

# **The activity reaction core and plasticity of metabolic networks**

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**Supplementary Material**

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## **1. Calculation of P-values:**

To estimate the statistical validity of our results, we calculate their P-values; measuring the strength of the null hypothesis. We do so either through analytical or numerical calculations. Generally, we calculate

$$P = \sum_{x>a}^b p(x), \quad (1)$$

representing the cumulative probability that an event  $x>a$  will happen by chance.

### **(a) P-value for the distribution of lethal reactions in the core**

We test the null hypothesis that the number of lethal reactions observed in the core is due to a random event by finding the total probability  $P$  that  $x$  lethal reactions out of  $n$  possible will be found in a core with  $M$  reactions when the total number of reactions is  $N$ . This probability is given by the hypergeometric distribution as:

$$P = \sum_{x=a}^b \binom{n}{x} \binom{N-n}{M-x} / \binom{N}{M}, \quad (2)$$

where  $a$  is the actual number of lethal core reactions, and  $b$  is the smaller of  $n$  or  $M$ .

### **(b) Connected core**

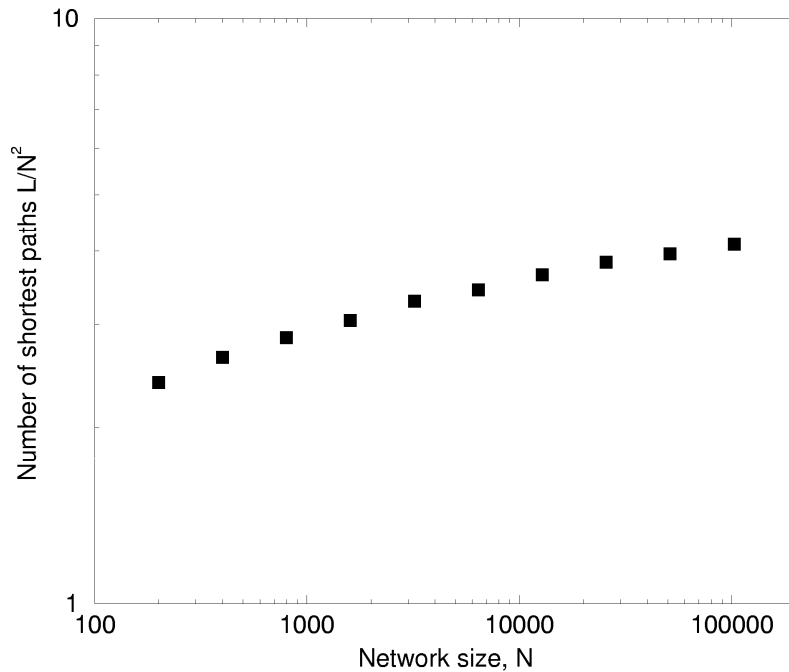
We test the null hypothesis that the metabolic core would be connected by chance. We cannot do this analytically, since the probability  $P$  depends on the actual network structure. Instead, we calculate this  $P$ -value numerically by randomly selecting  $x$  reactions, where  $x$  is the size of the actual core, from the full reaction set. Using a simple network-burning algorithm, we can then find the size of the biggest connected component in the randomly selected reaction set. The burning algorithm is simply implemented as follows: (1) select a node  $i$  among the  $x$  reactions. (2) recursively delete node  $i$  and all its neighbors until no further nodes can be reached. (3) Select a new node  $j$  among those remaining. We repeat this procedure a minimum of  $1e6$  times. An estimate for  $P$  is given by the fraction of times we found a connected component of equal or larger size than the actual core.

**(c) Evolutionary retention in the core**

We test the null hypothesis that the calculated evolutionary retention (ERI) of the metabolic core is a result of chance selection. Again, we need to resort to numerical calculations since the probability  $P$  depends on the actual ERI values of the reactions. We estimate  $P$  by randomly selecting  $x$  (the size of the core) numbers from the set of ERI values before calculating their average value  $\langle E \rangle$ . An estimate for  $P$  is now given by the number of times we find  $\langle E \rangle$  greater or equal to the actual value out of  $1e6$  trials.

**(d) Half-life times of the core**

We test the null hypothesis that the average mRNA half-life time of the metabolic core is the result of chance selection. We need to estimate  $P$  numerically, and we repeat the approach given in (c).



**Figure S1. Number of shortest paths.** We calculate the number of shortest paths as function of network size for the scale-free Barabási-Albert network model. We find that the average number of shortest paths increases faster than  $N^2$ .

## **2. Error analysis of lethality data:**

We simulate the effect of false-positive (F/P) and false-negative (F/N) determination of lethality as follows. (1) With probability  $p$ , we change the classification of every essential gene to non-essential to emulate an F/P determination in the data set. (2) We then calculate the average lethality for the metabolic core and the non-core. (3) We repeat steps (1) and (2) a total of 10,000 times to reach convergence in the average lethality calculation. Similarly, we simulate of the effect of F/N's in the data set by, in step (1), changing every non-essential gene into essential with a probability  $p$ . Our results are summarized in Table 1. For the simple situation where there is a one-to-one correspondence between genes and reactions, the lethality ratios will follow  $r=x(1-p)$  and  $r=x(1-p)+p$ , where  $x$  is the original ratio and  $p$  is the noise level, for F/P and F/N respectively. Comparing these expressions with the entries in Table 1, we find a good correspondence.

Noise, $p$	<i>E. coli</i>				<i>S. cerevisiae</i>			
	F/P; core	F/P; non-core	F/N; core	F/N; non-core	F/P; core	F/P; non-core	F/N; core	F/N; non-core
0.00	74.7%	19.6%	74.7%	19.6%	84.0%	15.6%	84.0%	15.6%
0.05	70.9%	18.7%	75.9%	23.6%	79.7%	14.8%	84.8%	19.8%
0.10	67.3%	17.7%	77.3%	27.7%	75.8%	14.0%	85.6%	24.0%
0.15	63.5%	16.7%	78.5%	31.7%	71.3%	13.2%	86.4%	28.2%
0.20	59.8%	15.7%	79.8%	35.7%	67.1%	12.5%	87.2%	32.5%
0.25	56.0%	14.7%	81.0%	39.7%	62.9%	11.7%	88.0%	36.7%

**Table 1:** Numerical simulation of noise in the lethality data. F/P (false-positive) and F/N (false-negative) designate if the experimental data respectively overestimate or underestimate the occurrence of lethal genes.

## **3. Calculation of shortest paths:**

We estimate the dependence of shortest paths on the size of a network by investigating the model of Barabási and Albert [1]. Growing the network according to the prescription for preferential attachment, we generate systems of size 200 to 102,400. We calculate the average number of all shortest paths by use of the breadth first search (BFS) algorithm

from a randomly selected node in the network. Note that the BFS algorithm is capable of finding *all* the shortest paths between any two nodes [2]. This is repeated for 1000 realizations of each network size. We find that the average number of shortest paths increases faster than  $N^2$  (see Figure S1).

#### **4. Metabolic core reactions and metabolic pathways:**

We investigated the membership of the metabolic core reactions in the various metabolic pathways. Of the core reactions, *E. coli* has 11 in the Glycolysis pathway, 7 in the Aromatic Amino Acid pathway, 7 in the salvage pathway, 15 in Membrane Lipid Biosynthesis, 9 in Riboflavin Biosynthesis (complete), 8 in Folate Biosynthesis (almost complete), 5 in Coenzyme A pathway, 19 in Cell Envelope Biosynthesis (almost complete), and 10 in the Peptidoglycan Biosynthesis pathway (complete). The remaining reactions are scattered over the metabolic network. For *S. cerevisiae*, we find 11 in the Cytosolic Fatty Acid Biosynthesis, 8 in Phospholipid Biosynthesis, 4 in the salvage pathways, and 6 in the Coenzyme A Biosynthesis. The rest are scattered over the metabolic network.

#### **5. Construction of *E. coli* metabolic core diagram:**

From the list of metabolic core reactions (see section 5) we constructed the diagram of the core metabolic network (Figure 2). For each reaction, we omitted cofactors like CoA and ATP for the sake of clarity. However, we kept all the substrates and products for the nucleoside-diphosphate, the cytidylate and the dTMP kinase reactions. We colored blue the metabolites that directly participate in the biomass production reaction, and links (enzymatic reactions) found to be lethal during LB conditions are colored red. The arrows on the links indicate a directed reaction. Links without arrows are capable of both positive and negative flux flow. To facilitate a simple layout, we had to repeat several metabolites in the diagram, and the dotted blue lines serve as guides to the eye for their duplicate placement.

## **6. Metabolic core reactions:**

We list the metabolic core reactions for the bacteria *H. pylori* and *E. coli* and the yeast *S. cerevisiae* in the supplementary Excel-formatted file. This file contains the core reaction names, gene names, enzyme classification numbers and a reaction description, when available. For *E. coli*, we have colored the lethal reactions red.

## **7. List of metabolite abbreviations:**

In the following, we give the complete list of the metabolite abbreviations used in the metabolic *in silico* model for *E. coli* and *H. pylori*. This is followed by a list of the metabolite abbreviations used in the model for *S. cerevisiae*.

<b>Abbreviation</b>	<b>Metabolite Name</b>	<b>Abbreviation</b>	<b>Metabolite Name</b>
Abbreviation	Metabolite Name	H2	Hydrogen
12PPD	1,2-Propanediol	H2O2	Hydrogen peroxide
13DPG	1,3-bis-Phosphoglycerate	H2S	Hydrogen sulfide
23DHB	2,3-Dihydroxybenzoate	H2SO3	Sulfite
23DHBA	2,3-Dihydroxybenzoyl-adenylate	HBA	4-Hydroxy-benzyl-alcohol
23DHDHB	2,3-Dihydro-2,3-dihydroxybenzoate	HCYS	Homocysteine
2A3O	2-Amino-3-oxobutanoate	HEMEO	Heme O
2KD6PG	2-keto-3-deoxy-6-phospho-gluconate	HEXT	External H+
2O6H	2-Octaprenol 6-hydroxyphenol	HIS	Histidine
2OMHMB	2-Octaprenyl-3-methyl-5-hydroxy-6-methoxy-1,4-benzoquinone	HISOL	Histidinol
2OPMB	2-Octaprenyl-6-methoxy-1,4-benzoquinone	HISOLP	L-Histidinol-phosphate
2OPMMB	2-Octaprenyl-3-methyl-6-methoxy-1,4-benzoquinone	HMB	Hydroxymethylbilane
2OPMP	2-Octaprenyl-6-methoxyphenol	HPHPYR	para-Hydroxy phenyl pyruvate
2OPPP	2-Octaprenylphenol	HSER	Homoserine
2PG	2-Phosphoglycerate	HYXN	Hypoxanthine
3DDAH7P	3-Deoxy-d-arabino heptulosonate-7-phosphate	ICHOR	Isochorismate
3PG	3-Phosphoglycerate	ICIT	Isocitrate
3PSER	3-Phosphoserine	IDP	Inosine diphosphate
3PSME	3-Phosphate-shikimate	IGP	Indole glycerol phosphate
4HBZ	4-Hydroxybenzoate	ILE	Isoleucine
4HLT	4-Hydroxy-l-tyrosine	IMACP	Imidazole acetyl-phosphate
4PPNCYS	4'-Phosphopantothienoylcysteine	IMP	Inosine monophosphate
4PPNTE	4'-Phosphopantetheine	INDOLE	Indole
4PPNTO	4'-Phosphopantothenate	INS	Inosine
5MTA	5-Methylthioadenosine	IPPMAL	3-Isopropylmalate
5MTR	5-Methylthio-D-ribose	IPPP	Isopentyl pyrophosphate
5MTR1P	5-Methylthio-5-deoxy-D-ribose 1-phosphate	ISUCC	a-Iminosuccinate
5MTRP	S5-Methyl-5-thio-D-ribose 1-phosphate	ITP	Inosine triphosphate
A5P	D-Arabinose 5-phosphate	K	Potassium

A6RP	5-Amino-6-ribitylamino-2,4(1H,3H)-pyrimidinedione	K2LIPIV	(KDO(2))-lipid IV(A)
A6RP5P	5-Amino-6-(ribosylamino)-2,4-(1H,3H)-pyrimidinedione 5'-phosphate	KDO	2-Dehydro-3-deoxy-D-octonate
A6RP5P2	5-Amino-2,6-dioxy-4-(5'-phosphoribitylamino)pyrimidine	KDOLIPIV	(KDO)-lipid IV(A)
AA	D-Alanyl-D-alanine	KDOP	2-Dehydro-3-deoxy-D-octonate 8-phosphate
AACCOA	Acetoacetyl-CoA	KMB	a- keto-g-methiobutyrate
ABUT	2-Aceto-2-hydroxy butyrate	LAC	D-Lactate
AC	Acetate	LACAL	Lactaldehyde
ACACP	Acetyl-ACP	LCTS	Lactose
ACAL	Acetaldehyde	LEU	Leucine
ACCOA	Acetyl-CoA	LIPA	(KDO(2))-lipid A (Endotoxin)
ACLAC	Acetolactate	LIPIV	Lipid IV(A)
ACP	acyl-carrier protein	LIPX	Lipid X
ACTP	Acetyl-phosphate	LLAC	L-Lactate
AD	Adenine	LLCT	L-Cystathionine
ADCHOR	4-Amino-4-deoxychorismate	LPS	Lippolysaccharide
ADN	Adenosine	LRL5P	L-Ribulose-5-Phosphate
ADP	Adenosine diphosphate	LYS	L-Lysine
ADPGLC	From RBC	MAL	Malate
ADPHEP	ADP-Mannoheptose	MALACP	Malonyl-ACP
AGM	Agmatine	MALCOA	Malonyl-CoA
AHHMD	2-Amino-4-hydroxy-6-hydroxymethyl dihydropteridine-pp	MAN1P	Mannose 1-Phosphate
AHHMP	2-Amino-4-hydroxy-6-hydroxymethyl dihydropteridine	MAN6P	Mannose 6-Phosphate
AHM	4-Amino-5-hydroxymethyl-2-methylpyrimidine	MDAP	Meso-diaminopimelate
AHMP	4-Amino-5-hydroxymethyl-2-methylpyrimidine-phosphate	MELI	Melibiose
AHMPP	4-Amino-5-hydroxymethyl-2-methylpyrimidine-pyrophosphate	MET	Methionine
AHTD	2-Amino-4-hydroxy-6-(erythro-1-2-3-trihydroxypropyl) dihydropteridine-p	METHF	5,10-Methenyl tetrahydrofolate
AICAR	5-Phosphate-ribosyl-5-amino-4-imidazole carboxamide	METTHF	5,10-Methylene tetrahydrofolate
AIR	5-Phosphoribosyl-5-aminoimidazole	MK	Menaquinone
AKG	a-Ketoglutarate	MLT6P	Maltose 6-phosphate
AKP	a-Ketopantoate	MNT6P	Mannitol 6-Phosphate
ALA	Alanine	MTHF	5-Methyl tetrahydrofolate
ALAV	D-Aminolevulinate	NA	Sodium
AMP	Adenosine monophosphate	NAAD	Nicotinic acid adenine dinucleotide
AN	Antranilate	NAARON	N-a-Acetyl ornithine
AONA	8-Amino-7-oxononanoate	NAC	Nicotinate
APS	Adenylyl sulfate	NAD	Nicotinamide adenine dinucleotide
ARAB	Arabinose	NADH	Nicotinamide adenine dinucleotide reduced
ARG	Arginine	NADP	Nicotinamide adenine dinucleotide phosphate
ARGSUCC	L-Arginio succinate	NADPH	Dihyronicotinamide adenine dinucleotide phosphate reduced
ASER	O-Acetylserine	NAG	N-Acetylglucosamine
ASN	Asparagine	NAGLU	N-Acetyl glutamate
ASP	Aspartate	NAGLUSAL	N-Acetyl glutamate semialdehyde
ASPSA	Aspartic beta-semialdehyde	NAGLUYP	N-Acetyl glutamyl -phosphate
ASUC	Adenilsuccinate	NAGP	N-Acetylglucosamine 6-phosphate
ATP	Adenosine triphosphate	NAm	Nicotinamide
bALA	b-Alanine	NAMAN	N-Acetyl-D-mannosamine
BASP	b-Aspartyl phosphate	NAMN	Nicotinic acid mononucleotide
BCAA	Branched chain amino acid	NCAIR	5'-Phosphoribosyl-5-carboxyaminoimidazole
bDG6P	b-D-Glucose 6-Phosphate	NH3	Ammonia
bDGLC	b-D-Glucose	NMN	Nicotinamide mononucleotide
BT	Biotin	NPRAN	N-5-phosphoribosyl-antranilate
C120ACP	Dodecanoyl-[acyl-carrier protein]	NS26DP	N-Succinyl-L,L-2,6-diaminopimelate
C140	Myristic acid	NS2A6O	N-Succinyl-2-amino-6-ketopimelate

C140ACP	Myristoyl-[acyl-carrier protein]	O2	Oxygen
C141ACP	Tetradecenoyl-[acyl-carrier protein]	O4HBZ	3-Octaprenyl-4-hydroxybenzoate
C160	Palmitic acid	OA	Oxaloacetate
C160ACP	Hexadecanoyl-[acyl-carrier protein]	OBUT	Oxobutyrate or 2-ketobutyrate
C161ACP	Hexadecenoyl-[acyl-carrier protein]	OGT	Oxidized glutathione
C180	Stearic acid	OHB	3-Hydroxy-4-phospho-hydroxy-alpha-ketobutyrate
C181ACP	Oleoyl-[acyl-carrier protein]	OICAP	2-Oxoisocaproate
CAASP	Carbamoyl aspartate	OIVAL	Oxoisovalerate
CADV	Cadaverine	OMP	Orotidylate
CAIR	5-Phosphoribosyl-5-aminoimidazole-4-carboxylate	OMVAL	Oxomethylvalerate
CAP	Carbamoyl phosphate	OPEP	Oligopeptide
CBHCAP	3-Carboxy-3-hydroxy-isocaproate	OPP	trans Octaprenyl pyrophosphate
CDP	Cytidine diphosphate	ORN	Ornithine
CDPDG	CDP-1,2-Diacylglycerol	OROA	Orotic acid
CDPETN	CDP-Ethanolamine	OSB	O-Succinylbenzoic acid
CHCOA	6-Carboxyhexanoyl-coa	OSBCOA	O-Succinylbenzoyl-CoA
CHOR	Chorismate	OSLHSER	O-Succinyl-L-homoserine
CIT	Citrate	OTHIO	Thioredoxin (oxidized form)
CITR	L-Citrulline	P5P	Pyridoxine-5'-phosphate
CL	Cardiolypin	PA	Phosphatidyl acid
CMP	Cytidine monophosphate	PABA	para-Aminobenzoic acid
CMPKDO	CMP-2-keto-3-deoxyoctanoate	PANT	Pantoate
CO2	Carbon dioxide	PAP	Adenosine-3',5'-diphosphate
COA	Coenzyme A	PAPS	3-Phosphoadenylyl sulfate
CPAD5P	1-O-Carboxyphenylamino 1-deoxyribose-5-phosphate	PBG	Probilinogen III
CPP	Coproporphyrinogen III	PC2	Percorrin 2
CTP	Cytidine triphosphate	PDLA	Pyridoxamine
CYS	Cysteine	PDLA5P	Pyridoxamine-5-phosphate
CYTD	Cytidine	PE	Phosphatidyl ethanolamine
CYTS	Cytosine	PEP	Phosphoenolpyruvate
D23PIC	2,3-Dihydro dipicolinate	PEPT	Peptide
D26PIM	L,L-2,6-Diamino pimelate	PEPTIDO	Peptidoglycan
D6PGC	D-6-Phosphate-gluconate	PG	Phosphatidyl glycerol
D6PGL	D-6-Phosphate-glucono-delta-lactone	PGP	L-1-Phosphatidyl-glycerol-phosphate
D6RP5P	2,5-Diamino-6-(ribosylamino)-4-(3H)-pyrimidinone 5'-phosphate	PHE	Phenylalanine
D8RL	6,7-Dimethyl-8-(1-D-ribyl)lumazine	PHEN	Prephenate
DA	Deoxyadenosine	PHP	3-Phosphohydroxypyruvate
DADP	Deoxyadenosine diphosphate	PHPYR	Phenyl pyruvate
DALA	D-Alanine	PHSER	O-Phospho-L-homoserine
DAMP	Deoxyadenosine monophosphate	PHT	Phospho-hydroxy-threonine
DANNA	7,8-Diaminononanoate	PI	Phosphate (inorganic)
DATP	Deoxyadenosine triphosphate	PIP26DX	Delta-piperidine-2,6-dicarboxylate
DB4P	3,4-Dihydroxy-2-butanone-4-phosphate	PL	Pyridoxal
DC	Deoxycytidine	PL5P	Pyridoxal 5'-phosphate
DCDP	Deoxycytidine diphosphate	PNTO	Pantothenate
DCMP	Deoxycytidine monophosphate	PPHG	Protoporphyrinogen
DCTP	Deoxycytidine triphosphate	PPI	Pyrophosphate
DG	Deoxyguanosine	PPIX	Protoporphyrin IX
DGDP	Deoxyguanosine diphosphate	PRAM	5-Phosphate-b-D-ribosyl amine
DGLU	D-Glutamate	PRBAMP	Phosphoribosyl -AMP
DGMP	2-Deoxy-guanosine-5-phosphate	PRBATP	Phosphoribosyl-ATP
DGR	D-1,2-Diacylglycerol	PRFICA	5-Phosphate-ribosyl-formamido-4-imidazole carboxamide
DGTP	Deoxyguanosine triphosphate	PRFP	Phosphoribosyl-formimino-AICAR-phosphate
DHF	Dihydrofolate	PRLP	Phosphoribulosyl- formimino-AICAR-phosphate
DHMVA	2,3-Dihydroxy-3-methyl-valerate	PRO	Proline
DHNA	1,4-Dihydroxy-2-naphthoic acid	PRPP	Phosphoribosyl pyrophosphate

DHP	Dihydroneopterin	PS	Phosphatidyl serine
DHPP	Dihydroneopterin phosphate	PTH	Protoheme
DHPT	7,8-Dihydropteroate	PTRC	Putrescine
DHSK	Dehydroshikimate	PYR	Pyruvate
DHVAL	Dihydroxy-isovalerate	PYRDX	Pyridoxine
DIMGP	D-Erythro imidazoleglycerol-phosphate	Q	Ubiquinone
DIN	Deoxyinosine	QA	Quinolinatone
DIPEP	Dipeptide	QH2	Ubiquinol
DISAC1P	2,3-bis(3-hydroxytetradecanoyl)-D-glucosaminyl-1,6-beta-D-2,3-bis(3-hydroxytetradecanoyl)-beta-D-glucosaminyl 1-phosphate or dissacharide 1-P	R1P	Ribose 1-phosphate
DKMPP		R5P	Ribose 5-phosphate
DMK	Demethylmenaquinone	RBL	Ribulose
DMPP	Dimethylallyl pyrophosphate	RGT	Reduced glutathione
DOROA	Dihydroorotic acid	RIB	Ribose
DPCOA	Dephosphocoenzyme A	RIBFLV	Riboflavin
DQT	3-Dehydroquinone	RL5P	D-Ribulose 5-phosphate
DR1P	Deoxyribose 1-Phosphate	RML	Rhamnulose
DR5P	Deoxyribose 5-Phosphate	RML1P	Rhamnulose 1-phosphate
DSAM	Decarboxylated adenosylmethionine	RMN	Rhamnose
DSER	D-Serine	RTHIO	Thioredoxin (reduced form)
DT	Thymidine	S7P	sedo-Heptulose 7-phosphate
DTB	Dethiobiotin	SAH	S-Adenosyl homocystine
DTDP	Thymidine diphosphate	SAICAR	5-Phosphoribosyl-4-(N-succinocarboxamide)-5-amino-imidazole
DTMP	Thymidine monophosphate	SAM	S-Adenosyl methionine
DTP	1-Deoxy-d-threo-2-pentulose	SAMOB	S-Adenosyl-4-methylthio-2-oxobutanoate
DTTP	Thymidine triphosphate	SER	Serine
DU	Deoxyuridine	SERA	L-Seryl-adenylate
DUDP	Deoxyuridine diphosphate	SHCHC	2-Succinyl-6-hydroxy-2,4-cyclohexadiene-1-carboxylate
DUMP	Deoxyuridine monophosphate	SHCL	Sirohydrochlorin
DUTP	Deoxyuridine triphosphate	SHEME	Siroheme
DX5P	1-D-Deoxyxylulose-5-phosphate	SLA	Sialic acid
E4P	Erythrose 4-phosphate	SLF	Sulfate
ENTER	Enterochelin	SME	Shikimate
ER4P	Erythronate-4-phosphate	SME5P	Shikimate-5-phosphate
ETH	Ethanol	SPMD	Spermidine
F1P	Fructose 1-Phosphate	SSALTPP	Succinate semialdehyde - thiamine pyrophosphate
F6P	Fructose 6-phosphate	SUC6P	Sucose 6-phosphate
FAD	Flavin adenine dinucleotide	SUCC	Succinate
FADH	Flavin adenine dinucleotide reduced	SUCCOA	Succinyl-CoA or Succinate CoA
FCL	Fuculose	SUCCSAL	Succinate semialdehyde
FCL1P	Fuculose 1-Phosphate	T3P1	Glyceraldehyde 3-phosphate
FDP	Fructose 1,6-diphosphate	T3P2	Dihydroxyacetone phosphate or glycerone phosphate
FGAM	5-Phosphoribosyl-n-formylglycineamidine	TAG16P	Tagatose-1,6 diphosphate
FGAR	5-Phosphoribosyl-n-formylglycineamide	TAG6P	Tagatose-6-phosphate
FMN	flavin mononucleotide	THF	Tetrahydrofolate
FOR	Formate	THIAMIN	Thiamin
FPP	trans, trans Farnesyl pyrophosphate	THMP	Thiamine-phosphate
FRU	Fructose	THR	Threonine
FTHF	10-Formyltetrahydrofolate	THY	Thymine
FUC	Fucose	THZ	4-Methyl-5-(beta-hydroxyethyl)thiazole
FUM	Fumarate	THZP	4-Methyl-5-(beta-hydroxyethyl)thiazole phosphate
G1P	Glucose 1-phosphate	TPP	Thiamine-pyrophosphate
G6P	Glucose 6-phosphate	TRE6P	Trehalose 6-phosphate
GA1P	Glucosamine 1-phosphate	TRP	Tryptophan
GA6P	D-Glucosamine	TYR	Tyrosine
GABA	4-Aminobutanoate	UDP	Uridine diphosphate
GABAL	g-aminobutyraldehyde	UDPG	UDP Glucose

GAL1P	Galactose 1-Phosphate	UDPG23A	UDP-2,3-bis(3-hydroxytetradecanoyl)glucosamine
GAR	5-Phosphate-ribosyl glycineamide	UDPG2A	UDP-3-O-(3-hydroxytetradecanoyl)glucosamine
GC	L-g-Glutamylcysteine	UDPG2AA	UDP-3-O-(3-hydroxytetradecanoyl)-N-acetylglucosamine
GDP	Guanosine diphosphate	UDPGAL	UDP Galactose
GL	Glycerol	UDPNAG	UDP N-acetyl glucosamine
GL3P	Glycerol 3-phosphate	UDPNAGEP	UDP-N-acetyl-3-O-(1-carboxyviny)-D-glucosamine
GLAC	Galactose	UDPNAM	UDP-N-acetyl-D-muramate
GLAL	D-Glyceraldehyde	UDPNAMA	UDP-N-acetylmuramoyl-L-alanine
GLC	a-D-Glucose	UDPNAMAG	UDP-N-acetylmuramoyl-L-alanyl-D-glutamate
GLCN	Gluconate	UDPP	Undecaprenyl pyrophosphate
GLN	Glutamine	UMP	Uridine monophosphate
GLT6P	Glucitol 6-Phosphate	UNAGD	UDP-N-acetylmuramoyl-L-alanyl-D-glutamyl-meso-2,6-diaminoheptanedioate
GLTL1P	Galacitol-1-Phosphate	UNAGDA	UDP-N-acetylmuramoyl-L-alanyl-D-glutamyl-meso-2,6-diaminoheptanedioate- D-alanyl-D-alanine
GLU	Glutamate	UNPTDO	UDP-N-acetylmuramoyl-L-alanyl-D-glutamyl-meso-2,6-diaminoheptanedioate- D-alanyl-D-alanine- diphosphoundecaprenol
GLUGSAL	L-Glutamate g-semialdehyde	UPRG	Uroporphyrinogen III
GLUP	Glutamyl phosphate	URA	Uracil
GLX	Glyoxylate	UREA	Urea
GLY	Glycine	URI	Uridine
GLYCOGEN	Glycogen	UTP	Uridine triphosphate
GMP	Guanosine monophosphate	VAL	Valine
GN	Guanine	X5P	D-Xylulose-5-phosphate
GPP	trans Geranyl pyrophosphate	XAN	Xanthine
GSA	Glutamate-1-semialdehyde	XMP	Xantosine monophosphate
GSN	Guanosine	XTSN	Xanthosine
GTP	Guanosine triphosphate	XUL	D-Xylulose
GTRNA	L-Glutamyl-tRNA(glu)	XYL	D-Xylose

The metabolite abbreviations used in the model for *S. cerevisiae* are as follows:

Abbreviation	Metabolite Name	Abbreviation	Metabolite Name
13GLUCAN	1,3-beta-D-Glucan	H3MCOA	(S)-3-Hydroxy-3-methylglutaryl-CoA
13PDG	3-Phospho-D-glycerol phosphate	H3MCOAm	(S)-3-Hydroxy-3-methylglutaryl-CoAM
23DAACP	2,3-Dehydroacyl-[acyl-carrier-protein]	HACNm	But-1-ene-1,2,4-tricarboxylateM
23PDG	2,3-Bisphospho-D-glycerate	HACOA	(3S)-3-Hydroxyacyl-CoA
2HDACP	Hexadecenoyl-[acp]	HAN	3-Hydroxyanthranilate
2MANPD	("alpha"-D-mannosyl),(2)-"beta"-D-mannosyl-diacetylchitobiosyldiphosphod olichol	HBA	4-Hydroxy-benzyl alcohol
2N6H	2-Nonaprenyl-6-hydroxyphenol	HCIT	2-Hydroxybutane-1,2,4-tricarboxylate
2NMHMBm	3-Demethylubiquinone-9M	HCITm	2-Hydroxybutane-1,2,4-tricarboxylateM
2NPMBm	2-Nonaprenyl-6-methoxy-1,4-benzoquinoneM	HCYS	Homocysteine
2NPMMBm	2-Nonaprenyl-3-methyl-6-methoxy-1,4-benzoquinoneM	HEXT	H+EXT
2NPMP	2-Nonaprenyl-6-methoxyphenol	HHTRNA	L-Histidyl-tRNA(His)
2NPMPm	2-Nonaprenyl-6-methoxyphenolM	HICITm	HomoisocitrateM
2NPPP	2-Nonaprenylphenol	HIS	L-Histidine
2PG	2-Phospho-D-glycerate	HISOL	L-Histidinol
3DDAH7P	2-Dehydro-3-deoxy-D-arabino-heptonate 7-phosphate	HISOLP	L-Histidinol phosphate
3HPACP	(3R)-3-Hydroxypalmitoyl-[acyl-carrier protein]	HKYN	3-Hydroxykynurenine
3PG	3-Phospho-D-glycerate	Hm	H+M
3PSER	3-Phosphoserine	HMB	Hydroxymethylbilane
3PSME	5-O-(1-Carboxyvinyl)-3-phosphoshikimate	HOMOGEN	Homogentisate
4HBZ	4-Hydroxybenzoate	HPRO	trans-4-Hydroxy-L-proline
4HLT	4-Hydroxy-L-threonine	HSER	L-Homoserine
4HPP	3-(4-Hydroxyphenyl)pyruvate	HTRNA	tRNA(His)
4PPNCYS	(R)-4'-Phosphopantothienoyl-L-cysteine	HYXN	Hypoxanthine
4PPNTE	Pantetheine 4'-phosphate	IAC	Indole-3-acetate
4PPNTEm	Pantetheine 4'-phosphateM	IAD	Indole-3-acetamide
4PPNTO	D-4'-Phosphopantothenate	ICIT	Isocitrate
5MTA	5'-Methylthioadenosine	ICITm	IsocitrateM
6DGLC	D-Gal alpha 1->6D-Glucose	IDP	IDP
A6RP	5-Amino-6-ribitylamino-2,4 (1H, 3H)-pyrimidinedione	IDPm	IDPM
A6RP5P	5-Amino-6-(5'-phosphoribosylamino)uracil	IGP	Indoleglycerol phosphate
A6RP5P2	5-Amino-6-(5'-phosphoribitylamino)uracil	IGST	4,4-Dimethylcholesta-8,14,24-trienol
AACCOA	Acetoacetyl-CoA	IIMZYMST	Intermediate_Methylzymosterol_II
AACP	Acyl-[acyl-carrier-protein]	IIZYMST	Intermediate_Zymosterol_II
ABUTm	2-Aceto-2-hydroxy butyrateM	ILE	L-Isoleucine
AC	Acetate	ILEm	L-IsoleucineM
ACACP	Acyl-[acyl-carrier protein]	IMACP	3-(Imidazol-4-yl)-2-oxopropyl phosphate
ACACPM	Acyl-[acyl-carrier protein]M	IMP	IMP
ACAL	Acetaldehyde	IMZYMST	Intermediate_Methylzymosterol_I
ACALm	AcetaldehydeM	INAC	Indoleacetate
ACAR	O-Acetylcarnitine	INS	Inosine
ACARm	O-AcetylcarnitineM	IPC	Inositol phosphorylceramide
ACCOA	Acetyl-CoA	IPPMAL	2-Isopropylmalate
ACCOAm	Acetyl-CoAM	IPPMALm	2-IsopropylmalateM
ACLAC	2-Acetolactate	IPPP	Isopentenyl diphosphate
ACLACm	2-AcetolactateM	ISUCC	a-Iminosuccinate
ACm	AcetateM	ITCCOAm	Itaconyl-CoAM
ACNL	3-Indoleacetoneitrile	ITCm	ItaconateM
ACOA	Acyl-CoA	ITP	ITP
ACP	Acyl-carrier protein	ITPm	ITPM
ACPM	Acyl-carrier proteinM	IZYMST	Intermediate_Zymosterol_I
ACTAC	Acetoacetate	K	Potassium

ACTACm	AcetoacetateM	KYN	L-Kynurenine
ACYBUT	gamma-Amino-gamma-cyanobutanoate	LAC	(R)-Lactate
AD	Adenine	LACALm	(S)-LactaldehydeM
ADCHOR	4-amino-4-deoxychorismate	LACm	(R)-LactateM
ADm	AdenineM	LCCA	a Long-chain carboxylic acid
ADN	Adenosine	LEU	L-Leucine
ADNm	AdenonsineM	LEUm	L-LeucineM
ADP	ADP	LGT	(R)-S-Lactoylglutathione
ADPm	ADPM	LGTm	(R)-S-LactoylglutathioneM
ADPRIB	ADPribose	LIPOm	LipoamideM
ADPRIBm	ADPriboseM	LLACm	(S)-LactateM
AGL3P	Acyl-sn-glycerol 3-phosphate	LLCT	L-Cystathionine
AHHMD	2-Amino-7,8-dihydro-4-hydroxy-6-(diphosphooxymethyl)pteridine	LLTRNA	L-lysyl-tRNA(Lys)
AHHMP	2-Amino-4-hydroxy-6-hydroxymethyl-7,8-dihydropteridine	LLTRNAm	L-lysyl-tRNA(Lys)M
AHM	4-Amino-5-hydroxymethyl-2-methylpyrimidine	LNST	Lanosterol
AHMP	4-Amino-2-methyl-5-phosphomethylpyrimidine	LTRNA	tRNA(Lys)
AHMPm	2-Methyl-4-amino-5-hydroxymethylpyrimidine diphosphate	LTRNAm	tRNA(Lys)M
AHTD	2-Amino-4-hydroxy-6-(erythro-1,2,3-trihydroxypropyl)-dihydropteridine triphosphate	LYS	L-Lysine
AICAR	1-(5'-Phosphoribosyl)-5-amino-4-imidazolecarboxamide	LYSm	L-LysineM
AIR	Aminoimidazole ribotide	MACOA	2-Methylprop-2-enoyl-CoA
AKA	2-Oxoadipate	MAL	Malate
AKAm	2-OxoadipateM	MALACP	Malonyl-[acyl-carrier protein]
AKG	2-Oxoglutarate	MALACPM	Malonyl-[acyl-carrier protein]M
AKGm	2-OxoglutarateM	MALCOA	Malonyl-CoA
AKP	2-Dehydropantoate	MALm	MalateM
AKPm	2-DehydropantoateM	MALT	Malonate
ALA	L-Alanine	MALTm	MalonateM
ALAGLY	R-S-Alanylglycine	MAN	alpha-D-Mannose
ALAm	L-AlanineM	MAN1P	alpha-D-Mannose 1-phosphate
ALAV	5-Aminolevulinate	MAN2PD	beta-D-Mannosyldiacetylchitobiosyldiphosphodolichol
ALAVm	5-AminolevulinateM	MAN6P	D-Mannose 6-phosphate
ALTRNA	L-Arginyl-tRNA(Arg)	MANNAN	Mannan
AM6SA	2-Aminomuconate 6-semialdehyde	MELI	Melibiose
AMA	L-2-Amino adipate	MELT	Melibiitol
AMASA	L-2-Amino adipate 6-semialdehyde	MET	L-Methionine
AMG	Methyl-D-glucoside	METH	Methanethiol
AMP	AMP	METHF	5,10-Methenyltetrahydrofolate
AMPm	AMPm	METHFm	5,10-MethenyltetrahydrofolateM
AMUCO	2-Aminomuconate	METTHF	5,10-Methylenetetrahydrofolate
AN	Anthranilate	METTHFm	5,10-MethylenetetrahydrofolateM
AONA	8-Amino-7-oxononanoate	MHIS	N(pai)-Methyl-L-histidine
APEP	Nalpha-Acetylpeptide	MI	myo-Inositol
APROA	3-Aminopropanal	MI1P	1L-myo-Inositol 1-phosphate
APROP	alpha-Aminopropionitrile	MIP2C	Inositol-mannose-P-inositol-P-ceramide
APRUT	N-Acetylputrescine	MIPC	Mannose-inositol-P-ceramide
APS	Adenylylsulfate	MLT	Maltose
ARAB	D-Arabinose	MMET	S-Methylmethionine
ARABLAC	D-Arabinono-1,4-lactone	MNT	D-Mannitol
ARG	L-Arginine	MNT6P	D-Mannitol 1-phosphate
ARGSUCC	N-(L-Arginino)succinate	MTHF	5-Methyltetrahydrofolate
ASER	O-Acetyl-L-serine	MTHFm	5-MethyltetrahydrofolateM
ASN	L-Asparagine	MTHGXL	Methylglyoxal
ASP	L-Aspartate	MTHN	Methane
ASPERMD	N1-Acetylspermidine	MTHNm	MethaneM
ASPm	L-AspartateM	MTHPTGLU	5-Methyltetrahydropteroyltri-L-glutamate

ASPRM	N1-Acetylspermine	MTRNA <sub>m</sub>	L-Methionyl-tRNA <sub>M</sub>
ASPSA	L-Aspartate 4-semialdehyde	MVL	(R)-Mevalonate
ASPTRNA	L-AsparaginyI-tRNA(Asn)	MVL <sub>m</sub>	(R)-Mevalonate <sub>M</sub>
ASPTRNA <sub>m</sub>	L-AsparaginyI-tRNA(Asn) <sub>M</sub>	MYOI	myo-Inositol
ASUC	N6-(1,2-Dicarboxyethyl)-AMP	MZYMST	4-Methylzymsterol
AT3P2	Acyldihydroxyacetone phosphate	N4HBZ	3-Nonaprenyl-4-hydroxybenzoate
ATN	Allantoin	NA	Sodium
ATP	ATP	NAAD	Deamino-NAD <sup>+</sup>
ATP <sub>m</sub>	ATP <sub>M</sub>	NAAD <sub>m</sub>	Deamino-NAD <sup>+</sup> <sub>M</sub>
ATRNA	tRNA(Arg)	NAC	Nicotinate
ATRP	P1,P4-Bis(5'-adenosyl) tetraphosphate	NAC <sub>m</sub>	Nicotinate <sub>M</sub>
ATT	Allantoate	NAD	NAD <sup>+</sup>
bALA	beta-Alanine	NADH	NADH
BASP	4-Phospho-L-aspartate	NADH <sub>m</sub>	NADH <sub>M</sub>
bDG6P	beta-D-Glucose 6-phosphate	NAD <sub>m</sub>	NAD <sup>+</sup> <sub>M</sub>
bDGLC	beta-D-Glucose	NADP	NADP <sup>+</sup>
BIO	Biotin	NADPH	NADPH
BT	Biotin	NADPH <sub>m</sub>	NADPH <sub>M</sub>
C100ACP	Decanoyl-[acp]	NADP <sub>m</sub>	NADP <sup>+</sup> <sub>M</sub>
C120ACP	Dodecanoyl-[acyl-carrier protein]	NAG	N-Acetylglucosamine
C120ACP <sub>m</sub>	Dodecanoyl-[acyl-carrier protein] <sub>M</sub>	NAGA1P	N-Acetyl-D-glucosamine 1-phosphate
C140	Myristic acid	NAGA6P	N-Acetyl-D-glucosamine 6-phosphate
C140ACP	Myristoyl-[acyl-carrier protein]	NAGLU <sub>m</sub>	N-Acetyl-L-glutamate <sub>M</sub>
C140ACP <sub>m</sub>	Myristoyl-[acyl-carrier protein] <sub>M</sub>	NAGLUP <sub>m</sub>	N-Acetyl-L-glutamate 5-phosphate <sub>M</sub>
C141ACP	Tetradecenoyl-[acyl-carrier protein]	NAGLUS <sub>m</sub>	N-Acetyl-L-glutamate 5-semialdehyde <sub>M</sub>
C141ACP <sub>m</sub>	Tetradecenoyl-[acyl-carrier protein] <sub>M</sub>	NAM	Nicotinamide
C160	Palmitate	NAM <sub>m</sub>	Nicotinamide <sub>M</sub>
C160ACP	Hexadecanoyl-[acp]	NAMN	Nicotinate D-ribonucleotide
C160ACP <sub>m</sub>	Hexadecanoyl-[acp] <sub>M</sub>	NAMN <sub>m</sub>	Nicotinate D-ribonucleotide <sub>M</sub>
C161	1-Hexadecene	NAORN <sub>m</sub>	N2-Acetyl-L-ornithine <sub>M</sub>
C161ACP	Palmitoyl-[acyl-carrier protein]	NH3	NH3
C161ACP <sub>m</sub>	Palmitoyl-[acyl-carrier protein] <sub>M</sub>	NH3 <sub>m</sub>	NH3 <sub>M</sub>
C16A	C16_aldehydes	NPP	all-trans-Nonaprenyl diphosphate
C180	Stearate	NPRAN	N-(5-Phospho-D-ribosyl)anthranilate
C180ACP	Stearoyl-[acyl-carrier protein]	O2	Oxygen
C180ACP <sub>m</sub>	Stearoyl-[acyl-carrier protein] <sub>M</sub>	O2 <sub>m</sub>	Oxygen <sub>M</sub>
C181	1-Octadecene	OA	Oxaloacetate
C181ACP	Oleoyl-[acyl-carrier protein]	OACOA	3-Oxoacyl-CoA
C181ACP <sub>m</sub>	Oleoyl-[acyl-carrier protein] <sub>M</sub>	OAHSER	O-Acetyl-L-homoserine
C182ACP	Linolenoyl-[acyl-carrier protein]	OAm	Oxaloacetate <sub>M</sub>
C182ACP <sub>m</sub>	Linolenoyl-[acyl-carrier protein] <sub>M</sub>	OBUT	2-Oxobutanoate
CAASP	N-Carbamoyl-L-aspartate	OBUT <sub>m</sub>	2-Oxobutanoate <sub>M</sub>
CAIR	1-(5-Phospho-D-ribosyl)-5-amino-4-imidazolecarboxylate	OFP	Oxidized flavoprotein
CALH	2-(3-Carboxy-3-aminopropyl)-L-histidine	OGT	Oxidized glutathione
cAMP	3',5'-Cyclic AMP	OHB	2-Oxo-3-hydroxy-4-phosphobutanoate
CAP	Carbamoyl phosphate	OH <sub>m</sub>	HO-M
CAR	Carnitine	OICAP	3-Carboxy-4-methyl-2-oxopentanoate
CAR <sub>m</sub>	Carnitine <sub>M</sub>	OICAP <sub>m</sub>	3-Carboxy-4-methyl-2-oxopentanoate <sub>M</sub>
CBHCAP	3-Isopropylmalate	OIVAL	(R)-2-Oxoisovalerate
CBHCAP <sub>m</sub>	3-Isopropylmalate <sub>M</sub>	OIVAL <sub>m</sub>	(R)-2-Oxoisovalerate <sub>M</sub>
cCMP	3',5'-Cyclic CMP	OMP	Orotidine 5'-phosphate
cdAMP	3',5'-Cyclic dAMP	OMVAL	3-Methyl-2-oxobutanoate
CDP	CDP	OMVAL <sub>m</sub>	3-Methyl-2-oxobutanoate <sub>M</sub>
CDPCHO	CDPcholine	OPEP	Oligopeptide
CDPDG	CDPdiacylglycerol	ORN	L-Ornithine
CDPDG <sub>m</sub>	CDPdiacylglycerol <sub>M</sub>	ORN <sub>m</sub>	L-Ornithine <sub>M</sub>
CDPETN	CDPethanolamine	OROA	Orotate

CER2	Ceramide-2	OSLHSER	O-Succinyl-L-homoserine
CER3	Ceramide-3	OSUC	Oxalosuccinate
CGLY	Cys-Gly	OSUCm	OxalosuccinateM
cGMP	3',5'-Cyclic GMP	OTHIO	Oxidized thioredoxin
CHCOA	6-Carboxyhexanoyl-CoA	OTHIOm	Oxidized thioredoxinM
CHIT	Chitin	OXA	Oxaloglutarate
CHITO	Chitosan	OXAm	OxaloglutarateM
CHO	Choline	P5C	(S)-1-Pyrroline-5-carboxylate
CHOR	Chorismate	P5Cm	(S)-1-Pyrroline-5-carboxylateM
cIMP	3',5'-Cyclic IMP	P5P	Pyridoxine phosphate
CIT	Citrate	PA	Phosphatidate
CITm	CitrateM	PABA	4-Aminobenzoate
CITR	L-Citrulline	PAC	Phenylacetic acid
CLm	CardiolipinM	PAD	2-Phenylacetamide
CMP	CMP	PALCOA	Palmitoyl-CoA
CMPm	CMPM	PAm	PhosphatidateM
CMUSA	2-Amino-3-carboxymuconate semialdehyde	PANT	(R)-Pantoate
CO2	CO2	PANTm	(R)-PantoateM
CO2m	CO2M	PAP	Adenosine 3',5'-bisphosphate
COA	CoA	PAPS	3'-Phosphoadenylylsulfate
COAm	CoAM	PBG	Porphobilinogen
CPAD5P	1-(2-Carboxyphenylamino)-1-deoxy-D-ribose 5-phosphate	PC	Phosphatidylcholine
CPP	Coproporphyrinogen	PC2	Sirohydrochlorin
CTP	CTP	PCHO	Choline phosphate
CTPm	CTPM	PDLA	Pyridoxamine
CYS	L-Cysteine	PDLA5P	Pyridoxamine phosphate
CYTD	Cytidine	PDME	Phosphatidyl-N-dimethylethanolamine
CYTS	Cytosine	PE	Phosphatidylethanolamine
D45PI	1-Phosphatidyl-D-myo-inositol 4,5-bisphosphate	PEm	PhosphatidylethanolamineM
D6PGC	6-Phospho-D-gluconate	PEP	Phosphoenolpyruvate
D6PGL	D-Glucono-1,5-lactone 6-phosphate	PEPD	Peptide
D6RP5P	2,5-Diamino-6-hydroxy-4-(5'-phosphoribosylamino)-pyrimidine	PEPm	PhosphoenolpyruvateM
D8RL	6,7-Dimethyl-8-(1-D-ribityl)lumazine	PEPT	Peptide
DA	Deoxyadenosine	PETHM	Ethanolamine phosphate
DADP	dADP	PGm	PhosphatidylglycerolM
DAGLY	Diacylglycerol	PGPm	PhosphatidylglycerophosphateM
DAMP	dAMP	PHC	L-1-Pyrroline-3-hydroxy-5-carboxylate
DANNA	7,8-Diaminononanoate	PHE	L-Phenylalanine
DAPRP	1,3-Diaminopropane	PHEN	Prephenate
DATP	dATP	PHP	3-Phosphonoxyypyruvate
DB4P	L-3,4-Dihydroxy-2-butanone 4-phosphate	PHPYR	Phenylpyruvate
DC	Deoxycytidine	PHSER	O-Phospho-L-homoserine
DCDP	dCDP	PHSP	Phytosphingosine 1-phosphate
DCMP	dCMP	PHT	O-Phospho-4-hydroxy-L-threonine
DCTP	dCTP	PI	Orthophosphate
DFUC	alpha-D-Fucoside	PIm	OrthophosphateM
DG	Deoxyguanosine	PIME	Pimelic Acid
DGDP	dGDP	PINS	1-Phosphatidyl-D-myo-inositol
DGMP	dGMP	PINS4P	1-Phosphatidyl-1D-myo-inositol 4-phosphate
DGPP	Diacylglycerol pyrophosphate	PINSP	1-Phosphatidyl-1D-myo-inositol 3-phosphate
DGTP	dGTP	PL	Pyridoxal
DHF	Dihydrofolate	PL5P	Pyridoxal phosphate
DHFm	DihydrofolateM	PMME	Phosphatidyl-N-methylethanolamine
DHMVAm	(R)-2,3-dihydroxy-3-methylbutanoateM	PMVL	(R)-5-Phosphomevalonate
DHP	2-Amino-4-hydroxy-6-(D-erythro-1,2,3-trihydroxypropyl)-7,8-dihydropteridine	PNTO	(R)-Pantothenate
DHPP	Dihydroneopterin phosphate	PPHG	Protoporphyrinogen IX

DHPT	Dihydropteroate	PPHGm	Protoporphyrinogen IXM
DHSK	3-Dehydroshikimate	PPI	Pyrophosphate
DHSP	Sphinganine 1-phosphate	PPIm	PyrophosphateM
DHSPH	3-Dehydrosphinganine	PPIXm	ProtoporphyrinM
DHVALm	(R)-3-Hydroxy-3-methyl-2-oxobutanoateM	PPMAL	2-Isopropylmaleate
DIMGp	D-erythro-1-(Imidazol-4-yl)glycerol 3-phosphate	PPMVL	(R)-5-Diphosphomevalonate
DIN	Deoxyinosine	PRAM	5-Phosphoribosylamine
DIPEP	Dipeptide	PRBAMP	N1-(5-Phospho-D-ribose)-AMP
DMPP	Dimethylallyl diphosphate	PRBATP	N1-(5-Phospho-D-ribose)-ATP
DMZYMST	4,4-Dimethylzymosterol	PRFICA	1-(5'-Phosphoribosyl)-5-formamido-4-imidazolecarboxamide 5-(5-Phospho-D-ribosylaminoformimino)-1-(5-phosphoribosyl)- imidazole-4-carboxamide N-(5'-Phospho-D-1'-ribosylformimino)-5-amino-1-(5'-phospho-D- ribose)-4-imidazolecarboxamide
DOL	Dolichol	PRFP	
DOLMANP	Dolichyl beta-D-mannosyl phosphate	PRLP	
DOLP	Dolichyl phosphate	PRO	L-Proline
DOROA	(S)-Dihydroorotate	PROm	L-ProlineM
DPCOA	Dephospho-CoA	PRPP	5-Phospho-alpha-D-ribose 1-diphosphate
DPCOAm	Dephospho-CoAM	PRPPm	5-Phospho-alpha-D-ribose 1-diphosphateM
DPTH	2-[3-Carboxy-3-(methylammonio)propyl]-L-histidine	PS	Phosphatidylserine
DQT	3-Dehydroquinate	PSm	PhosphatidylserineM
DR1P	Deoxy-ribose 1-phosphate	PSPH	Phytosphingosine
DR5P	2-Deoxy-D-ribose 5-phosphate	PTHm	HemeM
DRIB	Deoxyribose	PTRSC	Putrescine
DSAM	S-Adenosylmethioninamine	PURI5P	Pseudouridine 5'-phosphate
DT	Thymidine	PYR	Pyruvate
DTB	Dethiobiotin	PYRDX	Pyridoxine
DTBm	DethiobiotinM	PYRm	PyruvateM
DTDP	dTDP	QA	Pyridine-2,3-dicarboxylate
DTMP	dTMP	QAm	Pyridine-2,3-dicarboxylateM
DTP	1-Deoxy-d-threo-2-pentulose	QH2m	UbiquinolM
DTTP	dTTP	Qm	Ubiquinone-9M
DU	Deoxyuridine	R1P	D-Ribose 1-phosphate
DUDP	dUDP	R5P	D-Ribose 5-phosphate
DUMP	dUMP	RAF	Raffinose
DUTP	dUTP	RFP	Reduced flavoprotein
E4P	D-Erythrose 4-phosphate	RGT	Glutathione
EPM	Epimelibiose	RGTm	GlutathioneM
EPST	Episterol	RIB	D-Ribose
ERGOST	Ergosterol	RIBFLAV	Riboflavin
ERTEOL	Ergosta-5,7,22,24(28)-tetraenol	RIBFLAVm	RiboflavinM
ERTROL	Ergosta-5,7,24(28)-trienol	RIPm	alpha-D-Ribose 1-phosphateM
ETH	Ethanol	RL5P	D-Ribulose 5-phosphate
ETHm	EthanolM	RMN	D-Rhamnose
ETHM	Ethanolamine	RTHIO	Reduced thioredoxin
F1P	D-Fructose 1-phosphate	RTHIOm	Reduced thioredoxinM
F26P	D-Fructose 2,6-bisphosphate	S17P	Sedoheptulose 1,7-bisphosphate
F6P	beta-D-Fructose 6-phosphate	S23E	(S)-2,3-Epoxy-squalene
FAD	FAD	S7P	Sedoheptulose 7-phosphate
FADH2m	FADH2M	SACP	N6-(L-1,3-Dicarboxypropyl)-L-lysine
FADm	FADM	SAH	S-Adenosyl-L-homocysteine
FALD	Formaldehyde	SAHm	S-Adenosyl-L-homocysteineM 1-(5'-Phosphoribosyl)-5-amino-4-(N-succinocarboxamide)- imidazole
FDP	beta-D-Fructose 1,6-bisphosphate	SAICAR	
FERIm	Ferricytochrome cM	SAM	S-Adenosyl-L-methionine
FEROm	Ferrocyclochrome cM	SAMm	S-Adenosyl-L-methionineM
FEST	Fecosterol	SAMOB	S-Adenosyl-4-methylthio-2-oxobutanoate
FGAM	2-(Formamido)-N1-(5'-phosphoribosyl)acetamidine	SAPm	S-Aminomethyl-dihydrolypoylproteinM
FGAR	5'-Phosphoribosyl-N-formylglycinamide	SER	L-Serine
FGT	S-Formylglutathione	SERM	L-SerineM

FKYN	L-Formylkynurenine	SLF	Sulfate
FMN	FMN	SLFm	SulfateM
FMNm	FMNM	SME	Shikimate
FMRNA <sub>m</sub>	N-Formylmethionyl-tRNA <sub>M</sub>	SME5P	Shikimate 3-phosphate
FOR	Formate	SOR	Sorbose
FOR <sub>m</sub>	Formate <sub>M</sub>	SOT	D-Sorbitol
FPP	trans,trans-Farnesyl diphosphate	SPH	Sphinganine
FRU	D-Fructose	SPRM	Spermine
FTHF	10-Formyltetrahydrofolate	SPRMD	Spermidine
FTHF <sub>m</sub>	10-Formyltetrahydrofolate <sub>M</sub>	SQL	Squalene
FUACAC	4-Fumarylacetoacetate	SUC	Sucrose
FUC	beta-D-Fucose	SUCC	Succinate
FUM	Fumarate	SUCC <sub>m</sub>	Succinate <sub>M</sub>
FUM <sub>m</sub>	Fumarate <sub>M</sub>	SUCCO <sub>Am</sub>	Succinyl-CoAM
G1P	D-Glucose 1-phosphate	SUCCSAL	Succinate semialdehyde
G6P	alpha-D-Glucose 6-phosphate	T3P1	D-Glyceraldehyde 3-phosphate
GA1P	D-Glucosamine 1-phosphate	T3P2	Glycerone phosphate
GA6P	D-Glucosamine 6-phosphate	T3P2 <sub>m</sub>	Glycerone phosphate <sub>M</sub>
GABA	4-Aminobutanoate	TAG16P	D-Tagatose 1,6-bisphosphate
GABAL	4-Aminobutyraldehyde	TAG6P	D-Tagatose 6-phosphate
GABAL <sub>m</sub>	4-Aminobutyraldehyde <sub>M</sub>	TAGLY	Triacylglycerol
GABA <sub>m</sub>	4-Aminobutanoate <sub>M</sub>	TCOA	Tetradecanoyl-CoA
GAL1P	D-Galactose 1-phosphate	TGLP	N-Tetradecanoylglycylpeptide
GAR	5'-Phosphoribosylglycinamide	THF	Tetrahydrofolate
GBAD	4-Guanidino-butanamide	THFG	Tetrahydrofolyl-[Glu](n)
GBAT	4-Guanidino-butanoate	THF <sub>m</sub>	Tetrahydrofolate <sub>M</sub>
GC	gamma-L-Glutamyl-L-cysteine	THIAMIN	Thiamin
GDP	GDP	THMP	Thiamin monophosphate
GDP <sub>m</sub>	GDP <sub>M</sub>	THPTGLU	Tetrahydropteroyltri-L-glutamate
GDPMAN	GDPmannose	THR	L-Threonine
GGL	Galactosylglycerol	THR <sub>m</sub>	L-Threonine <sub>M</sub>
GL	Glycerol	THY	Thymine
GL3P	sn-Glycerol 3-phosphate	THZ	5-(2-Hydroxyethyl)-4-methylthiazole
GL3P <sub>m</sub>	sn-Glycerol 3-phosphate <sub>M</sub>	THZP	4-Methyl-5-(2-phosphoethyl)-thiazole
GLAC	D-Galactose	TPI	D-myo-inositol 1,4,5-trisphosphate
GLACL	1-alpha-D-Galactosyl-myo-inositol	TPP	Thiamin diphosphate
GLAL	Glycolaldehyde	TPPP	Thiamin triphosphate
GLAM	Glucosamine	TRE	alpha,alpha-Trehalose
GLC	alpha-D-Glucose	TRE6P	alpha,alpha'-Trehalose 6-phosphate
GLN	L-Glutamine	TRNA	tRNA
GLP	Glycylpeptide	TRNA <sub>m</sub>	tRNA <sub>M</sub>
GLT	L-Glucitol	TRP	L-Tryptophan
GLU	L-Glutamate	TRP <sub>m</sub>	L-Tryptophan <sub>M</sub>
GLUGSAL	L-Glutamate 5-semialdehyde	TRPTRNA <sub>m</sub>	L-Tryptophanyl-tRNA(T <sub>Trp</sub> ) <sub>M</sub>
GLUGSAL <sub>m</sub>	L-Glutamate 5-semialdehyde <sub>M</sub>	TYR	L-Tyrosine
GLU <sub>m</sub>	Glutamate <sub>M</sub>	UDP	UDP
GLUP	alpha-D-Glutamyl phosphate	UDPG	UDPglucose
GLX	Glyoxylate	UDPGAL	UDP-D-galactose
GLY	Glycine	UDPNAG	UDP-N-acetyl-D-galactosamine
GLYCOGEN	Glycogen	UDPP	Undecaprenyl diphosphate
GLY <sub>m</sub>	Glycine <sub>M</sub>	UGC	(-)-Ureidoglycolate
GLYN	Glycerone	UMP	UMP
GMP	GMP	UPRG	Uroporphyrinogen III
GN	Guanine	URA	Uracil
GN <sub>m</sub>	Guanine <sub>M</sub>	UREA	Urea
GPP	Geranyl diphosphate	UREAC	Urea-1-carboxylate
GSN	Guanosine	URI	Uridine

GSNm	GuanosineM	UTP	UTP
GTP	GTP	VAL	L-Valine
GTPm	GTPM	X5P	D-Xylose-5-phosphate
GTRNA	L-Glutamyl-tRNA(Glu)	XAN	Xanthine
GTRNAm	L-Glutamyl-tRNA(Glu)M	XMP	Xanthosine 5'-phosphate
GTRP	P1,P4-Bis(5'-guanosyl) tetraphosphate	XTSINE	Xanthosine
H2O2	H2O2	XUL	D-Xylulose
H2S	Hydrogen sulfide	XYL	D-Xylose
H2SO3	Sulfite	ZYMST	Zymosterol