

## CURRICULUM VITAE

### **Marvin H. Caruthers**

Place and Date of Birth: Des Moines, Iowa  
February 11, 1940

Educational Background:

B.S.	Iowa State University	1962
Ph.D.	Northwestern University (Thesis advisor: Professor Robert L. Letsinger)	1968

Academic Positions:

Predoctoral Fellow, Northwestern University	1963-68
Postdoctoral Fellow, University of Wisconsin	1968-70
Research Associate, Massachusetts Institute of Technology	1971-72
Senior Research Scientist, Massachusetts Institute of Technology	1972-73
Assistant Professor, University of Colorado	1973-78
Associate Professor, University of Colorado	1978-79
Professor, University of Colorado	1979-2000
Chairman, Department of Chemistry & Biochemistry	1992-1995
Distinguished Professor, University of Colorado	2000-

Honors and Awards:

USPHS Graduate Traineeship in Biochemistry	1963-64
USPHS Predoctoral Fellowship	1965-68
USPHS Postdoctoral Fellowship	1968-70
USPHS Career Development Award	1975-80
Guggenheim Fellow	1980-81
Council on Research and Creative Work, Faculty Research Lectureship	1984-85
Outstanding Faculty Researcher Award, Colorado Chapter, Golden Key National Honor Society	1986
International Biotechnology Ventures Award	1992
Elliott Cresson Medal of The Franklin Institute	1994
Elected Member, American Academy of Arts & Sciences	1994
Elected Member, National Academy of Sciences	1994
Bonfils-Stanton Award for Science	1995
Alumni Merit Award, Northwestern University	1996
Doctor of Science Honorary Degree University of Nebraska	1996
ABRF — Hewlett Packard Award for Outstanding Contributions to Biomolecular Technologies	1999
Lifetime Achievement Award, Esprit Entrepreneur Awards	2003
Citation of Merit, Iowa State University Alumni Association	2003
Esprit Entrepreneurship Award, Boulder Chamber of Commerce	2004
Lifetime Achievement Award, Colorado Bioscience Association	2004
Prelog Medal in Recognition of Pioneering Work on the Chemical Synthesis of DNA, ETH, Zurich Switzerland	2004
National Academy of Sciences Award for Chemistry in Service to Society	2005
Promega Biotechnology Research Award, ASM, Orlando, FL	2006
The Economist Innovation Award, London, England	2006
National Medal of Science, Washington, D.C.	2006
Imbach-Townsend Award of the International Society of Nucleic Acid Research	2006

Robert Stearns Award for Extraordinary Contributions to the University of Colorado	2008
Iowa State University Distinguished Alumnus Award	2009
Girindus Leadership in Oligonucleotides Award	2009
Icon of Boulder Award	2009
Boulder County Business Hall of Fame Award	2010
The Biotech Meeting 25 <sup>th</sup> Anniversary Hall of Fame Recognition Award, Laguna Beach, CA.	2012
National Academy of Science Award in Chemical Sciences	2014
ACS Award for Creative Invention	2014
Frantisek Sorm Medal, Academy of Sciences of the Czech Republic	2014
Elected as a Corresponding Member of the Academy of Sciences Göttingen, Germany	2015
Selection Committee for the National Blavatnik Awards	2017
Selection Committee for the University of Colorado Distinguished Professors	2017
Oligonucleotide Therapeutic Society Lifetime Achievement Award	2018
Elected National Inventors Hall of Fame	2018
Elected American Association Advancement of Science Fellow	2018
Elected National Academy of Inventors	2018

Citation Classics Recognition in *Current Contents: Physical, Chemical and Earth Sciences* 27, 12 (1987) for S. L. Beaucage and M. H. Caruthers, Deoxynucleoside Phosphoramidites - A New Class of Key Intermediates for Deoxypolynucleotide Synthesis, *Tetrahedron Letters* 22, 1859 (1981). The number of citations by 1987 was 265. As of August 1996, the number had increased to 1216.

Citation Classics Recognition in *Current Contents: Engineering, Technology and Applied Sciences* 18 (1987) for S. L. Beaucage and M. H. Caruthers, Deoxynucleoside Phosphoramidites - A New Class of Key Intermediates for Deoxypolynucleotide Synthesis, *Tetrahedron Letters* 22, 1859 (1981).

Reproduction of M. D. Matteucci and M. H. Caruthers, Synthesis of Deoxyoligonucleotides on a Polymer Support, *J. Am. Chem. Soc.* 103, 3185 (1981) in *Milestones in Biotechnology, Classic Papers on Genetic Engineering* (J. Davis and W. S. Reznikoff, Editors), Butterworth-Heinemann, Stoneham, Mass. (1992), pp. 92-98.

#### Professional Societies:

American Chemical Society  
Phi Lambda Upsilon  
Alpha Chi Sigma  
American Association for the Advancement of Science  
American Society of Biological Chemists  
National Academy of Sciences  
American Academy of Arts and Sciences  
International Society for Nucleosides, Nucleotides and Nucleic Acids  
Oligonucleotides Therapeutic Society

#### Other Professional Activities :

Scientific Advisory Board - AMGEN Inc.	1980-1988
Consultant - AMGEN Inc.	1980-1998
Consultant - Applied Biosystems Inc.	1980-1987
Consultant - Nordberg Capital Inc.	1988-1995

Consultant - Hagstroemer and Nordberg Selective Fund-Biotechnology	1988-1990
Nucleic Acids Editorial Board	1980-1982
Co-Chairman of the Nucleic Acids Gordon Conference	1981
Scientific Organizing Committee - ASBC	1981
Co-organizer of the Letsinger Symposium, Evanston, IL	1987
Journal of Biotechnology Editorial Board	1982-1986
Journal of Protein Engineering Editorial Board	1986-1990
Journal of Molecular Recognition Editorial Board	1987-1989
Board of Directors, Skandigen AB	1988-1998
Board of Directors, Biostar	1990-1998
Board of Directors, Access Pharmaceuticals	1990-1995
AIDS and Related Research Study Section (NIH)	1988-1993
Co-Chairman of IUB Conference on Nucleic Acids Therapeutics	1991
National Academy of Sciences Board on Chemical Sciences and Technology	1994-1997
Board of Directors, Oxigene	1998-2003
Board of Directors, Genomica	1999-2001
Boulder Ventures, Advisory Committee	1997-
Board of Directors, Array Biopharma	1998-2011
Consultant – Nanogen	1998-2005
Board of Directors, Dharmacon	2001-2004
Board of Trustees, University of Puget Sound	2003-
Member, National Research Council Workshop on DNA/Formalin	2006
Board of Directors, Barofold	2006-2009
Executive Advisory Board for the Chemistry of Life Processes Institute, Northwestern University	2006-
Selection Committee, the Economist's Innovation Awards	2007-2011
Chemical Sciences Roundtable, National Academy of Science	2007-2011
Board of Directors, miRagen	2008-2016
Consultant - AmideBio	2009-
Systems Biology Advisory Council, Harvard University	2010-2014
Board of Directors, ArcherDX	2017-
Co-Founder of Amgen, Applied Biosystems, Genomica, Barofold, Array BioPharma and miRagen.	

Ph.D. Degrees Conferred:

D. V. Goeddel (recipient of ACS Eli Lilly Award in Biological Chemistry; elected National Academy of Science, 1994)	1977
E. Kawashima	1979
M. Matteucci	1980
E. Fisher	1983
J. Dubendorff	1984
L. McBride	1985
L. Bracco	1989
W. Brill	1989
P. deLannoy	1990
D. Dellinger	1991
W. Marshall	1991
L. Cummins	1992
D. Graff	1995
P. Seeberger	1995
M. Willis	1995
S. Scaringe	1996
J. Lee	1996
C. Greef	1997
K. Jenkins	1999
D. Sheehan	2001
B. Lunstad	2002
H. Brummel	2002
C. Yamada	2003
B. Stell	2013
A. Alawneh	2018

Master Degrees Conferred:

D. G. Yansura	1978
P. Feist	1978
H. Sista	1979
C. Winston	1980
M. Insley	1980
J. Carlson	1981
M. Dorman	1982
A. Walsh	1984
J. Sutton	1985
S. Roman	1991
A. Marble	1992
J. Jordan	1997
C. Ives	2000

Patents (U. S. and Early Japanese and European Patents, Other Countries Excluded):

- Process for Preparing Polynucleotides. U. S. Patent No. 4458066
- Process for Preparing Polynucleotides. U. S. Patent No. 5153319
- Phosphoramidite Compounds and Processes. U. S. Patent No. 4415732
- Nucleosides Useful in the Preparation of Polynucleotides. U. S. Patent No. 4500707
- Phosphoramidite Nucleoside Compounds. U. S. Patent No. 4668777
- Hybrid Lymphoblastoid-Leukocyte Human Interferons. U.S. Patent No. 4716217
- DNA Sequences Encoding Hybrid Lymphoblastoid Leukocyte Human Interferons. U. S. Patent No. 4734491
- Process for Oligonucleotide Synthesis Using Phosphoramidite Intermediates. U. S. Patent 4973679.
- Process for Preparing Polynucleotides. U.S. Patents 5132418. and 5153319
- Nucleoside Thiophosphoramidites. U. S. Patent 5218103
- Polynucleotide Phosphorodithioates. U. S. Patent 5278302
- Polynucleotide Phosphorodithioate. U. S. Patent 5453496
- Polynucleotide Phosphorodithioate Compounds. U. S. Patent 5602244
- Nucleoside Thiophosphoramidites. U. S. Patent 5684148
- Inhibition of Reverse Transcriptase by Phosphorodithioates. U. S. Patent 5695979
- Polynucleotide Phosphorodithioate Compounds. U. S. Patent 5750666
- Orthoester Protecting Groups in RNA Synthesis. U. S. Patent 5889136
- Metal Dependent Catalytic Antibodies and Method for Producing the Same. U.S. Patent 5962291
- Solid Phase Synthesis of Oligonucleotides Using Carbonate Protecting Groups and Alpha-Effect Nucleophile Deprotection. U.S. Patent 6222030
- Process for Removing Trityl Blocking Groups from 5'-O-Trityl Nucleosides and Oligonucleotides. European Patent No. 0035255
- Modified Inorganic Polymers. European Patent No. 0035719
- Phosphoramidite Compounds and Their Use in Producing Oligonucleotides. European Patent No. 0061746
- Process for Preparing Modified Inorganic Polymers. European Patent No. 0173356
- Support for Use in Synthesis of Polynucleotides and Process for Making the Same. Japanese Patent No. 1,484,971
- Process for Producing Oligonucleotides. Japanese Patent No. 1,515,844
- Monomers for Solid Phase Synthesis of Oligonucleotides Using Carbonate Protecting Groups and Alpha-Effect Nucleophile Deprotection. U. S. Patent 6630581
- Synthesis of Polynucleotides Using Combined Oxidation/Deprotection Chemistry. U. S. Patent 7135565 B2
- Methods of Synthesizing Oligonucleotides Using Carbonate Protecting Groups and Alpha-effect Nucleophile Deprotection. U. S. Patent 7101986 B2

Orthoester Reagents for Use as Protecting Groups in Oligonucleotide Synthesis. U. S. Patent 6008400

Exocyclic Amine Triaryl Methyl Protecting Groups in Two-Step Polynucleotide Synthesis. U. S. Patent 7193077 B2

Methods of Oligonucleotide Synthesis Using Carbonate Protecting Groups and Alpha-Effect Nucleophile Deprotection. U. S. Patent 7271258 B2

Phosphorus Protecting Groups. U. S. Patent 7368550 B2

Cleavable Linker for Polynucleotide Synthesis. U. S. Patent 7385050 B2

Method for Polynucleotide Synthesis. U. S. Patent 7417139 B2

Precursors for Two-Step Polynucleotide Synthesis. U. S. Patent 7427679

Uses of Cationic Salts for Polynucleotide Synthesis. U. S. Patent 7524950 B2

Methods and Compounds for Polynucleotide Synthesis. U. S. Patent 7572907 B2

Cleavable Linkers for Polynucleotides. U. S. Patent 7572908 B2

Monomer Compositions for the Synthesis of RNA, Methods of Synthesis, and Methods of Deprotection. U.S. Patent 7759471

Thiocarbonate Linkers for Polynucleotides. U. S. Patent 7790387

Cleavable Thiocarbonate Linkers for Polynucleotide Synthesis. U.S. Patent 7855281

2'-Silyl Containing Thiocarbonate Protecting Groups for RNA synthesis. US Patent 7999087

Thioester Substituted Aryl Carbonate Protecting Group. US Patent 8097711

Thiocarbon-Protecting Groups for RNA Synthesis. US Patent 8202983

Monomer Compositions for the Synthesis of Polynucleotides, Methods of Synthesis, and Methods of Deprotection. U. S. Patent 8202985

Protecting Groups for RNA synthesis. U. S. Patent 8242258

Methods of Synthesizing Oligonucleotides Using Carbonate Protecting Groups. US Patent 8309706

Monomer Compositions for the Synthesis of RNA, Methods of Synthesis, and Methods of Deprotection. European patent 2597964

Solutions, Methods, and Processes for Deprotection of Polynucleotides. U. S. Patent 8552174

Thiocarbon-protecting groups for RNA Synthesis. U. S. Patent 9067961 B2

Current Research Support:

C. U. Foundation, Fund 0122649, Marvin Caruthers Research Fund

Agilent Technologies, Research Plan: Improved Long RNA Purification 06/01/2017- 2/28/2020

Agilent Technologies, Research Plan: Improved Long RNA Synthesis 11/01/2012- 2/28/2020

Agilent Technologies, Research Plan: 2-step DNA Synthesis 08/01/2011-10/31/2019

Agilent Technologies, Research Plan: Chemistries for Advanced Sequencing 5/1/2016-4/30/2019

Invited Symposium Lectures:

38th Annual Meeting of the Genetics Society of America. Symposium Session (1969) Madison, Wisconsin. "Current Work on the Total Synthesis of the Gene for an Alanine Transfer RNA."

Meeting of the American Association for the Advancement of Science, Symposium Session on Living Systems: Synthesis, Assembly, Origins (1971) Philadelphia, Pennsylvania. "Chemical and Enzymatic Synthesis of Completely Defined DNA."

Sixth International Symposium on Molecular Biology sponsored by Miles Laboratories at Johns Hopkins University (1973). "Current Work on the Synthesis of Transfer RNA Genes."

Nucleic Acids Gordon Conference (1975). "Polymer Supported Nucleic Acid Synthesis."

Symposium on Molecular Aspects of *Lac* Operon Control. Cold Spring Harbor Laboratories (1976) Cold Spring Harbor, New York. "Studies on *Lac* Operator-*Lac* Repressor Interactions."

Eleventh International Congress of Biochemistry (1979) Toronto, Canada. "Gene Regulatory Proteins and How They Interact with DNA. "

Gordon Research Conference on Nucleic Acids (1979) New Hampton, New Hampshire. "The *Lac* Repressor-*Lac* Operator Interaction."

Gordon Research Conference Nucleic Acids (1980) New Hampton, New Hampshire. "Modern Methods of Polynucleotide Synthesis."

International Symposium on Chemical Synthesis of Nucleic Acids (1980) Hamburg, Federal Republic of Germany. "Synthesis of Oligodeoxynucleotides on a Polymer Support."

IUPAC International Symposium on Macromolecules (1980) Florence, Italy. "Synthesis of Sequence Defined Polynucleotides via Diester, Triester and Phosphite Coupling Methods."

Symposium on Promoters: Structure and Function (1981) Monterey, California. "New Methods for Synthesizing Promoters and Other Gene Control Regions."

Third Cleveland Symposium on Macromolecules (1981) Cleveland, Ohio. "The Design and Synthesis of Gene Control Regions Useful for Genetic Engineers."

A Symposium of the Nucleotide and Nucleic Acids Group of the Biochemical Society and the Royal Society of Chemistry (1981) Cambridge, England. "Solving Important Biological Problems with Synthetic Oligonucleotides."

Symposium on the Applications of Genetic Engineering in Basic Sciences, Medicine and Agriculture (1981) Cairo, Egypt. "Organic Chemical Synthesis of Genes."

Life Science '81 (1981) New York City, New York. "Methods for Synthesis of Oligonucleotides."

Twelfth International Symposium of the Princess Takamatsu Cancer Research Fund (1981) Tokyo, Japan. "The Application of Nucleic Acid Chemistry to Studies on the Functional Organization of Gene Control Regions."

The Fourteenth Miami Winter Symposium (1982) Miami, Florida. "The Synthesis and Biochemical Reactivity of Biologically Important Genes and Gene Control Regions."

Second Annual Congress for Recombinant DNA Research (1982) Los Angeles, California. "The Role of Synthetic DNA in Recombinant DNA Research."

EMBO Workshop on Prospects of Automation in Gene Synthesis (1982) Darmstadt, West Germany. "Our Cloning Work with Synthetic DNA."

Meeting-in-Miniature of the Colorado Section of the American Chemical Society (1982) Denver, Colorado. "Applications of DNA Chemistry to Biological Problems."

Cold Spring Harbor Meeting on *in vitro* Mutagenesis (1982) Cold Spring Harbor, New York. "Chemical Synthesis and Biological Studies on Mutated Promoters."

XLVII Cold Spring Harbor Symposium on Quantitative Biology, Structures of DNA (1982) Cold Spring Harbor, New York. "Chemical Synthesis and Biological Studies on Mutated Gene Control Regions."

Eleventh Biennial Symposium on High Performance Polymers (1982) San Juan, Puerto Rico. "Gene Synthesis-Toward a Future World."

Tenth Anniversary Symposium on Nucleic Acid Chemistry (1982) Kyoto, Japan. "How To Do Genetics Through Chemistry."

Seventh Annual Parvin Cancer Research Laboratories Symposium on Basic Cancer Research (1983) UCLA, Los Angeles, California. "Directed Mutagenesis of Gene Control Regions."

Meeting of the American Association for the Advancement of Science. Symposium Session on Polynucleotide Chemistry and the Regulation of Life (1983) Detroit, Michigan. "Recent Advances in the Chemistry of Polynucleotides and Some Applications to Biological Research."

Cologne Spring Meeting on Protein-DNA Interactions (1984) Cologne, Federal Republic of Germany. "Cro Repressor-Operator and *lac* Repressor-Operator Complexes."

Joint Meeting of the Great Lakes and Central Regions of the American Chemical Society (1984) Kalamazoo, Michigan. "Synthesis of Cro Protein Mutant Genes."

Workshop on Synthetic Oligonucleotides: Chemistry and Applications, University of Rochester Medical Center (1984) Rochester, New York. "Directed Mutagenesis Studies in Gene Regulation Sequences."

16th Meeting of the Federation of European Biochemical Societies (1984) Moscow, USSR. "Chemical and Biochemical Studies on Gene Control Regions."



14th International Symposium on the Chemistry of Natural Products, IUPAC, Colloquium on the Synthesis of Nucleic Acid Fragments (1984) Poznan, Poland. "Synthesis of Oligodeoxynucleotides Using the Phosphoramidite Method."

American Chemical Society Annual Meeting, Lilly Award Symposium (1984) Philadelphia, Pennsylvania. "Biochemical Studies Using Synthetic DNA."

Symposium on the Chemistry of Heterocyclic Compounds (VIIIth) and Nucleic Acid Components (VIth) (1984) Prague, Czechoslovakia. "New Chemical Methods for Synthesizing Oligodeoxynucleotides."

Symposium on Chemical Synthesis in Molecular Biology (1984) Braunschweig, Federal Republic of Germany. "Protein-DNA Recognition: The Interaction of *Lac*, *Cro*, and *E. coli* RNA polymerase with Operators and Promoters."

From Genes to the Clinic - A Symposium in Molecular Biology (1984) Stockholm, Sweden. "New Methods for the Synthesis and Assembly of Complete Genes."

Vth International Round Table on Nucleosides, Nucleotides and Biological Applications (1984) Montpellier, France. "Synthesis of Oligodeoxynucleotides Using Amidine Protected Nucleosides."

Japan First Biotechnology Symposium (1984) Tokyo and Kyoto, Japan. "Nucleic Acid Chemistry and Its Application to Molecular Biology and Biotechnology."

UCLA Symposium on Molecular Biology (1985) Keystone, Colorado. "The Interaction of *Cro*, *cl*, and *E. coli* RNA Polymerase with Operators and Promoters."

Meeting of the American Society of Biological Chemists. Workshop on DNA Synthesis (1985) Anaheim, California. "The Chemical Synthesis of RNA."

Peter A. Leermakers Symposium, The Changing Face of Organic Synthesis (1985) Middletown, Connecticut. "How To Do Genetics Through Chemistry."

Twenty-Fourth Harden Conference, Protein Engineering and Site Directed Mutagenesis (1985) Wye College, Ashford, Kent, United Kingdom. "New Chemical Methods for Synthesizing Polynucleotides and Biochemical Applications of These Procedures."

Progress in Nucleic Acids Research, 1953-1985, A Symposium Honouring Professor H. Gobind Khorana (1985) Cambridge, United Kingdom. "Oligodeoxynucleotide Synthesis and Applications."

The Second International Congress on Synthetic Oligonucleotides in Molecular Biology (1985) Uppsala, Sweden. "Protein-DNA Recognition: The Interaction of *lac*, *cro*, and *E. coli* RNA Polymerase with Operators and Promoters."

American Chemical Society Annual Meeting, Pfizer Award Symposium (1985) Chicago, Illinois. "New Chemical Methods for Synthesizing DNA and RNA."

Symposium on Eukaryotic Membrane Proteins and Investigations of Their Genetic Structures (1985) Frankfurt, W. Germany. "Engineering Proteins through Nucleic Acid Synthesis."

Twenty-Ninth Symposium on Chemical Biology, The Welch Foundation (1985) Houston, Texas. "Polymer Supported Polynucleotide Synthesis and Applications to Molecular Biology."

CU-Syntex Synthetic Chemistry Symposium, University of Colorado (1986) Boulder, Colorado. "Modern Methods for Synthesizing Polynucleotides on Polymeric Supports."

American Society of Biological Chemists Joint Meeting with American Chemical Society (1986) Washington, D. C. "Studies on the Cro Repressor-Operator Recognition Problem."

Physics and Physical Chemistry of Biopolymers Gordon Conference (1986) Plymouth, New Hampshire, Session Chairman. "Cro-DNA Interactions."

3rd International Conference on Polymer-Supported Reactions in Organic Chemistry (1986) Jerusalem, Israel. "Modern Methods of Nucleic Acid Synthesis on Polymeric Supports."

X. International Conference on Phosphorus Chemistry (1986) Bonn, Federal Republic of Germany. "Phosphoramidites as Synthons for Polynucleotide Synthesis."

2nd International Symposium on Phosphorus Chemistry Directed Towards Biology (1986) Lodz, Poland. "Chemical Methods for Synthesizing DNA, RNA, and Nucleic Acid Analogs."

UCLA Symposium on Protein Structure and Design (1987) Steamboat Springs, Colorado. "Altering the Binding Specificity of Cro Repressor for Operator."

Cologne Spring Meeting on Protein-DNA Recognition (1987) Cologne, Federal Republic of Germany. "Altering the Binding Specificity of Cro Repressor for Operators."

5th Conversation in Biomolecular Stereodynamics (1987) Albany, New York. "Redesigning Cro Repressor to Interact with New Operators."

Symposium on Chemically Modified Surfaces (1987) Ft. Collins, Colorado. "New Chemical Methods for Synthesizing DNA and RNA on Silica Supports."

XIV International Botanical Congress (1987) Berlin (West). "Directed Mutagenesis Studies on DNA Binding Protein."

Gordon Research Conference on Reactive Polymers, Ion Exchangers and Adsorbents (1987) Newport, Rhode Island. "Nucleic Acid Synthesis on Polymeric Supports."

The Association for the Progress of New Chemistry Seminar on "At the Front of Protein Engineering" (1987) Fujinomiya, Japan. "New Developments in Protein Engineering."

Symposium on Therapeutic and Diagnostic Applications of Synthetic Nucleic Acids (1987) Cambridge, England. "Engineered Mutagenesis of Proteins and Polynucleotides."

Symposium on Molecular Recognition in Order to Celebrate the 20th Anniversary of the Nucleotide Group, The Biochemical Society and Royal Society of Chemistry (1987) Birmingham, England. The First Khorana Lecture, "Thirty Years of DNA Synthesis Wedded to Molecular Biology - A Review of the Past and a Preview of the Future."

NIH Workshop on Anti-Sense Oligonucleotides as Therapeutic Agents (1987) Annapolis, Maryland. Panel: Recommendations for Future Research Directions.

DNA Synthesis Workshop, American Society of Biological Chemists, FASEB Meeting (1988) Las Vegas.

Gordon Research Conference on Natural Products (1988) New Hampton, New Hampshire. "Synthesis of DNA and DNA Analogs."

International Workshop on Perspectives in Therapeutic and Diagnostic Applications of Oligonucleotide Derivatives (1988) Novosibirsk, USSR. "Synthesis of DNA Analogs Having Potential Therapeutic and Diagnostic Applications."

Thirtieth Harden Conference, Nucleic Acids and Their Interactions with Proteins (1988) Wye College, Ashford, Kent, United Kingdom. "New DNA Analogues and Potential Uses in Molecular Biology."

Symposium on Frontiers of Chemistry: Biotechnology (1988) Columbus, Ohio. "Synthesis of DNA, RNA and Biochemically Interesting Analogs."

UCLA Symposium on Biotechnology and Human Genetic Predisposition to Disease (1989) Steamboat Spring, Colorado. "Synthesis and Biochemical Studies of DNA Analogs."

Symposium on Recognition Studies in Nucleic Acids (1989) Sheffield University, Sheffield, England. "Synthesis and Biological Studies with DNA Containing Phosphorodithioate Internucleotide Linkages."

NIH Conference on Oligonucleotides as Inhibitors of Gene Expression: Therapeutic Implications (1989) Bethesda, Maryland. "Synthesis and Biological Studies with DNA Containing Phosphorodithioate Internucleotide Linkages."

Gordon Research Conference on Nucleic Acids (1989) New Hampton, New Hampshire. "Applications of Phosphorodithioate DNA in Biochemistry."

Gordon Research Conference on Purines and Pyrimidines (1989) Newport, Rhode Island. "Synthesis of Antisense Oligonucleotides."

Sixteenth Symposium on Nucleic Acids Chemistry (1989) Narashino, Japan. "Synthesis of Oligonucleoside Phosphorodithioates."

Medtech '89, Biotechnologie in Forschung und Industrie, USA-Berlin (1989) Berlin, West Germany. "Oligonucleotides as Potential Therapeutic Agents."

Gordon Research Conference on Nucleic Acids (1990) New Hampton, New Hampshire. "The Application of DNA Analogs to Biological Problems."

The Ciba Foundation Symposium 158 on Host-Guest Molecular Interactions (1990) London, England. "Synthesis of and Biological Studies With Dithioate DNA."

NIH Workshop on Antisense DNA (1990) NIH, Bethesda, MD. "Potential Therapeutic Applications of Dithioate DNA."

Ninth International Round Table on Nucleosides, Nucleotides, and Their Biological Applications (1990) Uppsala, Sweden. "Synthesis and Biological Studies with DNA Analogs."

The Fifth San Diego Conference on Nucleic Acids: New Frontiers. American Association of Clinical Chemistry (1990) San Diego, California. "Synthesis and Biological Applications of Dithioate DNA."

International Symposium on Synthetic Oligonucleotides: Problems and Frontiers of Practical Applications (1991) Moscow, USSR. "Synthesis and Biological Studies with Dithioate DNA."

ACS National Meeting: Symposium on Synthetic Methods for Production of Biological Macromolecules (1992) San Francisco, California. "Phosphorodithioate DNA as a Potential Therapeutic Drug."

First International Workshop on the Biological Effects of Antisense Oligonucleotides (1992) Arcachon, France. "Chemistry of Novel Oligonucleotides."

INSERM/NIH Conference on Antisense Oligonucleotides and Ribonuclease H (1992) Arcachon, France. "Deoxyoligonucleotide Dithioates as Potential Therapeutic Drugs."

Banbury Conference on Oligonucleotides (1992) Cold Spring Harbor, New York. "Synthesis, Biochemistry, and Biological Applications of New Polynucleotide Analogs."

Irvine Synthesis Symposium (1992) Irvine, California. "Synthesis of Biologically Useful Polynucleotides and Polynucleotide Analogs."

Fourth International Conference on Nucleic Acids (1993) Cancun, Mexico. "Chemical and Biological Studies with DNA Analogs."

American Chemical Society National Meeting (1993) Denver, Colorado. "Synthesis, Biochemistry, and Biological Applications of New Polynucleotide Analogs."

Keystone Symposium on Genetically Targeted Research & Therapeutics: Antisense & Gene Therapy (1993) Keystone, Colorado. "Synthesis, Biochemistry, and Biological Applications of New Polynucleotide Analogs."

Eighth Conversation: Biomolecular Stereodynamics (1993) Albany, New York. "Biochemical Studies with DNA Analogs."

International Symposium on Nucleic Acids and Membranes (1993) Vancouver, British Columbia. "Chemical Synthesis and Biological Studies with Dithioate DNA."

Science Innovation '93 (1993) Boston, Massachusetts. "Synthesis of Polynucleotides and Polynucleotide Analogs."

Third International Symposium on Solid Phase Synthesis & Complementary Technologies (1993) Oxford, UK. "Synthesis of Oligonucleotides and Oligonucleotide Analogs on Polymer Supports."

Third Cambridge Symposium: Oligonucleotides and Analogues (1993) Cambridge, UK. "Chemical and Biological Studies with DNA Analogs."

Franklin Institute Awards Convocation (1994) Philadelphia, PA. "The Gene Machine and the Biotechnology Revolution."

First International Antisense Conference of Japan (1994) Kyoto, Japan. "New DNA and RNA Analogs as Potential Antisense Drugs."

XIII International Conference on Phosphorus Chemistry (1995), Jerusalem, Israel. "Synthesis and Biological Activity of New Polynucleotide and Phosphopeptide Analogs."

Nucleic Acids Symposium (1995), Leiden, The Netherlands. "Synthesis of Polynucleotides and Polynucleotide Analogs."

Nature Medicine Conference on The Art of Antisense (1995), New Orleans, Louisiana. "Keynote Address: Assessing the Tools."

Modified Nucleic Acids: Chemistry and Applications (1996), The Banbury Center, Cold Spring Harbor Laboratories, Cold Spring Harbor New York. "Chemical Synthesis and Biochemical Studies with Dithioate and Boranephosphonate DNA."

International Congress on Therapeutic Oligonucleotides, Accademia Nazionale Di Medicina (1996), Rome, Italy. "Synthesis and Biological Studies of New DNA Analogs."

Ciba Foundation Symposium 209, Oligonucleotides as Therapeutic Drugs, Chairman of Symposium, (1997), London, England.

American Association for the Advancement of Science Annual Meeting, February 13-18, 1997, Seattle, WA. "University/Academic Issues that Relate to Starting Innovative Biotechnology Companies."

Nature Biotechnology Conference on Antisense '97, May 1-2, 1997, Chair of session on "Antisense Anticancer Approaches." Cambridge, MA.

Nobel Workshop, Gene Targeted Drugs: Function and Delivery (1998), Stockholm, Sweden. "Recent Developments in the Synthesis and Biochemistry of Nucleic Acids."

4th International Meeting on Recognition Studies in Nucleic Acids (1998), University of Sheffield, Sheffield, England. "Synthesis of RNA and Boranophosphate DNA."

Xth International Symposium on Molecular Recognition and Inclusion (1998), Warsaw, Poland. "Synthesis of New Oligonucleotide and Phosphopeptide Analogs."

Minisymposium on Frontiers of Bioorganic Chemistry (1998), Centre of Molecular and Macromolecular Studies, Polish Academy of Sciences, Łódź, Poland. "Oligonucleotide and Phosphopeptide Analogs."

8th International Symposium on Polymer Based Technologies (1998), Ma'ale Hachamisha, Israel. "Synthesis of DNA, RNA, and Various New Analogs on Polymer Supports."

XIVth International Conference on Phosphorus Chemistry (1998), Cincinnati, OH. "Recent Developments in the Synthesis and Biochemistry of Nucleic Acids."

Volcano Conference (1999), University of Washington, Seattle, WA. "Recent Developments in Nucleic Acid Chemistry" (Plenary Lecture).

International Symposium on Bioinformatics and Biomolecular Technologies: Linking Genomes, Proteomes and Biochemistry, Sponsored by the Association of Biomolecular Resource Facilities. 1999 ABRF - Hewlett-Packard Award (1999), Durham, NC. "Synthesis of Oligonucleotides and Oligonucleotide Analogs."

7th International Symposium on Molecular Aspects of Chemotherapy (1999) Gdansk, Poland. "Synthesis and Biochemical Studies with DNA Analogs Having Chemotherapeutic Applications."

Colloque Interfaces et Innovations Scientifiques SITEF (2002) Toulouse, France. "Nucleic Acids and Technology Transfer to Biotechnology."

Nucleotide Meeting,(2004), Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany. "New Methods for Synthesizing DNA, RNA and Phosphonoacetate/Phosphonoformate Analogs."

International Symposium on Nucleic Acids, Membranes and Signal Transduction (2004) Okayama, Japan. "New Synthetic Methods for DNA, RNA, and Analogs Having Phosphonoacetate Internucleotide Linkages."

Eurotides Conference (2005) Munich, Germany. "Synthesis and Biological Studies with New DNA Analogs."

International Meeting: Nucleic Acids Chemistry Towards Biology: 50 Years On (2005) University of Cambridge, U. K. "Nucleic Acid Chemistry – From Todd and Michelson Onward to the Present."

106th General Meeting of the American Society for Microbiology (2006) Orlando FL. "Biochemical Studies with Phosphonoacetate and Phosphonoformate DNA."

Colorado Initiative in Molecular Biotechnology Mini-symposium (2006) Boulder CO. "CU-Boulder — Inventions and Technology Transfer."

Regional Meeting of Tech Transfer Association (2006) Boulder, CO. "My Adventures in Biotech Land."

American Society for Microbiology 106th General Meeting (2006) Orlando, FL. "Biochemical Studies with Phosphonoacetate and Phosphoformate DNA."

XVII - International Roundtable (2006) Bern Switzerland. "Synthesis of Phosphonocarboxylate and Borane Phosphonate DNA Analogs."

TIDES Conference (2007) Las Vegas, NV. "The Landscape for the OLIGO Market – A Technology Update."

Gordon Conference on Nucleosides, Nucleotides and Oligonucleotides (2007) Newport, RI. "New Methods for Synthesizing RNA/DNA and Borane Phosphonate DNA."

Oligonucleotide Therapeutics Society Meeting (2007) Berlin, Germany. Keynote Address, "Current Status of Using Oligonucleotides as Diagnostic and Therapeutic Agents in Cancer Research."

Girindus Leadership in Oligonucleotides Symposium (2009) Cincinnati, OH. Keynote Address, "Synthesis of RNA and Nucleic Acid Analogs — The Next Chapters."

University of Colorado Denver Research and Creative Activities Symposium (2009) Denver, CO. Keynote Address: "Gene Machines and Opportunities in Science."

21st International Symposium on Chirality (2009) Breckenridge, CO. "Constructing Complex Nanstructures with DNA."

41st National Organic Chemistry Symposium (2009) Boulder, CO. "Future Research Areas in Organic Chemistry."

33rd Steenbock Symposium Synthetic Genes to Synthetic Life, on the Exploration and Synthesis of Biological Systems (2009) Madison, WI. "Nucleic Acid Chemistry- From Gobind to the Present."

IBC's Second Annual Asia TIDES (2010) Tokyo, Japan. "Synthesis and Biological Activity of the Nucleic Acids and Their Analogs."

XIX International Round Table on Nucleosides (2010) Lyon, France. "Synthesis and Biological Activities of New Oligonucleotide Analogs."

NACON VIII (2010) Sheffield, England. "New Developments in the Synthesis of DNA/RNA and Several New Analogues."

International Conference on Phosphorus Chemistry (2010) Wroclaw, Poland. "Synthesis and Biological Activity of Borane Phosphonate DNA."

11th Eurasia Conference on Chemical Sciences (2010) The Dead Sea, Jordan. "New Developments in the Synthesis of DNA/RNA and Their Analogs."

5th Nucleic Acid Chemistry Meeting (2011) Frankfurt, Germany. "New Developments in the Synthesis of DNA and New Analogs"

From Innovations in Nucleic Acids Research to Regulation of Biological Processes, (2011) Bangalore, India. A Seminar Honoring Tom RajBhandary“

Khorana Memorial Comments (2012) MIT, Cambridge, USA

A Brief, Biased Lecture on Oligonucleotide Synthesis Interfaced with Molecular Biology. (2012) Celebration of Alnylum's 10th Anniversary, Cambridge, MA.

New DNA Analogs – Synthesis, Biological, and Chemical Properties. (2012) IS3NA Meeting, Montreal, Canada

Synthesis and Biological Applications for Various New DNA Analogs. (2012) Tetrahedron Symposium, Amsterdam, Netherlands

Oligonucleotide Synthesis Interfaced with Molecular Biology. (2012) ISBOC-ICSMS8 Meeting, Beijing, China.

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nano Technology. (January 2013) Eijkman Institute for Molecular Biology, Jakarta, Indonesia

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nano Technology. (January 2013) Nanyang Technological University, Singapore.

My Adventures in Biotechnology. Nanyang Technological University, (January 2013) Singapore.

Oligonucleotide Synthesis Interfaced with Molecular Biology. (March 2013) A lecture in the What is Life Series, Karolinska Institute, Stockholm, Sweden.

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nanotechnology. (April 2013) Eckstein Symposium, Goettingen, Germany.

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nanomaterials. (May 2013) 5th Symposium on Advances in Synthetic and Medicinal Chemistry (ASMC13). Moscow, Russia

Oligonucleotide Synthesis Interfaced with Molecular Biology. (July,2013) 38th FEBS Congress. St. Petersburg, Russia.

Chemical Synthesis/Biological Studies on the Nucleic Acids and Their Derivatives. (November, 2013) A Symposium Devoted to the 150th Anniversary of the Department of Medicinal Chemistry and Physics, Kazan University, Kazan, Russia.

Chemical Synthesis, Biochemistry, and Biological Activity of Long DNAs/RNAs and Their Analogs. 16th Symposium on Chemistry of Nucleic Acid Components. (June 2014) Award Address, Frantisek Sorm Medal, Cesky Krumlov (Czech Republic).

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nanotechnology. (June 2014) Plenary Lecture for A Symposium Honoring Michael Blackburn on the Occasion of His 80<sup>th</sup> Birthday. University of Edinburgh, Scotland.

Chemical Synthesis, Biochemistry, and Biological Activity of Long DNAs/RNAs and Their Analogs. (June 2014) Plenary Lecture, International Conference on Phosphorus Chemistry. Dublin, Ireland.

Oligonucleotide Synthesis on Glass Chips. Plenary Lecture, (September 2014) Automation in Chemistry: Carbohydrate Synthesis and Continuous Flow. Ringberg Castle, Munich, Germany.

Chemical Synthesis, Biochemistry, and Biological Activity of Long DNAs/RNAs and Their Analogs. (March 2014) Spring 2014 Meeting of the American Chemical Society. Dallas, TX. Award Lecture for the ACS Award for Creative Invention. DNA/RNA Chemical Synthesis.

Plenary Lecture honoring Doug and Gigi Dellinger for receiving the Barney Oliver Award. (May 2014) Agilent Technologies, Santa Clara, CA

Boulder Conversations with Extraordinary People. A Lecture on My Career at the University of Colorado. Boulder History Museum. (March, 2015)

Wearing Two Hats at the University of Colorado. ACS Meeting of the American Chemical Society, Denver, Colorado (March 2015)

Synthesis and Applications of Long DNAs/RNAs/Certain Analogs. 2nd Precision Medicine Conference. London (September 2015)

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nanotechnology The Sixth Annual August M. Watanabe Symposium, Indiana University, Bloomington, Indiana (October 2015)

Oligonucleotide Synthesis Interfaced with Molecular Biology & Nanotechnology. A Symposium Honoring Wojciech Stec. Lodz, Poland. (October, 2015)

Oligonucleotide Synthesis Interfaced with Molecular Biology. A Symposium in Honor of Keiichi Itakura, City of Hope, California (May, 2016)

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nanotechnology. The 6<sup>th</sup> International Conference on Nucleic Acid-Protein Chemical and Structural Biology for Novel Drug Discovery, Chengdu, China (May, 2016)

Oligonucleotide Synthesis Interfaced with Molecular Biology. 21<sup>st</sup> International Conference on Phosphorus Chemistry, Kazan, Russia, (June, 2016)

Oligonucleotide Synthesis Interfaced with Molecular Biology. The 43rd International Symposium on Nucleic Acids Chemistry, Kumamoto University, Japan (September, 2016)

Oligonucleotide Synthesis Interfaced with Molecular Biology. Frontier Institute for Biomolecular Engineering Research, Kobe, Japan (September, 2016)

Oligonucleotide Synthesis Interfaced with Molecular Biology. V Russian Congress on Biochemistry, Sochi, Russia (October, 2016)

Synthesis and Biological Activity of New DNA Analogues. AsiaTides 2017, Kyoto, Japan (February, 2017)

Chemical and Biological Activity of New Synthetic DNA Analogues. Nelson Leonard Centennial Symposium, University of Illinois, USA, (April, 2017)

Synthesis, Biochemistry, and Biology of New Morpholino and Thiomorpholino DNA Analogues. 17<sup>th</sup> SCNAC Conference, Cesky Krumlov, Czech Republic (June, 2017)

Synthesis, Biochemistry, and Biology of New DNA Analogues. 7<sup>th</sup> Cambridge Symposium Cambridge, England, (September, 2017)



Synthesis, Biochemistry, and Biology of Thiomorpholino DNAs and Their DNA Chimeras. 13<sup>th</sup> Annual Meeting of the Oligonucleotide Therapeutic Society, Bordeaux, France, (September, 2017)

Workshop on DNA Synthesis and the Organism: Biology, Chemistry, and Engineering, University of Edinburgh and The Chemical Heritage Foundation, Philadelphia, (November, 2017).

Oligonucleotide Synthesis Interfaced with Molecular Biology and Nanotechnology. The 22<sup>nd</sup> International Conference on Phosphorus Chemistry, Budapest, Hungary (July, 2018)

DNA Analogues for CRISPER/CAS Fidelity and Exon Skipping. 4<sup>th</sup> International Congress on Epigenetics & Chromatin, London, England (September, 2018)

Chemical Synthesis of DNA/RNA and Biological Activity of Selected Analogues. 14<sup>th</sup> Annual Meeting of The Oligonucleotide Therapeutic Society, Seattle, Washington, USA) (September, 2018)

Chemical Synthesis and Biochemical/Biological Activity of Thiomorpholino Oligonucleotides. 2<sup>nd</sup> International Symposium on Functional Nucleic Acids: From Laboratory To Targeted Molecular Therapy, Perth, Western Australia, (November, 2018)

Wearing Two Hats @ The University of Colorado Basic Research and Biotechnology. Life Science R&D Data Intelligence Leaders Forum, Basel, Switzerland, (January, 2019)

Biological Activity of Thiomorpholino Oligonucleotides and an RNA Analogue Useful for CRISPER/CAS Research. Life Science R&D Data Intelligence Leaders Forum, Basel, Switzerland, (January, 2019)

Biological Activity of Thiomorpholino Oligonucleotides and an RNA Analogue Useful for CRISPER/CAS Research. 6<sup>th</sup> Nucleic Acids Conference, Nassau, Bahamas, (February (2019)

#### Invited Lectures (University and Industry, 1980-present)

Genentech Inc.	1980
University of California at San Francisco	1980
University of California at Berkeley	1980
The Upjohn Company	1980
Syntex Research	1980
Hoffman La Roche	1980
Hoechst Chemical Company	1981
National Science Teachers Regional Convention, Denver	1981
Harvard University, Department of Chemistry	1981
Washington University of St. Louis, Department of Chemistry	1981
University of Wisconsin, Department of Biochemistry	1981
The Wistar Institute	1981
E. Roosevelt Institute for Cancer Research, Department of Medicine	1981

E. I. DuPont de Nemours and Company, Central Research and Development Department	1982
University of California, San Francisco, Department of Pharmaceutical Chemistry	1982
Duke University Medical Center, Department of Biochemistry	1982
Michigan State University, Department of Biochemistry	1982
Ortho Pharmaceutical Corporation	1982
Pfizer Central Research	1982
Howard Florey Institute of Experimental Physiology and Medicine, University of Melbourne, Australia	1982
Institute of Biophysics, Academia Sinica, Beijing, China	1982
Institute of Chemistry, Academia Sinica, Beijing, China	1982
Beijing University	1982
Shanghai Institute of Biochemistry, Academia Sinica	1982
Shanghai Institute of Cell Biology, Academia Sinica	1982
Shanghai Institute of Organic Chemistry, Academia Sinica	1982
Fudan University, Shanghai, China	1982
University of Colorado, Department of Chemical Engineering	1982
Synergen Associates	1982
Abbott Laboratories, Department of Molecular Biology	1982
E. Roosevelt Institute for Cancer Research, Department of Medicine	1982
University of Utah, Department of Chemistry	1983
The Upjohn Company, Kalamazoo, Michigan	1983
University of Toronto, Department of Biochemistry	1983
University of Colorado, Alumni Association	
90 Minute Lecture Series	1983
University of Wyoming, Department of Biochemistry	1984
Akademgorodok, Siberia, USSR, Institute of Bioorganic Chemistry	1984
University of Wurzburg, Institute of Biochemistry, Wurzburg, Federal Republic of Germany	1984
Max Planck Institute for Experimental Medicine, Goettingen, Federal Republic of Germany	1984
University of Paris, Institute Jacques Monod, Paris, France	1984
University of Cologne, Institute of Genetics, Cologne, Federal Republic of Germany	1985
Eastman Kodak, Rochester, New York	1986
Yale University, Department of Chemistry	1986
E. I. DuPont de Nemours and Company, Central Research and Development Department	1986
University of Minnesota, Twin Cities, Department of Chemistry	1986
Lehigh University, Bethlehem, Pennsylvania	1986
E. Roosevelt Institute for Cancer Research, Department of Medicine	1987
Tokyo Institute of Technology, Department of Life Chemistry, Yokohama, Japan	1987
Ajinomoto Co., Inc., Kawasaki, Japan	1987
Hokkaido University, Faculty of Pharmaceutical Sciences, Sapporo, Japan	1987
Kirin Research Institute, Maebashi, Japan	1987
Protein Engineering Research Institute, Tokyo, Japan	1987
Glaxo Group Research Greenford Lectures, England	1987
University of California, Santa Barbara, Department of Biological Sciences	1987
Shanghai Institute of Biochemistry	1988
University of Delaware, Newark, Delaware	1988
Uppsala University, Uppsala, Sweden	1989
University of California at Irvine, Irvine, California	1989
University of Stockholm, Stockholm, Sweden	1989
Bayer, Leverkusen, Federal Republic of Germany	1989
University of Utah, Department of Medicinal Chemistry	1990
Johns Hopkins University, Department of Biochemistry	1991

University of Nebraska, Department of Chemistry	1992
Northwestern University, Department of Chemistry	1992
Colorado State University, Department of Chemistry	1994
University of Minnesota, Twin Cities, Department of Medicinal Chemistry	1994
Central Laboratories for New Technology, Kirin Brewery Co., Kanagawa, Japan	1994
Protein Engineering Research Institute, Osaka, Japan	1994
University of California at Riverside, Department of Chemistry	1995
Northwestern University	1996
University of Nebraska at Kearney	1996
Brigham Young University, Chemistry and Biochemistry, (two lectures), Provo, Utah	1997
University of Pennsylvania School of Medicine	1998
Duke University, Hill Memorial Lecture,	2000
Massachusetts Institute of Technology, Department of Chemistry	2000
Washington University, Chemistry –Biology Interface Pathway, St. Louis, MO	2003
University of Pennsylvania, Philadelphia, PA	2003
Lifetime Achievement Award, Denver, CO	2004
Prelog Award, ETH, Zurich, Switzerland	2004
Frontiers in Pharmacology Seminar Series, University of Wisconsin, Madison, WI	2008
Methods in Chemistry Seminar, University of Colorado, Department of Chemistry	2008
Iowa State University, Department of Chemistry, Ames, IA	2009
Northwestern University, Hurd Lecture 1, My Adventures in Biotechnology	2015
Northwestern University, Hurd Lecture 2. Oligonucleotide Synthesis Interfaced With Molecular Biology and Nanotechnology.	2015

Book Review:

DNA Synthesis by Arthur Kornberg, W. H. Freeman and Company, San Francisco. Reviewed for J. Am. Chem. Soc. 97, 5318 (1975).

Publications

1. Oligonucleotide Synthesis Utilizing Benzoylpropionyl, A Blocking Group with a Trigger for Selective Cleavage. R. L. Letsinger, M. H. Caruthers, P. S. Miller, and K. K. Ogilvie. *J. Am. Chem. Soc.* 89, 7146 (1967).
2. Reactions of Nucleosides on Polymer Supports. Synthesis of Thymidylylthymidylylthymidine. R. L. Letsinger, M. H. Caruthers, and D. M. Jerina. *Biochemistry* 6, 1379 (1967).
3. Progress in the Total Synthesis of the Gene for Alanine tRNA. H. G. Khorana, H. Büchi, M. H. Caruthers, S. H. Chang, N. K. Gupta, A. Kumar, E. Ohtsuka, V. Sgaramella, and H. Weber. *Cold Spring Harbor Symp. Quant. Biol.* 33, 55 (1968).
4. Total Synthesis of the Gene for an Alanine Transfer RNA from Yeast. K. L. Agarwal, H. Büchi, M. H. Caruthers, N. Gupta, H. G. Khorana, K. Kleppe, A. Kumar, E. Ohtsuka, U. L. RajBhandary, J. H. van de Sande, V. Sgaramella, H. Weber, and T. Yamada. *Nature* 227, 27 (1970).
5. Studies on Polynucleotides. CIII. The Total Synthesis of the Structural Gene for an Alanine Transfer RNA from Yeast. (General Introduction) H. G. Khorana, K. L. Agarwal, H. Büchi, M. H. Caruthers, N. Gupta, K. Kleppe, A. Kumar, E. Ohtsuka, U. L. RajBhandary, J. H. van de Sande, V. Sgaramella, T. Terao, H. Weber, and T. Yamada. *J. Mol. Biol.* 72, 209 (1972).
6. Studies on Polynucleotides. CX. Synthesis of Three Deoxyribodecanucleotides Corresponding to the Nucleotide Sequence 51-70. M. H. Caruthers, J. H. van de Sande, and H. G. Khorana. *J. Mol. Biol.* 72, 375 (1972).
7. Studies on Polynucleotides. CXI. Synthesis of a Deoxyribododecanucleotide and a Deoxyriboheptanucleotide Corresponding to the Nucleotide Sequence 66-77. M. H. Caruthers and H. G. Khorana. *J. Mol. Biol.* 72, 407 (1972).
8. Studies on Polynucleotides. CXIV. Enzymatic Joining of the Chemically Synthesized Segments to Form the DNA Duplex Corresponding to Nucleotide Sequence 46-77. J. H. van de Sande, M. H. Caruthers, V. Sgaramella, T. Yamada, and H. G. Khorana. *J. Mol. Biol.* 72, 457 (1972).
9. Studies on Polynucleotides. CXV. Total Synthesis of the Structural Gene for an Alanine tRNA from Yeast. Enzymatic Joining of the DNA Duplexes A, B, C, to Form the Total DNA Duplex. M. H. Caruthers, K. Kleppe, J. H. van de Sande, V. Sgaramella, K. L. Agarwal, H. Büchi, N. Gupta, A. Kumar, E. Ohtsuka, U. L. RajBhandary, H. Weber, T. Yamada, and H. G. Khorana. *J. Mol. Biol.* 72, 475 (1972).
10. Studies on Polynucleotides CXVII. Hybridization of Deoxyribopolynucleotides with Tyrosine tRNA Sequences to the r-Strand of phi 80 - psuIII DNA. P. Besmer, R. C. Miller, M. H. Caruthers, A. Kumar, K. Minamoto, J. H. van de Sande, N. Siderova, and H. G. Khorana. *J. Mol. Biol.* 72, 503 (1972).
11. Current Work on the Synthesis of Transfer RNA Genes, M. H. Caruthers. In *Cellular Modification and Genetic Transformation by Exogenous Nucleic Acids*. (Roland F. Beers, Jr. and R. Carmichael Tilghman, eds.) Johns Hopkins University Press, pp 1-13 (1973).
12. Optimal Strategies for the Chemical and Enzymatic Synthesis of Bihelical Deoxyribonucleic Acids. G. J. Powers, R. L. Jones, G. A. Randall, M. H. Caruthers, J. H. van de Sande, and H. G. Khorana. *J. Am. Chem. Soc.* 97, 875 (1975).
13. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 1. General Introduction. H. G. Khorana, K. L. Agarwal, P. Besmer, H. Büchi, M. H. Caruthers, P. Cashion, M. Fridkin, E. Jay, K. Kleppe, R. Kleppe, A. Kumar, P. Loewen, R. Miller, K. Minamoto, A. Panet, U. RajBhandary, B. Ramamoorthy, T. Sekiya, T. Takeya, and J. H. van de Sande. *J. Biol. Chem.* 251, 565 (1976).

14. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 2. Chemical Synthesis of the Deoxyribopolynucleotide Segments Corresponding to the Nucleotide Sequence 1-31. J. H. van de Sande, M. H. Caruthers, A. Kumar, and H. G. Khorana. *J. Biol. Chem.* 251, 571 (1976).
15. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 3. Synthesis of Deoxyribopolynucleotide Segments Corresponding to the Nucleotide Sequence 27-51. K. Minamoto, M. H. Caruthers, B. Ramamoorthy, J. H. van de Sande, N. Sidorova, and H. G. Khorana. *J. Biol. Chem.* 251, 587 (1976).
16. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 4. Synthesis of Deoxyribopolynucleotide Segments Corresponding to the Nucleotide Sequence 47-78. K. L. Agarwal, M. H. Caruthers, M. Fridkin, A. Kumar, J. H. van de Sande, and H. G. Khorana. *J. Biol. Chem.* 251, 599 (1976).
17. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 5. Synthesis of the Deoxyribopolynucleotide Segments Representing the Nucleotide Sequence 71-103, E. Jay, P. Cashion, M. Fridkin, B. Ramamoorthy, K. Agarwal, M. H. Caruthers and H. G. Khorana. *J. Biol. Chem.* 251, 609 (1976).
18. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 6. Synthesis of the Deoxyribopolynucleotide Segments Corresponding to the Nucleotide Sequence 100-126. K. Agarwal, M. H. Caruthers, H. Büchi, J. H. van de Sande, and H. G. Khorana. *J. Biol. Chem.* 251, 624 (1976).
19. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 10. Enzymatic Joining of Chemically Synthesized Segments to Form the DNA Duplex Corresponding to the Nucleotide Sequence 96-126. M. H. Caruthers, R. Kleppe, K. Kleppe, and H. G. Khorana. *J. Biol. Chem.* 251, 658 (1976).
20. Total Synthesis of the Structural Gene for the Precursor of a Tyrosine Suppressor Transfer RNA from *Escherichia coli*. 11. Enzymatic Joining to Form the Total DNA Duplex. R. Kleppe, T. Sekiya, P. Loewen, K. Kleppe, K. Agarwal, H. Büchi, P. Besmer, M. H. Caruthers, P. Cashion, M. Fridkin, E. Jay, A. Kumar, R. Miller, K. Minamoto, A. Panet, U. RajBhandary, B. Ramamoorthy, N. Sidorova, T. Takeya, J. H. van de Sande, and H. G. Khorana. *J. Biol. Chem.* 251, 667 (1976).
21. Synthesis of *Lac* and Lambda Operator DNA Sequences. D. V. Goeddel, D.G. Yansura, E. Kawashima, T. Gadek, and M.H. Caruthers. In *Molecular Mechanism in the Control of Gene Expression* (W. Rutter, ed.), Academic Press, Inc., New York, p. 159 (1976).
22. Studies on Gene Control Regions. I. Chemical Synthesis of Lactose Operator Deoxyribonucleic Acid Segments. D. V. Goeddel, D. G. Yansura, and M. H. Caruthers. *Biochemistry* 16, 1765 (1977).
23. Studies on Gene Control Regions. II. Enzymatic Joining of Chemically Synthesized Lactose Operator Deoxyribonucleic Acid Segments. D. G. Yansura, D. V. Goeddel, and M.H. Caruthers. *Biochemistry* 16, 1772 (1977).
24. Studies on Gene Control Regions. III. Binding of Synthetic and Modified Synthetic Lac Operator DNAs to Lactose Repressor. D. G. Yansura, D. V. Goeddel, D. L. Cribbs, and M. H. Caruthers. *Nucleic Acids Res.* 4, 723 (1977).
25. Studies on Gene Control Regions. IV. Synthesis and Biological Activity of a  $\lambda$  Pseudo Operator. E. Kawashima, T. Gadek, and M. H. Caruthers. *Biochemistry* 16, 4209 (1977).
26. Studies on Gene Control Regions. V. Binding of Synthetic Lactose Operator DNAs to Lactose Repressors. D. V. Goeddel, D. G. Yansura, and M. H. Caruthers. *Proc. Natl. Acad. Sci. USA* 74, 3292 (1977).

27. Studies on Gene Control Regions. VI. The 5-Methyl of Thymine, A *Lac* Repressor Recognition Site. D. V. Goeddel, D.G. Yansura, and M.H. Caruthers. *Nucleic Acids Res*, 4, 3039 (1977).
28. Cloning of Chemically Synthesized Lactose Operators. J. R. Sadler, M. Techlenburg, J. L. Betz, D. V. Goeddel, D. G. Yansura, and M. H. Caruthers. *Gene* 1, 305 (1977).
29. Studies on Gene Control Regions. VII. The Effects of 5-Bromouracil Substituted *Lac* Operators on the *Lac* Operator-*Lac* Repressor Interaction. D. V. Goeddel, D. G. Yansura, C. Winston, and M. H. Caruthers. *J. Mol. Biol.* 123, 661 (1978).
30. Cloning of Chemically Synthesized Lactose Operators. II. Eco RI-Linkered Operators. J. R. Sadler, M. Techlenburg, J. L. Betz, D. V. Goeddel, D. G. Yansura, and M. H. Caruthers. *Gene* 3, 211 (1978).
31. Studies on Gene Control Regions. VIII. How *Lac* Repressor Recognizes *Lac* Operator. D. V. Goeddel, D. G. Yansura, and M. H. Caruthers. *Proc. Nat. Acad. Sci. USA* 75, 3578 (1978).
32. Studies on Gene Control Regions. IX. The Effect of Hypoxanthine-Substituted *Lac* Operators on the *Lac* Operator-*Lac* Repressor Interaction. D. G. Yansura, D. V. Goeddel, A. Kundu, and M. H. Caruthers. *J. Mol. Biol.* 133, 117 (1979).
33. Studies on Gene Control Regions. X. The Effect of Specific Adenine-Thymine Transversions on the *Lac* Repressor-*Lac* Operator Interaction. H. S. Sista, R. T. Loder, and M. H. Caruthers. *Nucleic Acids Res.* 6, 2583 (1979).
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35. Studies on Gene Control Regions. XI. Deciphering the Protein-DNA Recognition Code. M. H. Caruthers. *Acc. Chem. Res.* 13, 155 (1980).
36. Studies on Nucleotide Chemistry I. The Synthesis of Oligodeoxypyrimidines on a Polymer Support. M. D. Matteucci and M. H. Caruthers. *Tetrahedron Lett.* 21, 719 (1980).
37. Studies on Nucleotide Chemistry II. The Use of Zinc Bromide for Removal of Dimethoxytrityl Ethers from Deoxynucleosides. M. D. Matteucci and M. H. Caruthers. *Tetrahedron Lett.* 21, 3243 (1980).
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41. Synthesis of Sequence Defined Polynucleotides via Diester, Triester and Phosphite Coupling Methods. M. H. Caruthers. In *International Union of Pure Applied Chemistry (IUPAC). Structural Order in Polymers* (F. Ciardelli and P. Gusti, eds.), Pergamon Press, New York, p. 111 (1981).
42. Sequencing and Synthesis of Nucleic Acids. M. H. Caruthers. *Annual Reports in Medicinal Chemistry* 16, 299 (1981).
43. The Design and Synthesis of Gene Control Regions Useful for Genetic Engineers. M. H. Caruthers. In *Recombinant DNA*, Proceedings of the Third Cleveland Symposium on Macromolecules, Cleveland, Ohio (A. G. Walton, ed.), Elsevier, Amsterdam, The Netherlands, p. 261 (1981).

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45. *Lac* Repressor-*Lac* Operator Interaction: NMR Observations. H. Nick, K. Arndt, F. Boschelli, M. A. C. Jarema, M. Lillis, J. Sadler, M. Caruthers, and P. Lu. *Proc. Natl. Acad. Sci. USA* 79, 218 (1982).
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51. Studies on Nucleotide Chemistry VI. New Methods of Synthesizing Promoters and Other Gene Control Regions. M. H. Caruthers, Y. Stabinsky, Z. Stabinsky, and M. Peters. In *Promoters: Structure and Function* (M. Chamberlin, and R. Rodriguez, eds.), Praeger, Publishers, New York, p. 432 (1982).
52. The Application of Nucleic Acid Chemistry to Studies on the Functional Organization of Gene Control Regions. M. H. Caruthers. In *The Proceedings of the Princess Takamatsu Cancer Research Fund*, Japan Scientific Societies Press, Tokyo, p. 295 (1982).
53. Studies on Nucleotide Chemistry IX. The Synthesis and Biochemical Reactivity of Biologically Important Genes and Gene Control Regions. Marvin H. Caruthers. In *From Gene to Protein: Translation into Biotechnology* (F. Ahmad, J. Schultz, E. E. Smith and W. J. Whelan, eds.), Academic Press, New York, p. 235 (1982).
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