

Structural aspects of protein synthesis

Anders Liljas and Salam Al-Karadaghi

Structural studies of translation are in a state of rapid progress. For eubacterial systems, low resolution images of whole ribosomes can be combined with high resolution structures of individual components. For eucaryotic systems, the first individual structures are just beginning to emerge.

In the brief two year period since Peter Moore's mini review on translation entitled *Ribosomes seen through a glass less darkly*¹ appeared, significant progress has been made in the structural analysis of the ribosomal components and translational regulatory factors. Study of eubacterial systems are leading the way (unsurprisingly) but this is not to say that advances are not being made in eukaryotic systems; for example, ground breaking experiments have only recently provided structural insights into the eucaryotic initiation factor eIF4E, the cap-binding protein from two species^{2,3}. Here, we will relate these highlights to the more extensive work on eubacterial systems.

Ribosomal structure

The key issues of translation concern the binding of messenger RNA (mRNA) to the ribosome, the binding sites of the tRNA's and their movement through the ribosome, how translational fidelity is achieved and where and how peptidyl transfer occurs. A thorough understanding of the process will require a detailed structure of the ribosome. One important source of information on this RNA-protein machine has, over the last 25 years, been electron microscopy (EM). The development of electron cryo-microscopy and three-dimensional image reconstruction techniques has pushed the resolution of ribosome structures below 20 Å. Highly similar structures of bacterial ribosomes in the absence of ligands have been reported at ~20 Å. These studies have been extended to include tRNA as well as elongation fac-

tor Tu (EF-Tu) ligands, at a higher resolution of 18 Å^{4,5}. Modelling the rRNA and proteins into the EM contour is now becoming possible using chemical methods such as crosslinking, footprinting, and affinity labelling to explore proximity^{6,7,8}.

The crystallographic work on whole ribosomes and ribosomal subunits has for some time given promise of close to atomic resolution of the translation apparatus⁹. These are the largest asymmetric structures that have been analyzed by X-ray crystallography so far (the large subunit is ~1.5 × 10⁶ Å², and the small subunit is ~0.9 × 10⁶ Å²), and they pose formidable problems for determination of the phase angle¹⁰. However from structure determinations of very large enzymes^{11,12} it seems that classical isomorphous replacement, possibly with the added power of anomalous dispersion, may work for structures as large as ribosomal subunits.

The game isn't over yet, though. The resolution of the initial structures of the complete ribosome or its subunits — when they are finally forthcoming — will probably not be high enough for a detailed understanding of the mechanism of translation. Thus, studies of individual components or complexes of components (ribosomal proteins, fragments of the ribosomal RNAs, as well as translation factors) will still be needed to begin to understand protein synthesis at an atomic level. Nor will there be a shortage of questions to be answered: the number of species and functional states will be enough to keep a small army of structural biologists busy.

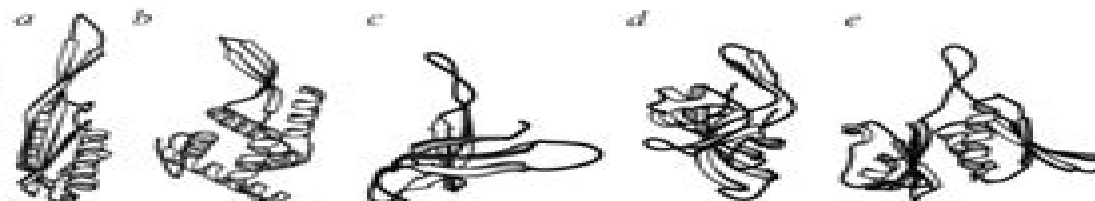
Ribosomal components

Crystallography and NMR methods have provided tremendous insight into the detailed construction of ribosomal proteins and fragments of rRNA. Structural information from both X-ray crystallography and NMR studies is now available for 14 out of more than 50 proteins from bacterial ribosomes: the L7/L12 C-terminal domain¹³, L30¹⁷, S5, L6, L9, S17, L14¹⁸, S6¹⁹, L1²⁰, S8²¹, S15²², L11 C-terminal RNA recognition domain²³, S1²⁴, and recently S7^{25,26} and L22 (I. Unge *et al.*, personal communication). NMR studies have also been performed on the L7/L12 dimer²⁷.

A number of common structural features are seen in these proteins. The most most frequently occurring motifs are based on antiparallel β-sheets. One recurring motif is the split β-α-β, or RNA recognition motif (RRM), first found in the RNA binding domain of the protein U1A²⁸ and, later, in many other proteins, including ribosomal proteins S6, L1, L6, L7/L12, L9, L22 and L30. Only one Rossmann fold-related motif has been identified so far (in one domain of protein L1²⁰), but this one is probably does not bind nucleotides because certain key residues are not conserved. Another type of fold based on an antiparallel β-sheet was previously identified in a bacterial cold shock protein and is found in S17²⁹ and as the repeated domain in the largest ribosomal protein S1²⁴. Purely helical proteins seem to be in a clear minority, with S15²² alone belonging to this class.

Two thirds of the bacterial ribosome is composed of RNA. Thus, ribosomal proteins must interact primarily with RNA,

Fig. 1 Several of the ribosomal proteins have unusually extended loops. The figure shows a gallery of five such structures: **a**, L22 (I. Unge *et al.*, personal communication); **b**, S7²⁶; **c**, S17²⁹; **d**, L14¹⁸ and **e**, S8²¹ (Shenkoye *et al.*, personal communication). In addition S6 (see Fig. 3) has a loop that in the structure determined rests against the β-sheet. It is highly likely that these loops have specific interactions with parts of the ribosomal RNA.



Structural Aspects Of Protein Synthesis

J. Robin Harris, Jon Marles-Wright



Structural Aspects Of Protein Synthesis:

Structural Aspects Of Protein Synthesis Anders Liljas, 2004-09-16 This comprehensive and highly illustrated book provides a basic and up to date summary of translation on bacterial ribosomes with emphasis on the structural insights It is an attempt to present the ribosome and its functional activities in a coherent manner Two types of illustrations are used to describe the translation field simplified black and white illustrations to depict aspects of translation and color plates to give correct structural representations The book presents essentially all aspects of the translation system focusing on the relation between structure and function Upper level undergraduates and graduate students with an interest in protein synthesis will find this lecture notes volume invaluable The book is also an essential source of information for researchers who want to get an overview of translation Structural Aspects Of Protein Synthesis (2nd Edition) Anders Liljas, Mans

Ehrenberg, 2013-06-06 This highly illustrated book provides an up to date description of the structure and function of the translation system including ribosomes tRNAs translation factors antibiotics and aminoacyl tRNA synthetases Research on translation is undergoing rapid changes and is receiving significant attention as evidenced by the Nobel Prize in Chemistry 2009 The structural research by crystallography and cryo EM forms part of an interactive framework that involves biochemistry and molecular computation The book provides a comprehensive overview of translation in light of the structural results It is a valuable resource for scientists in this and related fields as well as for students taking courses with a focus on translation There is no other book in this field currently except the previous edition of this book The authors have for a long time worked in the field of structure and function of the translation system **Conformational Proteomics Of**

Macromolecular Architecture: Approaching The Structure Of Large Molecular Assemblies And Their Mechanisms Of Action (With Cd-rom) R Holland Cheng, Lena Hammar, 2004-06-21 Biological processes involving large macromolecular assemblies are thought to be a dynamic consequence of cooperativity and metastability The folding of a peptide chain creates local environments from which activity can emerge In the same way the assembly of large molecular complexes creates dynamic features that would only be feasible in a large construct The biological implications of such adaptation are explored as it applies to the static quasisymmetry situations as well as to the dynamics of structural transitions The current wealth of solved high resolution complex structures makes this an appropriate time to summarize the state of the art in structural dynamics of living architectures With contributions by leading scientists in the fields of virology bacterial flagellum cytoskeleton ribosome and giant enzymes this important book presents cutting edge knowledge in the various fields of structural proteomics of very large molecular assemblies with the focus on their mechanisms of action Textbook Of Structural Biology (Second Edition) Anders Liljas, Lars Liljas, Goran Lindblom, Poul Nissen, Morten Kjeldgaard, Miriam-rose Ash, 2016-09-27 This book provides a comprehensive coverage of the basic principles of structural biology as well as an up to date summary of some main directions of research in the field The relationship between structure and function is described

in detail for soluble proteins membrane proteins membranes and nucleic acids There are several books covering protein structure and function but none that give a complete picture including nucleic acids lipids membranes and carbohydrates all being of central importance in structural biology The book covers state of the art research in various areas It is unique for its breadth of coverage by experts in the fields The book is richly illustrated with more than 400 color figures to highlight the wide range of structures

Brenner's Encyclopedia of Genetics Stanley Maloy, Kelly Hughes, 2013-03-03 The explosion of the field of genetics over the last decade with the new technologies that have stimulated research suggests that a new sort of reference work is needed to keep pace with such a fast moving and interdisciplinary field Brenner's Encyclopedia of Genetics Second Edition Seven Volume Set builds on the foundation of the first edition by addressing many of the key subfields of genetics that were just in their infancy when the first edition was published The currency and accessibility of this foundational content will be unrivalled making this work useful for scientists and non scientists alike Featuring relatively short entries on genetics topics written by experts in that topic Brenner's Encyclopedia of Genetics Second Edition Seven Volume Set provides an effective way to quickly learn about any aspect of genetics from Abortive Transduction to Zygotes Adding to its utility the work provides short entries that briefly define key terms and a guide to additional reading and relevant websites for further study Many of the entries include figures to explain difficult concepts Key terms in related areas such as biochemistry cell and molecular biology are also included and there are entries that describe historical figures in genetics providing insights into their careers and discoveries This 7 volume set represents a 25% expansion from the first edition with over 1600 articles encompassing this burgeoning field Thoroughly up to date with many new topics and subfields covered that were in their infancy or not in existence at the time of the first edition Timely coverage of emergent areas such as epigenetics personalized genomic medicine pharmacogenetics and genetic enhancement technologies Interdisciplinary and global in its outlook as befits the field of genetics Brief articles written by experts in the field which not only discuss define and explain key elements of the field but also provide definition of key terms suggestions for further reading and biographical sketches of the key people in the history of genetics

Biochemistry and Molecular Biology Compendium Roger L. Lundblad, 2019-11-11 This book is an accessible resource offering practical information not found in more database oriented resources The first chapter lists acronyms with definitions and a glossary of terms and subjects used in biochemistry molecular biology biotechnology proteomics genomics and systems biology There follows chapters on chemicals employed in biochemistry and molecular biology complete with properties and structure drawings Researchers will find this book to be a valuable tool that will save them time as well as provide essential links to the roots of their science Key selling features Contains an extensive list of commonly used acronyms with definitions Offers a highly readable glossary for systems and techniques Provides comprehensive information for the validation of biotechnology assays and manufacturing processes Includes a list of Log P values water solubility and molecular weight for selected chemicals Gives a detailed listing of

protease inhibitors and cocktails as well as a list of buffers *Human Biochemistry* Gerald Litwack, 2021-11-28 Selected for Doody's Core Titles 2024 in Biochemistry *Human Biochemistry* Second Edition provides a comprehensive pragmatic introduction to biochemistry as it relates to human development and disease Here Gerald Litwack award winning researcher and longtime teacher discusses the biochemical aspects of organ systems and tissue cells proteins enzymes insulins and sugars lipids nucleic acids amino acids polypeptides steroids and vitamins and nutrition among other topics Fully updated to address recent advances the new edition features fresh discussions on hypothalamic releasing hormones DNA editing with CRISPR new functions of cellular prions plant based diet and nutrition and much more Grounded in problem driven learning this new edition features clinical case studies applications chapter summaries and review based questions that translate basic biochemistry into clinical practice thus empowering active clinicians students and researchers Presents an update on a past edition winner of the 2018 Most Promising New Textbook College Award Texty from the Textbook and Academic Authors Association and the PROSE Award of the Association of American Publishers Provides a fully updated resource on current research in human and medical biochemistry Includes clinical case studies applications chapter summaries and review based questions Adopts a practice based approach reflecting the needs of both researchers and clinically oriented readers Cryo-Electron Microscopy in Structural Biology Krishnarao Appasani, 2024-10-17 Cryo electron microscopy in combination with tomography has emerged as a new technology for visualizing molecular structures at a resolution beyond even 1 Using this technology has revealed the native molecular details of viruses membranes enzymes ribosomes and cells This comprehensive volume brings together authoritative overviews of these methods from structural and biological perspectives It is a must have for researchers and graduate students as well as those working in industry primarily in the areas of biophysics structural biology crystallography and genomics Key Features Focuses on the applications of cryo EM to structural biology Documents the importance of cryo EM ET approaches in studying the structural determinants of cellular organelle and membrane protein biochemistry Reviews the applications of high resolution structures of viruses Emphasizes structural insights of nuclear and gene machineries Includes a section focused entirely on the applications of cryo EM ET in drug discovery and therapeutic development *Nucleic Acids and Proteins in Plants* I D. Boulter, 2012-12-06 D BOULTER and B PARTHIER At the time of the former edition of the Encyclopedia of Plant Physiology approximately 25 years ago no complete plant protein amino acid sequences or nucleic acid sequences had been determined Although the structure of DNA and its function as the genetic material had just been reported little detail was known of the mechanism of its action and D G CATCHSIDE was to write in the first chapter of the first volume of the Encyclopedia There is a considerable body of evidence that the gene acts as a unit of physiological action through the control of individual enzymes No cell free transcription and protein synthesizing systems were available and the whole range of powerful methods of recombinant DNA technology was still to be developed Today for the first time with plant systems it is possible not only to describe their

molecular biology but also to manipulate it i.e. to move from a description to a technological phase. The properties of living systems are inscribed by those of the proteins and nucleic acids which they synthesize. Proteins, due to their very large size, occur as macromolecules in colloidal solution or associated in supra-molecular colloidal form. The colloidal state confers low thermal conductivity, low diffusion coefficients and high viscosity properties which buffer a biological system from the effects of a changing environment. Biological systems not only have great stability but also the capacity to reproduce.

Structural Aspects of Quality Control in Protein Synthesis Cajetan Simon Johannes Neubauer, 2011

Mechanisms of Protein Synthesis E. Bermek, 2012-12-06. This volume contains the papers presented at the international symposium on Molecular Mechanisms in Protein Synthesis held on September 26-27, 1983 at the Beyaz K k in Emirgan Bosphorus, Istanbul. The symposium aimed to create a medium for information exchange and discussions regarding the current developments in the area of protein synthesis. To ensure an informal yet scientifically stimulating and productive atmosphere providing opportunity for relaxed and speculative discussions, the number of presentations was limited to twenty and that of attendants to about sixty. The emphasis in the symposium was laid on structure-function relations in the prokaryotic protein synthesizing systems and on the control mechanisms of eukaryotic protein synthesis in particular during chain initiation. Other issues like evolutionary aspects of protein synthesis, translational components, genes and proofreading were covered as well. The manuscripts represent the extended accounts of the oral presentations and it has been aimed with the concluding remarks at the end of the volume to give a summarizing view of the presentations and the discussions.

Mechanisms of Protein Synthesis Engin Bermek, 1985. This volume contains the papers presented at the international symposium on Molecular Mechanisms in Protein Synthesis held on September 26-27, 1983 at the Beyaz K k in Emirgan Bosphorus, Istanbul. The symposium aimed to create a medium for information exchange and discussions regarding the current developments in the area of protein synthesis. To ensure an informal yet scientifically stimulating and productive atmosphere providing opportunity for relaxed and speculative discussions, the number of presentations was limited to twenty and that of attendants to about sixty. The emphasis in the symposium was laid on structure-function relations in the prokaryotic protein synthesizing systems and on the control mechanisms of eukaryotic protein synthesis in particular during chain initiation. Other issues like evolutionary aspects of protein synthesis, translational components, genes and proofreading were covered as well. The manuscripts represent the extended accounts of the oral presentations and it has been aimed with the concluding remarks at the end of the volume to give a summarizing view of the presentations and the discussions.

Advances in Protein Molecular and Structural Biology Methods Timir Tripathi, Vikash Kumar Dubey, 2022-01-14. *Advances in Protein Molecular and Structural Biology Methods* offers a complete overview of the latest tools and methods applicable to the study of proteins at the molecular and structural level. The book begins with sections exploring tools to optimize recombinant protein expression and biophysical techniques such as fluorescence spectroscopy, NMR, mass spectrometry, cryo-electron

microscopy and X ray crystallography It then moves towards computational approaches considering structural bioinformatics molecular dynamics simulations and deep machine learning technologies The book also covers methods applied to intrinsically disordered proteins IDPs followed by chapters on protein interaction networks protein function and protein design and engineering It provides researchers with an extensive toolkit of methods and techniques to draw from when conducting their own experimental work taking them from foundational concepts to practical application Presents a thorough overview of the latest and emerging methods and technologies for protein study Explores biophysical techniques including nuclear magnetic resonance X ray crystallography and cryo electron microscopy Includes computational and machine learning methods Features a section dedicated to tools and techniques specific to studying intrinsically disordered proteins

Albumin: Structure, Function and Uses Victor M. Rosenoer, Murray Oratz, Marcus A. Rothschild, 2014-05-18 Albumin Structure Function and Uses reviews the many facets of serum albumin including its history and evolutionary development structure and function synthesis degradation distribution and transport and metabolic behavior The use misuse and abuse of albumin in the treatment of disease are also discussed This book is comprised of 17 chapters and begins with a commentary on how albumin is used misused and abused in the treatment of disease such as peptic ulcer and a description of the real indications for its use Concepts in albumin purification are then examined along with the amino acid sequence of serum albumin and some aspects of its structure and conformational properties Subsequent chapters explore the phylogenetics of albumin albumin binding sites clinical implications of drug albumin interaction genetics of human serum albumin and hepatic synthesis of export proteins Albumin catabolism and intracellular transport are also considered together with surgical and clinical aspects of albumin metabolism This monograph should be a useful resource for biochemists and clinicians

Ribosomes Structure, Function, and Dynamics Marina V. Rodnina, Wolfgang Wintermeyer, Rachel Green, 2011-12-10 The ribosome is a macromolecular machine that synthesizes proteins with a high degree of speed and accuracy Our present understanding of its structure function and dynamics is the result of six decades of research This book collects over 40 articles based on the talks presented at the 2010 Ribosome Meeting held in Orvieto Italy covering all facets of the structure and function of the ribosome New high resolution crystal structures of functional ribosome complexes and cryo EM structures of translating ribosomes are presented while partial reactions of translation are examined in structural and mechanistic detail featuring translocation as a most dynamic process Mechanisms of initiation both in bacterial and eukaryotic systems translation termination and novel details of the functions of the respective factors are described Structure and interactions of the nascent peptide within and emerging from the ribosomal peptide exit tunnel are addressed in several articles Structural and single molecule studies reveal a picture of the ribosome exhibiting the energy landscape of a processive Brownian machine The collection provides up to date reviews which will serve as a source of essential information for years to come Macromolecular Protein Complexes IV J. Robin Harris, Jon Marles-Wright, 2022-09-23 This book covers

the latest findings of a wide variety of viral prokaryotic and eukaryotic macromolecular protein complexes and builds upon the solid macromolecular foundations established by previous volumes of the Subcellular Biochemistry series. Thus an almost encyclopaedic coverage of the broad field of protein complex structure and function has been established. The 17 interesting chapters included in this book have been organised into four sections: Soluble Protein Complexes, Membrane Protein Complexes, Fibrous Protein Complexes and Viral Protein Complexes. Significant topics present here are Fatty Acid Synthase, the Fork Protection Complex, Ribonucleotide Reductase, the Kinetochore, G proteins, the FtsEX Complex, the Kainate Receptor, the Photosystem I antenna, the Mycobacterial Arabinofuranosyltransferases, the Bacterial Flagellum, the Actomyosin Complex, Motile Cilia, SLS, Collagen Polymorphic Structures and the Reovirus Capsid and Polymerase. Updates expansion of chapter topics present in earlier volumes are now included in chapters here e.g. those on Ferritin like proteins and the Multi tRNA Synthetase. The book is richly illustrated throughout the result of an impressive integration of structural data from X ray crystallography and cryo electron microscopy. The functional aspects of protein protein interactions are also given a high priority.

Protein Trafficking in Plant Cells J. Soll, 1998-08-31 The highly structured eucaryotic cell with its complex division of biochemical labour requires a distinct protein complement in each cellular structure and compartment. Nuclear coded and cytosolically synthesized polypeptides are specifically sorted to every corner of the cell in a post or co translational manner. The presence of separate genomes and protein translation machineries in plastids and mitochondria requires further coordination not only on the transcriptional translational but also most likely on the protein import level. Numerous different protein transport systems have developed and coexist within plant cells to ensure the specific and selective composition of every sub cellular compartment. This volume summarizes the current knowledge on protein trafficking in plant cells. Aside from the fundamental aspects in cell biology of how specific pre protein sorting and translocation across biological membranes is achieved a major focus is on transport modification and deposition of plant storage proteins. The increasing use of plants as bioreactors to provide custom designed proteins of different usage requires detailed understanding of these events. This text is directed not only at students and professionals in plant cell and molecular biology but also at those involved in horticulture and plant breeding. It is intended to serve as a text and guide for graduate level courses on plant cell biology and as a valuable supplement to courses in plant physiology and development. Scientists in other disciplines who wish to learn more about protein translocation in plants will also find this text an up to date source of information and reference.

Diffraction and Related Studies, Proceedings of the International Symposium on Biomolecular Structure, Conformation, Function and Evolution, Madras, January 1978, Biomolecular Structure, Conformation, Function, and Evolution R. Srinivasan, 2013-10-02 Diffraction and Related Studies Proceedings of the International Symposium on Biomolecular Structure Conformation Function and Evolution Madras January 1978 Biomolecular Structure Conformation Function and Evolution

Subject Index of Current Research Grants and Contracts Administered by the National

Heart, Lung and Blood Institute National Heart, Lung, and Blood Institute,1976 *Protein Misfolding in Neurodegenerative Diseases* Robert D. E. Sewell,2007-12-03 Current research suggests that neurodegenerative diseases such as Alzheimer s Parkinson s Huntington s and Creutzfeldt Jacob may be linked to disorders in protein shape referred to as protein misfolding Continued study in this area could lead to promising advances in future treatment of these diseases This groundbreaking text describes the latest findings regarding protein misfolding in the context of it being a marker and perhaps a cause in neurodegenerative diseases Comprehensive coverage includes the diverse biochemical targets markers for each disease the currently limited success of drug therapies and the cutting edge research that could lead to more promising treatments

This book delves into Structural Aspects Of Protein Synthesis. Structural Aspects Of Protein Synthesis is a vital topic that needs to be grasped by everyone, from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Structural Aspects Of Protein Synthesis, encompassing both the fundamentals and more intricate discussions.

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