
Encyclopedia of Signaling Molecules

Sangdun Choi
Editor

Encyclopedia of Signaling Molecules

Second Edition

With 1893 Figures and 247 Tables

 Springer

Editor

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Preface to Second Edition

Cellular physiology is controlled by the interaction of thousands of molecules that work either autonomously or in a complex form to bring about the desired cellular processes. Current research should focus on comprehensively documenting the vital roles of these molecules. With this in mind, the first edition of the *Encyclopedia of Signaling Molecules* was compiled, and now, the updated and revised second edition is in your hands. This edition of the *Encyclopedia of Signaling Molecules* is a Springer Major Reference Work that contains information spanning 766 chapters. Each chapter addresses an individual molecule or molecular family found in humans and other animals. The second edition has incorporated molecules that could not be included in the first edition. The original authors of the first edition have also updated and revised entries for molecules that were previously described. This monumental effort is truly inspiring, and this text has been brought into existence by the efforts of qualified scientists from around the globe.

This encyclopedia has been a long-standing dream for many years. While there have been some attempts to build comprehensive gene databases, these have been very partial and brief. Amid the excitement of recent discoveries of new genes and their novel functions, one of the greatest scientific tasks of this century will be to compile all the useful information on human and animal genes in one place. This may be arduous, but, in the end, it will fill many gaps in our knowledge and foster a deeper understanding of the vibrant biological systems around us. Improving our understanding of genes will significantly aid disease-oriented research, and this will be instrumental in the development of new therapeutic approaches.

There are multiple Internet sites containing gene information, such as Wikipedia, GenBank, and UniProt. However, these sites lack proper peer review. They are not comprehensive and are difficult to cite in scientific journals. Therefore, we need to accurately collect gene data, explain them appropriately, and suggest prospective areas of research regarding particular genes to better suit scientists' needs. These factors have been the motivation for creating this encyclopedia.

This encyclopedia is published in both print and online formats. It is indexed in all major databases, and searches performed in the Springer database and other reputable international databases/search engines will display results from this encyclopedia. This second edition will be an improved version of the first edition of the *Encyclopedia of Signaling Molecules*,

which was published in September 2012. The text focuses on the core aspects of each gene's function, along with early historical findings that will help readers understand the astonishing progress we have achieved in this field.

The editing of this encyclopedia was a tedious job, and the invitation and recruitment of renowned scientists were challenging. However, the purpose of serving the scientific community kept me motivated and enthusiastic about this project. Now that it has been compiled, I am relieved and excited to have fulfilled my dream in the best possible way. This project has taken a significant amount of time; nonetheless, it has been well worth the effort. My excitement has been shared by many scientists. In this regard, I would like to share the feedback of some accomplished scientists regarding the organization and usefulness of this encyclopedia.

I'm really impressed with the efforts made and dedication shown by my fellow scientists and clinicians to compile the *Encyclopedia of Signaling Molecules* (2nd Edition). This is an inspiring work that will undoubtedly serve a wide audience as a sophisticated reference and trusted guide for the coming years.

Roswell Park Cancer Institute
United States of America

Samar Masoumi-Moghaddam

It is always difficult to find an appropriate review when looking for information on a new protein. In that sense, the *Encyclopedia of Signaling Molecules* is particularly adapted, on the one hand by its exhaustiveness, and also because of simple and explicit figures found in each of its chapters.

Normandie University, France

Romain Guinamard

I am impressed by the work done by many researchers in compiling this valuable compendium on signaling molecules. Now, this synopsis offers a unique opportunity for advanced students, researchers, and teachers to utilize this updated collection of genes as a reference guide.

RWTH University Hospital Aachen, Germany

Ralf Weiskirchen

This encyclopedia provides its readership with a comprehensive, high-quality overview of signaling molecules. Each chapter is compiled by authors who devote their scientific research to shedding light on each specific gene and protein, thus offering the reader the most updated and timely information.

Federico II University, Italy

Maria Fiammetta Romano

The *Encyclopedia of Signaling Molecules* (2nd Edition) is an astonishing achievement, which discusses multiple aspects of biological macromolecules in a comprehensive way to facilitate the readers' interest in understanding the signaling mechanisms of a particular molecule or its entire family.

Swansea University, United Kingdom

Venkateswarlu Kanamarlapudi

The *Encyclopedia of Signaling Molecules* (2nd Edition) is an excellent collection. It includes the review of most of the important cell signaling molecules, and discusses our current understanding in a comprehensive way. The book aids advanced readers interested in understanding the signaling mechanisms of a particular protein.

Lund University, Sweden

Julhash U. Kazi

A remarkable collection of book chapters organized by gene name, this encyclopedia is particularly relevant for biologists, systems biologists, biochemists, and molecular biologists interested in some aspects of those genes; namely, their physiological and pathological roles in humans.

Universidade de Aveiro, Portugal

Sandra Rebelo

The *Encyclopedia of Signaling Molecules* (2nd Edition) can be recommended for all biologists, biochemists, molecular biologists, and geneticists. The book offers a comprehensive coverage of human genes and signaling pathways. It is very fun and useful to read this book.

Tokyo Medical and Dental University, Japan

Yutaka Hata

The second edition of the *Encyclopedia of Signaling Molecules* provides a wealth of information on a collection of genes, their backgrounds, and functions. This will undoubtedly constitute an important and useful reference guide for life science and medical professionals studying existing and new genes and their physiological roles in humans.

Texas Tech University Health Sciences Center
United States of America

Jorge L. Cervantes

The collection of genes, their backgrounds, and functions under one heading/title is an inspiring work that can be used as a reference, as well as a standard guide for new genes and their physiological and pathological roles in humans.

National Cancer Center, Japan

Masaru Katoh

The *Encyclopedia of Signaling Molecules* (2nd Edition) offers a comprehensive compendium of human genes, making it a pulsating inscription for the scientific community.

All India Institute of Medical Sciences, India

Samapika Routray

This book provides students and researchers with a comprehensive overview of genes, their backgrounds, signaling pathways, and functions. All readers will appreciate its comprehensive scope and depth.

Osaka University Graduate School of Dentistry, Japan

Hiroki Toyoda

This book represents a unique collection of genes, their molecular functions, and biological roles that can be of great use as a reference text by researchers and teachers around the world.

Mayo Clinic, United States of America

Martin E. Fernandez-Zapico

The second edition presents the most advanced and up-to-date information about these signaling molecules in a format that is easily correlated with the functions of other genes. Moreover, the therapeutic potential of many of these genes becomes evident from the available data presented in the text. As a result, this updated edition is valuable in all areas of the biological sciences. It is particularly suitable for graduate students actively involved in designing and executing their dissertation projects, researchers wanting to advance current knowledge, and teachers and professors providing advanced knowledge to their students and working on scientific projects and manuscripts.

The second edition of the encyclopedia consists of essays organized in an easily accessible A-Z format. Each chapter is divided into three main parts, including a brief description of the historical background for each gene, its physiological roles inside cells, and a short summary. The historical background familiarizes the reader with the discovery and early studies of the gene. Next, the reader can learn about the current literature regarding that gene and its function. Finally, the summary includes possible future research directions with regard to each gene. Each chapter has color illustrations to highlight key concepts, in addition to tables that summarize information not supplied in the text. Lists of gene synonyms have also been provided for the reader. Every chapter was intentionally kept brief to efficiently provide the most current and relevant knowledge to the reader.

The genes included here have been described by recognized scientific leaders in their respective areas of expertise, and the interactions of these genes in biological networks have also been explored. Additionally, genes related to certain diseases are highlighted, and possible therapeutic targets are also suggested. This encyclopedia will be an essential resource for those who want to review a particular gene in connection with interaction networks in order to solve new biological puzzles related to health and disease.

The success of this project is the result of the efforts of many contributing scientists. Therefore, it would be unjust if I did not give credit to their efforts. I am happy to be part of an amazing and wonderful research community that enthusiastically serves science through any means available. These scientists are the real assets of our community, and they are passionate about spreading knowledge and sharing ideas. The intellectual insights they convey here will positively affect future scientific endeavors. There were many individuals who regretted not being able to participate in this effort due to their busy schedule. I duly acknowledge their feelings and hope to work with them in the next scientific endeavor.

Finally, my job has been to compile, organize, and present these recent scientific advances to the community. Now, it is the community's duty to benefit from this work, convey it to others, and contribute positively to humanity.

Happy signaling!

Suwon, South Korea

Sangdun Choi

Preface to First Edition

Biological processes are driven by a complex system of functionally interacting signaling components within the cell. These signaling processes are initiated when a class of cell surface proteins, called receptors, receives information from the surrounding environment. This information is then routed through complex signaling pathways and decoded in the nucleus and other areas of the cell. In order to fully understand cell signaling, we must first appreciate the spatial and temporal dynamics of cell surface receptors as well as the downstream components of signaling pathways. The functional states and downstream interactions of cell signaling components are critical to the understanding of both normal and pathologic biological processes. In recent years, a steady increase in both clinical and experimental data on cell signaling has emerged. As we progress through the twenty-first century, it is clear that a systems biology approach, concomitant with the understanding of individual cell signaling components, is needed to delineate biologically relevant signaling networks. Furthermore, it is well understood that almost all diseases exhibit signaling pathway dysfunction. As a result, there has been a profound interest in identifying novel drug targets that regulate key signaling components in disease states.

Currently, there are more than 20,000 genes reported in the human genome; however, not all of the encoded proteins work equally to maintain homeostasis. Achieving a thorough understanding of the most potent signaling components and their associated signaling pathways will significantly improve our knowledge of the molecular mechanisms that regulate disease. Moreover, this insight will lead to the development of novel therapeutics. In recent years, there were multiple attempts to build molecule databases, which were still very partial and brief. Amid the excitement over the recent discoveries of new functional molecules, one of this century's greatest scientific tasks is to compile all information pertaining to signaling components into a single resource. Such an attempt may be arduous but, at the end, will fill the intellectual voids of the field and drastically streamline the understanding of critical signaling networks.

The Encyclopedia of Signaling Molecules is a testament to how far we have come in terms of identifying the function of and the interconnection between signaling molecules. This book represents biologically important signaling components from the level of a single gene, to that of gene families. The contents of this encyclopedia are built on the core concepts of the function of

signaling components along with the early historical findings to show readers the progress the field has achieved. The encyclopedia not only focuses on individual and groups of signaling components, but also explores the interactions between these groups of signaling components within signal transduction networks. Additionally, it also provides an abundance of information on the conversion of external signals generated by growth factors, hormones, neurotransmitters, chemokines, cytokines, etc., to the resultant cellular response. Applications of these data to disease and drug discovery efforts have also been discussed. Overall, the encyclopedia is designed to aid those who wish to investigate the function of specific signaling molecules and its role in signaling networks.

The encyclopedia is a Springer Major Reference Work, published in print and online. It consists of entries organized alphabetically. Each entry is concise, clearly written, and contains references to the literature for readers who wish to study each topic in depth. The broad coverage is expected to make the encyclopedia an indispensable reference tool in the field of biomedical research. The online version features colored illustrations and is fully searchable. In addition, cross-references are listed as hyperlinks to easily access related topics in the book.

There are many people to thank and whose help was critical for completing the Encyclopedia of Signaling Molecules. This encyclopedia is based on the expertise of hundreds of biomedical professionals who must receive my sincere gratitude for their dedication, efforts, and polite responsiveness to the continuous inquiries. Most importantly, the chapter authors have written outstanding pieces that provide the latest information in their respective field of research. I am grateful to the editors and staffs of Springer: Ann H. Avouris, Anil Chandy, Meetu Lall, Mansi Seth, and Rajneesh Roy for their outstanding help and assistance. Special thanks go to Mrs. Melanie Tucker who made certain that all the molecules were included for the final draft of the encyclopedia.

I hope that the information presented in the Encyclopedia of Signaling Molecules will not only aid in understanding the subject matter but also in using the biological information for the benefit of humankind.

Sangdun Choi

List of Topics

14-3-3
3-Phosphoinositide-Dependent Kinase 1 (PDK1)
5-HTT
5-Hydroxytryptamine Receptor 2C
5-Hydroxytryptamine Receptor 6
 Δ FosB
ABCA Transporters
ABCA3
ACAP1
Acetylcholine (Nicotinic) Receptor
Acetylcholinesterase
ACK1
ACSL4
ACT
Actinin Family
Activators of G-Protein Signaling (AGS)
ADAMTS13
ADAP
ADAP1
ADAP2
ADCY9 (Adenylyl Cyclase 9)
Adenomatous Polyposis Coli
Adenylyl Cyclase
ADGRB3
ADGRG2
Adhesion GPCRs
Adiponectin
ADP-Ribosylation Factor-6 (ARF6)
AGAP1
AIFM1
AIRE
A-Kinase Anchoring Protein (AKAP)
AKT
Alpha E Integrin
Alpha-1-Syntrophin
Alpha-2A Adrenergic Receptor
ALS2
AMP-Activated Protein Kinase (AMPK)
Androgen Receptor (AR)
Angiotensin Type 2 Receptor
ANT
AP-3
AP-4
APO2L/TRAIL
Apoptosis Regulator BAX
Apoptosis-Inducing Factor 1, Mitochondrial
App
Aquaporin
A-RAF
ARAP3
ARD1/TRIM23
ARF1
ArfGAP1
ARFRP1 (ADP-Ribosylation Factor Related Protein 1)
ARHGEF25
Arl8b
Aryl Hydrocarbon Receptor
Ataxia Telangiectasia and Rad3-Related (ATR)
ATF2
ATF3 Activating Transcription Factor 3
ATP-Binding Cassette Subfamily A Member 2
Aurora Kinases
Axin
AXL
B Lymphocyte Antigen CD19

BAFF/BLyS Family	CD40
BATF	CD43
BCL-2 Family	CD44
Beta-Catenin	CD45 (PTPRC)
BEX3	CD47
Bitter Taste Receptors	CD53
B-Myb	CD6
Bradykinin Receptors	CD69
BRCA1 and BRCA2	CD72
BTG/TOB	CD81
BTK	CD91
BUB1	Cdc7
BUBR1	CDC73
C3G	CDK11
Cadherins	CDK4
Calcineurin	CDK5
Calcitonin Receptor	CEACAMs
Calcium Calmodulin Kinase Kinase 2	CFL1
Calcium Sensing Receptor (CASR)	C-FLIP
Calmodulin (CALM1)	CFP (Complement Factor Properdin)
Calpain	CHEK2
Calreticulin	Chemokine Receptor CCR1
Cardiac Troponin Complex: Cardiac Troponin C (TNNC1), Cardiac Troponin I (TNNI3), and Cardiac Troponin T (TNNT2)	CHFR
CARMA1	CHIP
Casein Kinase II	Chk1
CASK	Cholecystokinin-1 Receptor
Caspase Family	Cholecystokinin-2 Receptor
Cathepsin B	Chop/GADD153
Caveolin-1	CHT1 (High-Affinity Choline Transporter)
Cbl	CKIP-1
Cbln1	CLEC-1
CCAAT/Enhancer-Binding Protein Beta	CLEC-2
CCL-21	CLEC4E
CCL3	CLEC5A
CCL4	CLEC7A
CCL5	CLK
CCN	c-Myb
CCR5	Complement Factor H (CFH)
CCT α	Copine
CD151	C-Reactive Protein
CD160	CREB
CD28	Csk
CD3	CSK-Homologous Kinase
CD38	c-Src Family of Tyrosine Kinases
CD3 ζ	CX3CL1
	CXCL10
	Cyclin A

Cyclin B
 Cyclophilin
 Cyclooxygenase
 CYR61/CCN1
 Cytochrome P450 (*cyp*)
 Cytosolic Phospholipase A2 (pla2G4A)
 DAPK1
 DARPP-32 (Ppp1r1b)
 Dbf4
 Defensin
 Delta Glutamate Receptor (*GluD1*, *GluD2*)
 Desmoglein-3
 DHHC Proteins
 Diacylglycerol Kinase
 Dickkopf 3
 Dipeptidyl Peptidase 4
 DLK (Dual Leucine Zipper-Bearing Kinase)
 DNAJB6
 DOCK2; Dedicator of Cytokinesis 2
 DPP8
 DPP9
 DRAK2
 DREAM (Downstream Regulatory Element Antagonist Modulator)
 Dual-Specificity Protein Phosphatases
 Dyrk1a
 Dystroglycan
 E3 Ubiquitin Ligase CBL-B
 Early Growth Response 3 (EGR3)
 E-Cadherin
 Ect2 (Epithelial Cell Transforming 2 Oncogene)
 Eif2ak1
 EIF2S1
 ENaC
 Endothelin A Receptor (ETAR)
 ENG
 E-NTPDase Family
 Eotaxins (CCL11, CCL24, CCL26)
 Epac
 Eph Receptor
 EphA3, Erythropoietin-Producing Hepatocellular Carcinoma Cell Receptor A3
 Ephrin Receptor A2
 Epidermal Growth Factor (EGF)
 Epidermal Growth Factor Receptor
 Eps8 (Epidermal Growth Factor Receptor Pathway Substrate 8)
 Epsin
 ERK1 and ERK2
 Erk3 and Erk4
 Erythropoietin Receptor
 Estrogen Receptor
 ETS
 EXO1 (Exonuclease 1)
 Ezrin
 FAP
 Fascin
 Fatty Acid Amide Hydrolase
 FGF (Fibroblast Growth Factor)
 FGF21
 FGR (Gene Name)
 FHIT
 Fibronectin
 Fibulins
 Filamin A
 FKBP (FK506 Binding Protein)
 Flotillin-1 (FLOT1)
 Flotillin-2 (*FLOT2*)
 FMS-Like Tyrosine Kinase-3
 Fn14
 Focal Adhesion Kinase (FAK)
 Follicle Stimulating Hormone Receptor (*FSHR*)
 Forkhead Box Protein O
 Formyl Peptide Receptor
 FoxO1
 FPR2/ALX
 Frabin
 FRS2
 FXYP1 (Phospholemman)
 FZD (Frizzled)
 G alpha o
 G Protein Alpha 12 and 13
 G Protein Alpha Transducin
 G Protein Beta/Gamma
 G Protein α i/o/z
 G Protein-Coupled Receptor Kinase
 Gab1
 Gab2
 GABA (γ -Aminobutyric Acid)
 GABA Transporters
 GABA_A Receptor
 GADD45
 Galectin-9
 GALR, Galanin Receptor

Gamma-1-Syntrophin
 Gamma-Interferon-Inducible Lysosomal Thiol
 Reductase (GILT)
 Gastrin-Releasing Peptide Receptor (GRPR)
 GATA-3
 GCAP (Guanylate Cyclase-Activating Protein)
 GCSF Receptor
 Gephyrin
 GHSR: Growth Hormone Secretagogue
 Receptor
 GIPC
 GIRK2
 GLI Family Zinc Finger 2
 Glioma-Associated Oncogene 1 (GLI1)
 GLP-1
 GLP-1R
 Glucanase Inhibitor Protein (GIP)
 Glucocorticoid Receptor (GR)
 Glucose-Dependent Insulinotropic Polypeptide
 Receptor (*GIPR*)
 GLUT
 Glutamate Receptor
 Glutathione-S-Transferases
 Glycogen Synthase Kinase-3
 Glypicans (GPCs)
GNAS Complex Locus
 GPR120
 GPR41/FFAR3
 GPR55
 GPR56/ADGRG1
 GPR84
 G-Protein α_q (GNAQ)
 G-Protein-Coupled Receptor Kinase 1 (GRK1)
 Granzyme B
 GRB10
 GRK2 (G Protein-Coupled Receptor Kinase 2)
 GRK5
 Growth Hormone Releasing Hormone (GHRH)
 Grp94 (HSP90B1)
 GTP-Binding Protein Rheb
 Guanylate Cyclase
 Guanylyl Cyclase C
 Guanylyl Cyclase Receptors
 HB-EGF (Heparin-Binding EGF-Like Growth
 Factor)
 Heat Shock Protein (HSP)
 Hepatocyte Growth Factor Receptor
 HGF (Hepatocyte Growth Factor)
 High Mobility Group Box B1
 HIPK2
 Hippocalcin
 Histone H2B
 Histone H3
 HLA Class I Histocompatibility Antigen, Alpha
 Chain E
 hnRNP D (AUF1)
 HNRNPA1
 Homer
 HPK1
 HSPA5
 HspB1
 HTR2B
 Human MCP Chemokine Cluster
 Hypoxia-Inducible Factor-1
 Icm1 (Isoprenylcysteine Carboxyl
 Methyltransferase)
 IDH1 (Isocitrate Dehydrogenase 1)
 I κ Bz
 IKK (I κ B Kinase) Complex
 IL-1 Family
 IL-1 Receptor Family
 IL-4 and IL-13 Receptors
 IL6
 IL6RA, Interleukin-6 Receptor Subunit Alpha
 IL7
 Immunity-Related GTPases (IRG)
 Inhibitor of Apoptosis (IAP) Proteins
 Inhibitor of DNA Binding 4 (ID4)
 Inhibitor of KappaB
 Inositol 1,4,5-Trisphosphate-Associated cGMP
 Kinase Substrate
 INSR
 Insulin-Like Growth Factor Receptor Type I
 (IGF1R) Signaling and Inflammation
 Integrin Alpha 4 (Itga 4)
 Integrin Alpha V (*ITGAV*)
 Integrin Alpha11 (ITGA11)
 Integrin $\alpha 1$ (ITGA1)
 Integrin $\alpha 2$ (ITGA2)
 Intercellular Adhesion Molecule 1
 Intercellular Adhesion Molecule-5
 Interferon Regulatory Factor
 Interferon-Gamma
 Interleukin 2

Interleukin-13 Receptor Subunit Alpha-2
(IL-13R α 2)
Interleukin-17 Receptor A
Interleukin-18
Involucrin
IQGAP
IRF5
ITPK1 (Inositol Tetrakisphosphate 1-Kinase)
ITSN
Kalirin
Kallikrein-K1
KEAP1
Kit
Krüppel-Like Factor 4 (KLF4)
Ku70 and Ku80
K ν 1.1
Kv5, Kv6, Kv8, and Kv9
Laforin
Laminin β 2
LAT
LCoR
LDHA (Lactate Dehydrogenase A)
Leptin and Leptin Receptor
Leucine Carboxyl Methyltransferase
Leukocyte Immunoglobulin-Like Receptor
(LILR)
LGR4 (Leucine-Rich Repeat G-Protein Coupled
Receptor 4)
LILRB
LIMK
Lyn
Lysophosphatidic Acid Receptor
Lysyl Oxidase
MAGI2/S-SCAM
MAGUK
MALT1 (Mucosa-Associated Lymphoid Tissue
Translocation Gene 1)
MAP Kinase-Activated Protein Kinase 5 (MK5)
MAP/Microtubule Affinity-Regulating Kinase
MAP4K3 (GLK)
MAPK Interacting Protein Kinase 1 and 2
(Mnk1 and Mnk2)
Mapkap Kinase 2/3 (MK2/3)
MASP-1
MASP1 and *MASP2*
Matriptase (ST14, Suppressor of Tumorigenicity
14 Protein)
Matrix Metalloproteinase-2
Matrix Metalloproteinases
MAVS-Mitochondrial Antiviral Signaling Protein
MDM2 (Murine Double Minute 2)
MDM4 (Murine Double Minute 4)
Mek
Mek3
MEK5/ERK5
Melanin-Concentrating Hormone Receptor 1
(MCHR1)
Melatonin Receptor MT₁ and MT₂
Merlin (*NF2*)
Microtubule Affinity Regulating Kinase-4
Microtubule Affinity Regulating Kinases
(MARK)
Mineralocorticoid Receptor
Miro (Mitochondrial Rho)
Mitochondrial Ubiquitin Ligase
MITOL/MARCH5
Mitogen-Activated Protein Kinases
MKK6
MK-STYX
MLK3
MMP-9
MOB1A
Monocarboxylate Transporter (SLC16A)
Monopolar Spindle 1 (Mps1)
MORG1 (Mitogen-Activated Protein Kinase
Organizer 1)
MOZ and MORF Lysine Acetyltransferases
MRC2
Mrck
MSK1
MSN (Moesin)
mTOR
MTUS1/ATIP
Mucins (MUCs)
MYC
MyD88 (Myeloid Differentiation Primary
Response Gene 88)
MYLK (Myosin Light Chain Kinase)
Myoglobin (Mb)
Myosin I (Myo1)
Myosin III
Myosin X
Myosins
Na⁺/HCO₃⁻ Cotransporter NBCn1

- Na⁺/K⁺-ATPase
 Natriuretic Peptide Receptor Type A (NPRA)
 Natriuretic Peptide Receptor Type B (NPRB)
 Natriuretic Peptide Receptor Type C (NPRC)
 NBCe1 Electrogenic Na⁺-Coupled
 HCO₃⁻(CO₃²⁻) Transporter
 NCAM1
 NDFIP1 and NDFIP2
 NEDD4
 NEDD4-2
 NEKs, NIMA-Related Kinases
 Net1 (Neuroepithelial Cell Transforming Gene 1
 Protein)
 Neurogenins
 Neurokinin-1 Receptor
 Neurotensin Receptor (NTSR)
 Neutral Ceramidase
 NFAT
 NF-κB Family
 NGF
 NHERF
 NK Receptor
 NKG2D
 NKp46
 NLK
 N-Lysine Methyltransferase SMYD
 NMT (*N*-Myristoyltransferase)
 N-Myc and STAT Interactor (NMI)
 Nonmuscle Myosin II
 Notch (Notch1, Notch2, Notch3, Notch4)
 Nr0b2
 NR4A2 (Nuclear Receptor Subfamily 4, Group A,
 Member 2)
 NR5a1
 Nrf2 (NF-E2-Related Factor2)
 NTCP (Sodium Taurocholate Cotransporting
 Polypeptide)
 Nuclear Myosin I
 Nuclear Receptor-Interacting Protein 1 (NRIP1)
 Nucleotide Receptor P2x
 Nucleotide Receptor P2Y
 N-WASP
 OCT4 (Octamer-Binding Transcription Factor 4)
 Olfactory Receptors
 Opioid Receptor
 Orexin Receptor-1 (OX₁R)
 OSBP and OSBPL1-11/ORP1-11
 Osteopontin (*Spp1*)
 Osteoprotegerin
 OTR (Oxytocin Receptor)
 p130Cas
 P2Y₁₄ Receptor
 p38 Gamma MAPK
 p38 MAPK Family
 p53
 p57
 p66Shc
 PABPN1
 Pak2
 PAKs
 Parkin
 PCAF Lysine Acetyltransferase
 PDE11A
 PDE2A
 PDE4
 PDGF
 Pea15
 PEBP-1
 PECAM
 PEPCK-M
 Periostin (POSTN)
 Peroxiredoxins
 Peroxisome Proliferator-Activated Receptor
 (PPAR)
 Peroxisome Proliferator-Activated Receptor
 Alpha (PPAR-Alpha)
 Peroxisome Proliferator-Activated Receptor-γ
 PGC-1α
 PH Domain Leucine-Rich Repeat Protein
 Phosphatase (PHLPP)
 PHLDA1 (Pleckstrin Homology-Like Domain,
 Family A, Member 1)
 Phosphatidylinositol 4-Kinase (PI4K2B)
 Phosphatidylinositol 4-Kinase Type II Alpha
 Phosphatidylinositol 5-Phosphate 4-Kinase
 Phosphodiesterase 1
 Phosphodiesterase 10A
 Phosphoinositide 3-Kinase
 Phosphoinositide-Specific Phospholipase C
 (PI-PLC)
 Phospholipase A₂
 Phospholipase D
 Pim-1
 Pin1

PITX2 (Pituitary Homeobox Gene 2)	Rab27
PKD	Rab7a in Endocytosis and Signaling
PKR	Rab8
Plasma Membrane Calcium-Transporting ATPase	Rac GTPase
Plasminogen Activator Inhibitor-1	RAF-1 (C-RAF)
Plasminogen Activator, Urokinase Receptor	Ral
Platelet-Activating Factor Acetylhydrolase (Pafah)	Ramp
Pleiotrophin	Ran
Podoplanin (pdpn)	RANK and RANKL
Polo-Like Kinase (PLK)	Rap GEF Family
Polycystin-2	Ras (H-, K-, N-Ras)
PP2C	RASA1
PPIP5K	RASD1
Prep	RasGrf1 and RasGrf2
Presenilin	RasGRP1
P-Rex	Ras-Related Associated with Diabetes
P-Rex1	RASSF Family
P-Rex2	RASSF6
Prion (<i>PRNP</i>)	RBR E3 Ubiquitin Ligases
PRKDC	RCAN
Proliferating Cell Nuclear Antigen	Receptor-Interacting Protein Kinase
Prostaglandin E2 Receptor EP2 Subtype	Recoverin
Protein Disulfide Isomerase	Regulator of Calcineurin 1 (RCAN1)
Protein Farnesyltransferase	Regulator of G Protein Signaling 5 (RGS5)
Protein Kinase C (<i>Prkc</i>)	Regulator of G-Protein Signaling 1 (RGS1)
Protein Phosphatase 1 (PP1)	Relaxin Family Peptide Receptors RXFP1 and RXFP2
Protein Tyrosine Kinase-6 (PTK6)	Relaxin Family Peptide Receptors RXFP3 and RXFP4
Proteinase-Activated Receptors (PARs)	RET Tyrosine Kinase Receptor
Protein-Glutamine Gamma-Glutamyltransferase	Retinal Guanylyl Cyclase-Activating Protein 1 and 2
PSD3	Retinoblastoma Tumor Suppressor Protein (RB)
PSD-95 (Postsynaptic Density Protein-95)	Retinoic Acid Receptors (RARA, RARB, and RARC)
PSGR	Retinol-Binding Protein 4 (RBP4)
PTEN	RGS Protein Family
PTEN-Induced Kinase 1 (PINK1)	RGS10
PTPe (RPTPe and Cyt-PTPe)	RGS13
PTPN3/PTPN4	RHEB
PTPN6	RhoA
PTPRH	RhoC (RHOC)
PTX3	RIAM (Rap1-Interactive Adaptor Molecule)
Pyruvate Kinase M2	Ribonuclease L (RNase L)
R7BP/R9AP	Ric-8
RAB Family	RIG-I (Retinoic Acid Inducible Gene-I)
Rab Geranylgeranyltransferase	Rin (Ras-Like Protein in Neurons)
RAB18	
Rab23	
Rab25	

RIN Family Proteins (RIN1, RIN2, and RIN3)	SLC9
ROCK	Slp (Synaptotagmin-Like Protein)
RPN8	SLP-76
RPT	SMAP1
RSK (p90 Ribosomal S6 Kinase)	SOCS
Rufy	Somatostatin Receptor
RUNX	Sonic Hedgehog (Shh)
RUNX3	Sorcin
Ryanodine Receptor (RyR)	Sox2 (SRY-Box 2)
S100 Proteins	Sp1
S100a13	Spectrin
S100A6	Sphingomyelinase, Acidic
S6K (S6 Kinase)	Sphingosine Kinase 2 (SPHK2)
SAMSN1 (SAM Domain, SH3 Domain, and Nuclear Localization Signal)	Sphingosine-1-Phosphate
SARA	Sprouty
Sarcolipin	Src-Like Adapter Protein (SLAP)
Sarcoplasmic/Endoplasmic Reticulum Calcium ATPase 1	Src-Like Adapter Protein 2 (SLAP2)
SARM1 (Sterile Alpha and TIR Motif-Containing Protein 1)	Sry
SCD (Stearoyl-CoA Desaturase)	StAR
SCF1	STAT
Secretin Receptor	STAT6
Secretory Leukocyte Protease Inhibitor (SLPI)	Steroid Receptor Coactivator Family
Septin	Striatal-Enriched Protein-Tyrosine Phosphatase (STEP)
Serine/Threonine-Protein Kinase SMG1	Stromal Interaction Molecule
Serine/Threonine-Protein Phosphatase 2A	Structural mRNAs
Serpine1	Structure and Functions of the Urokinase Receptor
SGK-1 (Serum- and Glucocorticoid-Inducible Kinase-1)	Sulfiredoxin
SH2B Adapter Protein 3 (SH2B3)	Superoxide Dismutase 1-3
SH2D2A	Survivin
SHIP	SWI/SNF Chromatin Remodeling Complex
SHIP2	SYK
Sigma Receptor (σ R)	Synapsin II
Sirpa	Synapsins (SYN)
SIRT2	Syndecan-1
Sirtuin	SYNJ1
SKAP-HOM	SYX/PLEKHG5, A RhoA Guanine Exchange Factor Involved in Cell Migration and Angiogenesis
SLC20	TAK1
SLC24A Family (K^+ -Dependent Na^+ - Ca^{2+} Exchanger, NCKX)	Task
SLC28 and SLC29	TBCC
SLC32	TBCCD1
SLC34	Tefl
SLC3A2	TDP1 (Tyrosyl-DNA Phosphodiesterase I)
	Tead

Tec
Tenascin-C (TNC, Tnc)
Tenascin-W (Tnn, TNN)
The 5-HT₃ Receptor
Thioredoxin (TXN)
Thioredoxin Reductase
Thrombospondin-1
Thymic Stromal Lymphopoietin (TSLP)
Thyrotropin Receptor
Tie1
TIF5 (eIF5)
TIF6 (eIF6)
Tissue Factor
Tissue Inhibitor of Metalloproteinase
Tissue-Type Plasminogen Activator
TLR4 (Toll-Like Receptor 4)
TLR5 (Toll-Like Receptor 5)
TLR7
TLR8
TMEM85 (Transmembrane Protein 85)
TNFAIP3 (Tumor Necrosis Factor, Alpha-Induced Protein 3)
Toll-Like Receptor 2
Toll-Like Receptor 3
Toll-Like Receptor 9
Toll-Like Receptor Adaptor Protein Family Members
Torsin 1A Interacting Protein 1
TPL2
Trace Amine-Associated Receptor 1 (TAAR1)
TRAF3
TRAF6
TRAIL Receptor 1/2 (Death Receptor 4/5, DR4/5)
Transcription Factor 4
Transcription Factor PU.1
Transferrin
Transient Receptor Potential Cation Channel Subfamily A Member 1 (TRPA1)
Transient Receptor Potential Cation Channel Subfamily C Member 5
Transient Receptor Potential Cation Channel Subfamily M Member 2
Transient Receptor Potential Cation Channel Subfamily M Member 7
Transient Receptor Potential Cation Channel Subfamily V Member 2 (TRPV2)
Transient Receptor Potential Cation Channel Subfamily V Member 4 (TRPV4)
Transient Receptor Potential Cation Channel, Subfamily C, Member 2, Pseudogene
TRAP1
Tribbles
Tribbles Homolog 1
Trio
Tristetraprolin (ZFP36) and TIS11B (ZFP36-L1)
TRP (Transient Receptor Potential Cation Channel)
TRPM1
TRPM3
TRPM4
TRPV3 (Transient Receptor Potential Channel Subfamily V Member 3)
TRPV6
Tryptophan Hydroxylase 2
Tumor Necrosis Factor-Like Weak Inducer of Apoptosis (TNFSFS12)
Tumor Protein D52 (TPD52)
Type I Interferons
Type-1 Cannabinoid Receptor
Tyrosine-Protein Phosphatase Nonreceptor Type 11 (PTPN11)
UBA2 (Ubiquitin-Like Modifier-Activating Enzyme 2)
Ubiquitin Carboxyl-Terminal Hydrolase CYLD
UBR4 (Ubiquitin Ligase E3 Component N-Recognin 4)
ULK1
Urocortin
USP7 (Ubiquitin-Specific Protease 7)
USP8 (Ubiquitin-Specific Protease 8)
UT (Urea Transporter)
VAMP1/2/3/7
Vascular Endothelial Growth Factor Receptor (VEGFR)
Vav Family
VDR, the Vitamin D Receptor
VEGF
Vimentin
Vinculin (VCL)
Vitronectin
Voltage-Gated Calcium Channels: Structure and Function (CACNA)
von Willebrand Factor

VRK1
VRK2
VRK3
WASH
WEE1
WISP1
WNT
ZAK
Zap-70

ZC3H14
ZEB1 (Zinc Finger E-Box Binding Homeobox 1)
Zinc Finger E-Box-Binding Homeobox 2
Zinc Transport in the Pancreatic β -Cell: Roles of
ZnT (*SLC30A*) and ZiP (*SLC39A*) Family
Members
ZNF202

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