2-HG - 2-Hydroxyglutarate
3-PHP - 3-Phosphate Hydroxypyruvate
3-Pser - 3-Phosphoserine
4AB - 4-Aminobutyraldehyde
4ABT - 4-Aminobutyrate Transaminase
4Fe-4S - Tetrakis(μ²-ion(1+)-ion) Tetrasulfane Tetrasulfanide
4-HB - 4-Hydroxybenzoic Acid
4-HBA - 4-Hydroxybenzaldehyde
4-HBS - 4-Hydroxybenzoate Synthase
4-HCA - 4-Hydroxycinnamic Acid
4-Mel - 4-Methylimidazole
4-MeIA - Methylimidazole Acetate
4-MeIAA - Methylimidazole Acetate Hydrolase
5-HIA - 5-Hydroxyindoleacetate
5-HIAA - 5-Hydroxyindoleacetic acid
5-MTHF - 5-Methyltetrahydrofolate
5,10-MTHF - 5,10-MethyleneTetrahydroFolate
6PGL - 6-Phosphoglucono-δ-Lactone
6PG - 6-Phosphogluconate
6PGD - 6-Phosphogluconate Dehydrogenase
AA - Amino Acids
AAA - Acetoacetic Acid
AAC - Acetoacetyl-CoA
AAD - Acetoacetate Decarboxylase
AADC - Aromatic L-Amino Acid Decarboxylase
AAO - L-Amino Acid Oxidase
AC - Aconitase
ACC - Acetyl-CoA Carboxylase
ACMS - 2-Amino-3-Carboxymuconic-6-Semialdehyde Acid
ACSBM12B - Mitochondrial Medium-chain Acyl-CoA Synthetases
A-CoA - Acetyl-CoA
AChE - Acetylcholinesterase
ACOD - cis-Aconitate Decarboxylase
ACS - Acetyl-CoA Synthetase
ACTH - Adrenocorticotropic Hormone
ADC - Arginine Decarboxylase
ADK - Adenylate Kinase (Myokinase)
ADH - Alcohol Dehydrogenase
ADHFE - Hydroxyacid-Oxoacid Transhydrogenase
ADO - 2-Aminoethanethiol dioxygenase
AdoCbl - Adenosylcobalamin
ADP - Adenosine Diphosphate
ADSL - Adenylosuccinate Lyase
ADSS - Adenylosuccinate Synthetase
AFMID - Kynurenine Formamidase
AGAT - Arginine:Glycine Amidinotransferase
AGXT - Alanine-Glyoxylate Aminotransferase
α-KB - α-Ketobutyrate
α-KG - α-Ketoglutarate
α-KGDH - alpha-Ketoglutarate Dehydrogenase
Ala - Alanine
ALD - Aldolase
ALDH - Aldehyde Dehydrogenase
ALP - Alkaline Phosphatase
ALT - Alanine Aminotransferase
AMP - Adenosine Monophosphate
AMPD - AMP Deaminase
AMPK - AMP-activated Protein Kinase
ARG1 - Arginase
ACS - Agmatinase
AR - Aldose Reductase
AO - Aldehyde Oxidase
APS - Adenosine-5-Phosphosulfate
APSK - APS Kinase
ASA - Argininosuccinate
ASDC - Aspartate Decarboxylase
ASL - Arginine Succinate
Asp - Aspartate
ASPT - Aspartate Transcarbamoylase
ASS - Argininosuccinate Synthetase
AST - Aspartate Aminotransferase
ASMT - Acetylserotonin O-Methyltransferase
ATP - Adenosine Triphosphate
BH_2 - Dihydrobiopterin
BH_4 - Tetrahydrobiopterin
BHB - β-hydroxybutyric Acid
BHMT - Betaine-Homocysteine S-methyltransferase
BPG - Biphosphoglycerate
BPGM - BPG Mutase
BPGP - 2,3 BPG Phosphatase
Br - Bromine
Ca - Calcium
cAMP - Cyclic Adenosine Monophosphate
Car - Carnosine
Car-ACA1A - Carnosine-Acetaldehyde-Imidazolidinone Adduct
CAT - Catalase
CBS - Cystathionine B-Synthase
CSAD - Cysteine Sulfinic Acid Decarboxylase
COO - Cysteamine Dioxygenase
CDP - Cytidine 5'-Diphosphate
CK - Creatine Kinase
CGL - Cystathionine gamma-Lyase
ChAT - Choline Acetyltransferase
CHDH - Choline Dehydrogenase
Cl - Chloride
CMP - Cytidine Monophosphate
CMPK - UMP-CMP Kinase
CNMT - Carnosine N-Methyl Transferase
CNDP - Cytosolic Non-Specific Dipeptidase
CO_2 - Carbon Monoxide
CO_3 - Carbon Dioxide
Co - Cobalt
CoA - Coenzyme A
CoAH - CoA Hydrolase
COMT - Catechol O-methyltrans
CP - Carbamoyl Phosphate
CPS1 - Carbamoyl Phosphate Synthase1
CR - Carbonyl Reductase
Cr - Chromium
Cre - Creatine
CRH - Corticotrophin-Releasing Hormone
CRNS - Carnosine Synthase
CS - Citrate Synthase
CSE - Cystathionase
CTP - Cytidine 5'-Triphosphate
Cu - Copper
CYP - Cytochrome P450 monooxygenase
DAT - Dopamine Transporter
DAO - Diamine Oxidase
DBH - Dopamine Beta Hydroxylase
DHBA - 3,4-Dihydroxybenzeneacetic Acid
DHF - Dihydrofolate
DHFR - Dihydrofolate Reductase
DHI - 5,6-Dihydroxyindole
DHICA - 5,6-Dihydroxyindole-2-Carboxylic Acid
DHMA - 3,4-Dihydroxymandelaldehyde
DHMC - 3,4-Dihydroxymandelic Acid
DMG - Dimethylglycine
DMGDH - DMG Dehydrogenase
DHO - Dihydroorotate
DHOase - Dihydroorotase
DHODH - Dihydroorotate Dehydrogenase
DOPAC - 3,4-Dihydroxyphenylacetic Acid
DOPAL - 3,4-Dihydroxyphenylacetaldehyde
DPCK - DephosphoCoA Kinase
DT - L-Dopachrome Tautomerase
dTMP - Thymidine Monophosphate
dUMP - Deoxyuridine Monophosphate
E4P - Erythrose-4-Phosphate
ENO - Enolase
ENPP - Ectonucleotide Pyrophosphatase/Phosphodiesterase
ETHE1 - Sulphur Dioxygenase
F1,6BP - Fructose 1,6-Bisphosphate
F2,6BP - Fructose 2,6-Bisphosphate
F6P - Fructose-6-Phosphate
FAA - 4-Fumarylacetoacetic Acid
FAAS - Fumarylacetoacetase
FAD - Adeflavin
FADS - FAD Synthetase
FBPase - Fructose 1,6-Bisphosphatase
FBPase2 - Fructose 2,6-Bisphosphatase
Fe - Ferritin
FIGLU - Formimidoylglutamic Acid
FIGLU-THF - Formiminoglutamate-THF
FMN - Flavin Mononucleotide
FMO - Flavin Monooxygenase
FOLH - Folate Hydrolase
FS - Fumarase
FT - Formiminotransferase
FTCD - Formiminotransferase Cyclodeaminase
G3P - Glyceraldehyde-3-Phosphate
G6Pase - Glucose 6-Phosphotase
G6PD - Glucose-6-Phosphate Dehydrogenase
GABA - Gamma-Aminobutyric Acid
GAD - Glutamate Decarboxylase
GAG - Glycosaminoglycan
GAMT - S-Adenosylmethionine:Guanidinoacetate Methyltransferase
GAPDH - Glyceraldehyde 3-Phosphate Dehydrogenase
GAT - Guanidinoacetate
γBBH - γ-Butyrobetaine Hydroxylase
GCA - γ-Glutamylcysteine Synthase
GCH1 - GTP Cyclohydrolase I
GDP - Guanosine Diphosphate
GDH - Glutamate Dehydrogenase
GFAT - Glutamine:Fructose-6P Amidotransferase
GHB - γ-Hydroxybutyrate
GK - Glucokinase
GlcNAc - N-Acetylglucosamine
GlcNAc-1-P - GlcNAc 1-Phosphate
GlcNAc-6-P - GlcNAc 6-Phosphate
GLN - Glutaminase
GLS - Glutathione Synthase
GLSH - Glutamate Dehydrogenase
GLYDH - Glycolaldehyde Dehydrogenase
GLYP - Glycogen Phosphorylase
GLYS - Glycogen Synthase
Glut - Glutamate
GOR - Glyoxylate Reductase
GOX - Glycolate Oxidase
GPX - Glutathione Peroxidase
GR - Glutathione Reductase
GS - Glutamine Synthetase
GSA - Glutamate-5-Semialdehyde
GSH - Glutathione, reduced
GSK3β - Glycogen Synthase Kinase-3 beta
GSSG - Glutathione disulfide (oxidised)
GSSH - Glutathione Persulfide
GTP - Guanosine Triphosphate
GTase - Glycosyltransferases
H - Hydrogen
H_2O - Water
H_2O_2 - Hydrogen Peroxide
H_2S - Hydrogen Sulfide
H2NTP - 7,8-Dihydroneopterin Triphosphate
HAAO - 3-Hydroxyanthranilic Acid Dioxygenase
HAL - Histidine Ammonia-Lyase
HAS - Hyaluronic Acid Synthase
HBDH - Hydroxybutyrate Dehydrogenase
HCO_3 - Bicarbonate
HK - Hexokinase
HIF - Hypoxia-Inducible Factor
HGA - Homogentisic Acid
HGD - Homogentisate 1,2-dioxygenase
HMPAL - 3-Methoxy-4-Hydroxyphenylacetaldehyde
HMT - Histidine Methyltransferase
HOGA - 4-Hydroxy-2-Ketoglutarate Aldolase
HPCL - HydroxyPyruvate Carboxy-Lyase
HT - Histidine Transaminase
HTMLA - β-hydroxy-ε-N-trimethyllysine aldolase
HTDH - Hypotaurine Dehydrogenase
HVA - Homovanillic Acid
HYPDH - 4-Hydroxyproline Dehydrogenase
I - Iodine
IAA - Imidazole Acetaldehyde
IAcA - Imidazole Acetic Acid
IAL - Imidazoleacetate-Lyase
ICL - Isocitrate Lyase
IDH - Isocitrate Dehydrogenase
IDO - Indoleamine 2,3-Dioxygenase
IFN - Interferon
IMP - Inosinic Acid
IP3 - Inositol Trisphosphate
IQ - Indole-5,6-Quinone
K - Potassium
KAT - Kynurenine Aminotransferase
KMO - Kynurenine 3-Monooxygenase
KYNU - Kynureninase
LDH - Lactate Dehydrogenase
LPA - Lipoamide
LPH4 - Lactoyl-PH4
MAA - Maleylacetoacetic Acid
MAAI - Maleylacetoacetate Isomerase
MAS - Malate Synthase
MAO - Monoamine Oxidase
MDH - Malate Dehydrogenase
ME1 - NADP-dependent Malic Enzyme
MeCBL - Methylcobalamin
Mg - Magnesium
MHPG - 3-Methoxy-4-Hydroxyphenylglycoladehyde
MIF - Macrophage Migration Inhibitory Factor
MMC-M - MethylMalonyl-CoA Mutase
MMC-R - MethylMalonyl-CoA Racemase
MMP - Matrix Metalloproteinase
Mn - Manganese
Mo - Molybdenum
MS - Methionine Synthase
MTA - 5'-Methylthioadenosine
MTHFR - MethyleneTetraHydroFolate Reductase
MTR - 3-Methoxytyramine
Na - Sodium
N-Ac-Put - N-Acetyl-Putrescine
N-Ac-ABAL - N-Acetyl-Gamma-Aminobutyraldehyde
N-Ac-GABA - N-Acetyl-Gamma-Aminobutyrate
NAD - Nicotinamide Adenine Dinucleotide
NADK - NAD Kinase
NADPT - NAD(P)+ Transhydrogenase
NADSYN - NAD Synthetase
NAGK - N-Acetylglucosamine Kinase
NAM - Nicotinamide
NAMPT - Nicotinamide Phosphoribosyltransferase
NAPRT - Nicotinate Phosphoribosyltransferase
N-AS - N-Acetylspermine
N-ASD - N-Acetylspermidine
NCS - Norcoclaurine Synthase
NDPK - Nucleoside Diphosphokinase
NET - Norepinephrine Transporter
NH_3 - Ammonia
NNMAT - Nicotinamide Mononucleotide Adenylyltransferase
NO - Nitric Oxide
NOS - Endothelial Nitric Oxide Synthase
O_2 - Oxygen
OAA - Oxaloacetate
OAADPR - 2'-O-Acetyl-ADP-Ribose
OAT - Ornithine Aminotransferase
ODC - Ornithine Decarboxylase
OH-ENP - 4-Hydroxy-Enol-Phenylpyruvate
OH-Glut - 4-Hydroxyglutamate
OH-GlutSA - 4-Hydroxyglutamate Semialdehyde
OH-KG - 4-Hydroxy-2-Ketoglutarate
OH-PSC - Pyrroline Hydroxycarboxylate
OH-PD - 4-Hydroxyphenylpyruvate Dioxygenase
OH-PHA - 1-Hydroxy-2-Oxopropyl Tetrahydropterin
OH-PLA - Hydroxyphenyllactic Acid
OH-PPA - 4-Hydroxyphenylpyruvic Acid
OH-PPD - 4-Hydroxyphenyl-Pyruvate Dioxygenase
OH-Pyr - Hydroxypyruvate
OMP - Orotidine-5'-Monophosphate
OMPDC - OMP Decarboxylase
OPRT - Orotate Phosphoribosyltransferase
OTC - Ornithine Transcarbamoylase
OX - Oxalate
OXH - Oxaloacetase
P5C - Pyrroline-5-Carboxylate
P5CR - P5C Reductase
P5P - Pyridoxal 5'-Phosphate
PAA - Phenylacetic Acid
PAcAL - Phenylacetaldehyde
PAGM - Phosphoacetylglucosamine Mutase
PAGS - Phenylacetylglutamine Synthetase
PAH - Phenylalanine Hydroxylase
PAL - Pyruvaldehyde
PAMOAT - Pyridoxamine:Oxaloacetate Aminotransferase
PANK - Pantetheine Kinase
PAO - Polyamine Oxidase
PAPS - 3'-Phosphoadenosine-5'-Phosphosulfate
PAT - Phenylalanine Aminotransferase
PATK - Pantheinate Kinase
PC - Phosphocreatine
PCB - Pyruvate Carboxylase
PCC - Propionyl-CoA Carboxylase
PDH - Pyruvate Dehydrogenase
PEPC - Phosphoenolpyruvate Carboxylase
PEPCK - Phosphoenolpyruvate Carboxykinase
PFK-1 - Phosphofructokinase
PFK-2 - 6-Phosphofructo-2-Kinase
PGAM - Phosphoglycerate Mutase
PGI - Phosphoglucose Isomerase
PGK - Phosphoglycerate Kinase
PGLS - 6-Phosphogluconolactonase
PGM - Phosphoglucomutase
PHCDH - Pyrroline-3-hydroxy-5-carboxylate Dehydrogenase
PHD - Prolyl Hydroxylase
PHGDH - Phosphoglycerate Dehydrogenase
PHT - Phenylpyruvate Tautomerase
Pi - Phosphate
PK - Pyridoxal Kinase
PKM - Pyruvate Kinase
PKA - Protein Kinase A
PKC - Protein Kinase C
PLA - Phenylactic Acid
PLD - Prolidase
PMP - Pyridoxamine 5'-Phosphate
PNMT - Phenylethanolamine N-Methyltransferase
PNPO - Pyridoxine 5'-Phosphate Oxidase
PPA - Phenylpyruvic Acid
PPP - Pyridoxal Phosphate Phosphatase
pp - Pyrophosphate
PPCDC - Phosphopantothenoylcysteine Decarboxylase
PPCS - Phosphopantothenoylcysteine Synthetase
PRDX - Peroxiredoxin
PRPP - 5-Phosphoribosyl-1-Pyrophosphate
PRPS - Phosphoribosyl Pyrophosphate Synthetase
PSP - Protein Synthesis Pathway
PS - Phosphatidyl Serine
PSAT - Phosphoserine Aminotransferase
PSPH - Phosphoserine Phosphatase
PSS - Phosphatidylserine Synthase
PTP - 6-Pyruvoyl-Tetrahydropterin
PTPS - 6-Pyruvoyl-tetrahydropterin Synthase
Pyr - Pyruvate
Q - Ubiquinone (Coenzyme Q10)
Qu - Ubiquinol (Reduced Coenzyme Q10)
Qu - Quinuine
Qus - Queuosine
QRPT - Quinolinate Phosphorybosyltransferase
R1P - Ribose-1-Phosphate
R5P - Ribose-5-Phosphate
RBKS - Ribokinase
RK - Riboflavin Kinase
ROS - Reactive Oxygen Species
RPE - Ribulose-5-Phosphate 3-Epimerase
RPIA - Ribose-5-Phosphate Isomerase A
Ru5P - Ribulose-5-Phosphate
S7P - Sedoheptulose-7-Phosphate
SADH - Sarcosine Dehydrogenase
SAH - S-Adenosyl-L-Homocysteine
SAMe - S-Adenosylmethionine
SAMeA - S-Adenosylmethionamine
SAMeD - S-Adenosylmethionine Decarboxylase
SAMeS - S-Adenosylmethionine Synthase
SAT - Serotonin N-Acetyltransferase
SCOT - Succinyl-CoA:3-ketoacid CoA Transferase
SCS - Succinyl-CoA Synthetase
SDH - Succinate Dehydrogenase
Se - Selenium
Ser - Serine
SGLT - Serine-Glyoxylate Transaminase
SHMT - Serine Hydroxymethyltransferase
Si - Silicon
SLC - Solute Carrier
SPDS - Spermidine Synthase
SPOX - Spermine Oxidase
SPS - Spermine Synthase
SQOR - Sulfide Quinone Oxidoreductase
SR - Sepiapterin Reductase
SSAL - Succinic Semialdehyde
SSAT1 - Spermidine/Spermine-N1-Acetyltransferase
Succ - Succinate
SULTs - Sulfotransferases
SUOX - Sulfite Oxidase
T3 - Triiodothyronine
TA - Tyrosinase
TALDO1 - Transaldolase 1
TAT - Tyrosine Aminotransferase
TGF - Transforming Growth Factor
TGT - tRNA Guanine Transglycosylase
TH - Tyrosine Hydroxylase
ThDP - Thiamine Diphosphate
THF - Tetrahydrofolate
THL - Thiolase
THP - Tetrahydropapaveroline
TKT - Transketolase
TMLH - Trimethyllysine Hydroxylase
TNF - Tumour Necrosis Factor
TPH - Tryptophan Hydroxylase
TPI - Triose Phosphate Isomerase
TPP - Thiamine Pyrophosphate
TPQ - Topaquinone
TS - Thymidylate Synthase
TST - Thiosulfate Sulfurtransferase
UCK - Uridine-Cytidine Kinase
UDP - Uridine Diphosphate
UGPase - UDP-Glucose Pyrophosphorylase
UGAPase - UDP-GlcNAc Pyrophosphorylase
UMP - Uridine Monophosphate
UPP - Uridine Phosphorylase
UROC - Urocanase
UTP - Uridine Triphosphate
V - Vanadium
Vit C - Ascorbic Acid
Vit E - Tocopherols, Tocotrienols
VMA - Vanillylmandelic Acid
VMAT - Vesicular Monoamine Transporter
VNN - Vanin-1 (Pantetheinase)
Xu5P - Xylulose-5-Phosphate
Zn - Zinc

Figure 1.Pathway Diagram: The role of mitochondrial dysfunction in chronic disease and aging.

ME/CFS: Correcting Chronic Mitochondrial Dysfunction

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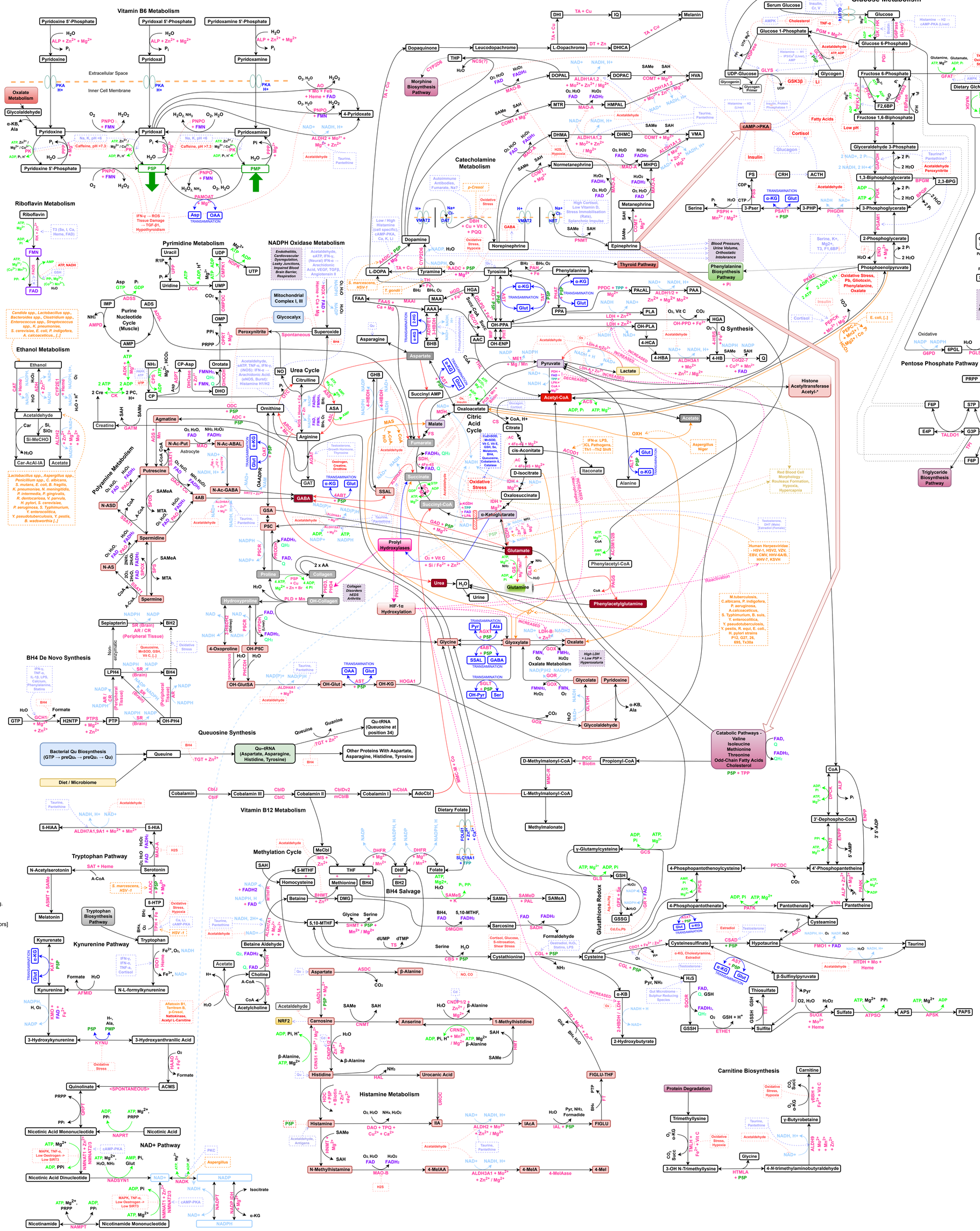
Vitamin B6 Metabolism
Glucose Metabolism
Riboflavin Metabolism
Pyrimidine Metabolism
NADPH Oxidase Metabolism
Catecholamine Metabolism
Ethanol Metabolism
Purine Nucleotide Cycle (Muscle)
Urea Cycle
Citric Acid Cycle
Pentose Phosphate Pathway
Polyamine Metabolism
Glycolysis
Glycogenolysis
Glycogenesis
Gluconeogenesis
Glycosaminoglycan Synthesis
Hexosamine Biosynthesis Pathway
Phenylalanine Biosynthesis Pathway
Q Synthesis
Histone Acetyltransferase Acetyl-*
Triglyceride Biosynthesis Pathway
Glycocalyx Assembly
Oxalate Metabolism
Catabolic Pathways - Valine Isoleucine Methionine Threonine Odd-Chain Fatty Acids Cholesterol
Glutathione Redox
Carnitine Biosynthesis
Histamine Metabolism
Methylation Cycle
BH4 Salvage
Vitamin B12 Metabolism
Tryptophan Pathway
Kynurenine Pathway
Tryptophan Biosynthesis Pathway
Melatonin
NAD+ Pathway
Nicotinic Acid Mononucleotide
Nicotinic Acid Dinucleotide
Nicotinamide
Nicotinamide Mononucleotide
Quinolinate
Acetylcholine
Choline
Acetate
Formate
Formaldehyde
Methylmalonate
Propionyl-CoA
Succinyl-CoA
Succinate
Fumarate
Malate
Oxaloacetate
Citrate
Isocitrate
α-Ketoglutarate
Glutamate
Glutamine
Urea
Urine
Glycine
Glyoxylate
Oxalate
Glycolate
Pyridoxine
Glycolaldehyde
Pyruvate
Lactate
Acetyl-CoA
Acetaldehyde
Ethanol
Serotonin
Melatonin
Tryptophan
Kynurenine
Kynurenate
3-Hydroxykynurenine
3-Hydroxyanthranilic Acid
Quinolinate
Nicotinamide
Nicotinic Acid
Nicotinamide Mononucleotide
Nicotinic Acid Dinucleotide
Nicotinic Acid Mononucleotide
Histamine
Urocanic Acid
Carnosine
Anserine
1-Methylhistidine
Carnitine
γ-Butyrobetaine
Trimethyllysine
Protein Degradation
Cysteine
Cysteine Sulfinate
Hypotaurine
Taurine
Cysteamine
Pantetheine
Pantothenate
4'-Phosphopantetheine
3'-Dephospho-CoA
CoA
Cystathionine
Methionine
Homocysteine
Betaine
Dimethylglycine
Sarcosine
Glycine
Serine
Tryptophan
Phenylalanine
Tyrosine
Dopamine
Norepinephrine
Epinephrine
Melatonin
Melatonin Pathway
Melatonin Synthesis
Melatonin Degradation
Melatonin Receptor Signaling
Melatonin Mitochondrial Function
Melatonin Immune Function
Melatonin Circadian Rhythm
Melatonin Sleep Regulation
Melatonin Antioxidant Activity
Melatonin Anti-Inflammatory
Melatonin Cardiovascular Effects
Melatonin Neuroprotection
Melatonin Metabolic Effects
Melatonin Gut Microbiome
Melatonin Aging
Melatonin Cancer
Melatonin Dosage
Melatonin Deficiency
Melatonin Supplementation
Melatonin Interactions
Melatonin Research
Melatonin Sources
Melatonin Synthesis
Melatonin Transport
Melatonin Receptors
Melatonin Mechanism
Melatonin Effects
Melatonin Benefits
Melatonin Risks
Melatonin Side Effects
Melatonin Toxicity
Melatonin Overdose
Melatonin Withdrawal
Melatonin Tolerance
Melatonin Dependence