two different requirements. The first is that the copy must be exact. No more than one error in 10,000 characters can be tolerated, if a cell is to function. Secondly it must be possible to regulate the transcription so that only certain elements of the genetic information in the DNA are activated in a specific cell at a specific time. It is this regulation that explains why different cells in our body look completely different and have different functions, even though they contain the same DNA. Regulation of transcription governs the way in which a fertilised ovum can develop into an embryo and also how our cells can respond to external signals so that we can adapt to changes in our environment. Errors in the regulation of transcription may result in illnesses such as cancer, heart disease and various inflammations.

This year's Laureate in Chemistry, Roger Kornberg, has studied what the transcription apparatus looks like in eukaryotes, organisms with cells that have a defined nucleus, which include all fungi, plants and mammals, human beings as well. In choosing the model system for his studies he swam against the stream and selected baker's yeast, which is one of the simplest eukaryotes. This was a crucial choice, as yeast cells offer a number of advantages in this endeavour compared to the cells from mammals that had previously been used. For instance, it is possible to cultivate yeast on a large scale and to benefit from the simplicity with which yeast cells can be modified genetically. The transcription apparatus in yeast cells is very similar to the corresponding system in mammal cells, which suggests that it came into being at a very early stage of development.

By combining biochemical methods and a depiction technique called X-ray crystallography, Roger Kornberg succeeded in producing particularly detailed molecular models of the transcription apparatus in yeast cells. These models are so detailed that individual atoms can be discerned. Through the study of a host of different models of the transcription apparatus both on its own and while fully engaged in copying DNA to RNA, Kornberg has been able to draw new, important conclusions about the mechanisms of transcription and how it is regulated. As a result of his study we now understand, for instance, how the transcription apparatus chooses where to start copying on the DNA strand, how it selects the correct RNA building blocks and how it moves along the DNA strand while the copy is being made. Kornberg's molecular models of the transcription apparatus are essential for any continued studies that attempt to acquire detailed understanding of how transcription is regulated. He has recently published very promising results that describe how several molecules that are also needed in transcription bind to and co-operate with the transcription apparatus. These findings make it possible to begin to understand at a molecular level the system of regulation in the cell that expresses the genetic information in DNA and generates the flora and fauna of living creatures that we see around us.

Professor Kornberg,

Your studies of the molecular basis of eukaryotic transcription have provided us with new, detailed atomic models of the transcription apparatus. We can now begin to understand at molecular level the mechanisms of transcription and its regulation. Furthermore, your structure of RNA polymerase II is the basis for the next generation of research to determine the precise role of all transcription factors in transcriptional regulation. On behalf of the Royal Swedish Academy of Sciences, I wish to convey to you our warmest congratulations, and I now ask you to step forward to receive the Nobel Prize in Chemistry from the hands of His Majesty the King.



Roger D. Kornberg