Part 1
Metabolic Pathways

Roche Biochemical Pathways
4th Edition, Part 1 – Editor: Gerhard Michal

SV-10903

Roche

General Remarks for Part 1 and 2

1) Enzymes are in blue. The "Recommended Names" in the "Enzyme Nomenclature" (Academic Press, San Diego, 1992) and its supplements (Eur. J. Biochem. 167, 1 (1987) and 179, 489 (1989)) are used. Enzymes not listed there are printed in parentheses.
2) Coenzymes are shown in red, other reaction participants in black.
3) Color of the arrows shows type of organism in which the reaction was observed or is likely to occur.
4) Regulatory effects are shown in orange. Metal ions and similar activators are located above the reaction arrow, inhibitors below the arrow. Where the exact biochemical mechanism there is nothing orange arrow coming from the effector with a "blow" regulation (e.g. induction or repression of the enzyme synthesis) is drawn. Where the exact biochemical mechanism is known, the orange arrow points to the enzyme that has only one of multiple isoenzymes is regulated in this way.
5) Compounds enclosed in black boxes are usually excreted by the cell.
6) Compounds enclosed in black brack: sharp edged boxes occur in several places in the pathways, rounded boxes only at one place in the pathways.
7) Boxes with hatched corners are sometimes used in part 2 to indicate enzyme clusters.
8) Compound names in orange boxes indicate entrance or exit products of metabolism.
9) Compound names in orange ovals indicate that the compound is a precursor for many structural formulae, usually since the free acid or some other fundamental group is not signal on different grades of ionization occur simultaneously. Therefore, participation of H+ or OH- ions in reactions is frequently not indicated.
10) Organic phosphates are usually drawn as the 2- or 1- anion, which predominates in cells.
11) All amino acids can be attached to their respective RNAs by the appropriate ligases. This is not shown in the pathways unless it is relevant.
12) Cellular surface structures of the eukaryotic cell, like endoplasmic reticulum, Golgi apparatus etc. have approximately the same thickness. For graphical reasons, however, they are drawn with different thicknesses.
13) RNA molecules are written with small letters, e.g. mRNA, tRNA, rRNA, snRNA, scRNA, hnRNA, snoRNA, 4.5S RNA, 5S RNA, 7S RNA. Ribosomal RNAs are designated by their sedimentation coefficient, e.g. 16S rRNA, 23S rRNA, 28S rRNA, designating them in a "A-T-C" - indicating the molecular weight (in kD) and the origin (A = cellular, T = mitotic).

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Layout Typesetting: CMS - Cross Media Solutions GmbH,Würzburg
Printed in Germany by Stürtz,Würzburg
Printed in Germany

Abbreviations for Part 1

ACC	acceptor (in redox reactions)
ACP	acyl carrier protein
ACTH	adrenocorticotropic hormone
AMP, ADP, ATP	adenosine 5'-mono-, di-, triphosphate (cAMP: 3',5'-cyclic monophosphate)
ANP	atrial natriuretic peptide, atrionatrin
Asn	asparagine
CAM	calmodulin
CDP, CMP, CTP	cytidine 5'-di-, monophosphate, -triphosphate
CoA	coenzyme A
DAG	diacylglycerol
DNA	deoxyribonucleic acid
DON	6-diazo-5-oxo-L-norleucine
EGF	epidermal growth factor
FAD	flavin adenine dinucleotide
FMN	flavin mononucleotide
FSH	follicle stimulating hormone
GABA	γ-aminobutyric acid
GDP, GMP, GTP	guanosine 5'-di-, mono-, triphosphate
GH	growth hormone
GnRH	gonadotropin releasing hormone
GSH	glutathione, reduced
GSSG	glutathione, oxidized
HMG-CoA	3-hydroxy-3-methylglutaryl-CoA
IMP	inosine 5'-monophosphate
IP$_3$	inositol 1,4,5-trisphosphate
LH	luteinizing hormone
MSH	melanocyte stimulating hormone
NAD, NADH	nicotinamide adenine dinucleotide, reduced
NADP, NADPH	nicotinamide adenine dinucleotide phosphate, reduced
NEF	non-esterified fatty acids
PAPS	3'-phosphoadenylyl sulfate
PEP	phosphoenolpyruvate
PRPP	5-phosphoribosyl 1-pyrophosphate
RNA, mRNA, tRNA, rRNA, 4.5-S, 5S, 7S	ribonucleic acid, messenger-, transfer-, ribosomal-, 4.5S-, 5S-, 7S RNA
SAM	S-adenosylmethionine
TPP	thiamine pyrophosphate
UDP, UMP, UTP	uridine 5'-di-, mono-, triphosphate

Notes for Part 1

1) D-Galactose is slowly D-glucose is also split by this enzyme.
2) Lactose is also formed by galactosyltransferase (EC 2.4.1.22) (Biochem. 167, 1 (1987)) and 179, 489 (1989)) are used. Enzymes not listed there are printed in parentheses.
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5) Regulatory effects are shown in orange. Metal ions and similar activators are located above the reaction arrow, inhibitors below the arrow. Where the exact biochemical mechanism there is nothing orange arrow coming from the effector with a "blow" regulation (e.g. induction or repression of the enzyme synthesis) is drawn. Where the exact biochemical mechanism is known, the orange arrow points to the enzyme that has only one of multiple isoenzymes is regulated in this way.
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21) NAD is used by the liver enzyme, NADP in both coenzymes by microbial enzymes.
22) NAD is used by the liver enzyme, NADP by another yeast enzyme, NADP by another yeast enzyme.
23) Phosphoserine dephosphatase or phosphorine diphosphate are intermediates of these reactions.
24) The conversion proceeds via 3-dehydroquinate. The enzymes responsible for this conversion are found in bacteria, fungi and plants, but not in animals.
25) Shikimate kinase has also been demonstrated in mammalian liver.
26) Degradation proceeds similarly to acetyl-CoA degradation.
27) Other enzymes (glycerol dehydrogenase and glycerol 2-dehydrogenase) convert glycerol into dihydroxyacetone phosphate.
28) Glycerol is also formed from glycerol 3-phosphate by a specific phosphatase. In adipose tissue, however, glycerol is formed from glucose via dihydroxyacetone phosphate instead of acetyl-CoA.
29) Acetyl-CoA is split off from here. The central SH group is written at the bottom the marginal SH group at the top. In animals and in E.coli, the enzyme is a complex of 3 different proteins.
30) Examples are DSH-homocysteine transhydrogenase and protein disulfide reductase.
31) Reduction of nucleoside triphosphates takes place in Lactobacillus leichmannii, E.coli, Klebsiella and Brevibacter reductase may be replaced by glutaredoxin plus GSH, which is then regenerated by GSH reductase.
32) Ribonucleoside triphosphate reductase is also found in Lactobacillus leichmannii.
33) Ribonucleoside diphosphate reductase is also found in cells which actively synthesize pyrimidine and purine groups, forming 2'-nucleotides. Other splitting types are also found.
34) In many species the biosynthesis of purines, pyrimidines amino acids,fatty acids etc. is subject to feedback inhibition by the respective end products of the pathways.
35) NADP is used by animal and yeast enzymes,NAD by the bacterial enzyme.
36) Glycine atoms are shown in positions 4 and 5 of purine ring. The same holds for positions 2 and 8.
37) Formation of α- and β-ureidene occurs via ureidene-α-carotene may also be formed from lycopene. Cyclization of the ψ-end group is also possible in some species.
38) Biosynthesis of cholesterol in mammalian systems is controlled by the regulation of microsomal HMG-CoA reductase.
39) Mevalonate is also formed from HMG-CoA by a hydrolytic enzyme.
40) These steps are analogous to the reactions of ornithine cycle.
41) These reactions appear to be similar to fatty acid activation and β-oxydation of fatty acids.
42) From decarboxylation of mevalonate-5-pyrophosphate.
43) Also from mevalonate-5-pyrophosphate via 5-phosphomevalonate.
44) A 6-oxidation type reaction takes place.
45) Cholesterol is transported from the liver to extrahepatic tissues.
46) Many D,L-lactate dehydrogenases react with D-glycerate.
47) Glutamate addition to the tetrahydrofolate moiety is catalyzed by folylpolyglutamate synthetase (EC 6.3.2.17).

Inositol metabolism
Pentose interconversions
Nucleotide sugars
Aromatic amino acids
Histidine metabolism
Purine biosynthesis
Pterine biosynthesis
Lysine metabolism
β-Lactam antibiotics
Butanol/butarate fermentation
Sulfur metabolism
Amino sugars
Entner-Doudoroff pathway
Pentose cycle
Methane oxidation
Glycolysis Gluconeogenesis
Anaplerotic reactions
Glyoxylate cycle
Citrate cycle
Glutamate decarboxy-lation pathway
Mesaconate pathway
Aspartate group of amino acids
Urea Cycle
Pyrimidine biosynthesis
Glutamate group of amino acids
Pyrimidines
Purines
Porphyrins
Bile pigments
Polysaccharides
Fatty acid synthesis
Lipid metabolism
Fatty acid oxidation
Ketone
Phosphatides
One carbon pool
Methanogenesis
Branched chain amino acids
Carotenoids
Isoprenoids
Phytosterols
Mycosterols
Zoosterols
Mineralocorticoids
Glucocorticoids
Gestagen
Corticoids and Gestagens
Androgens
Estrogens
Bile Acids