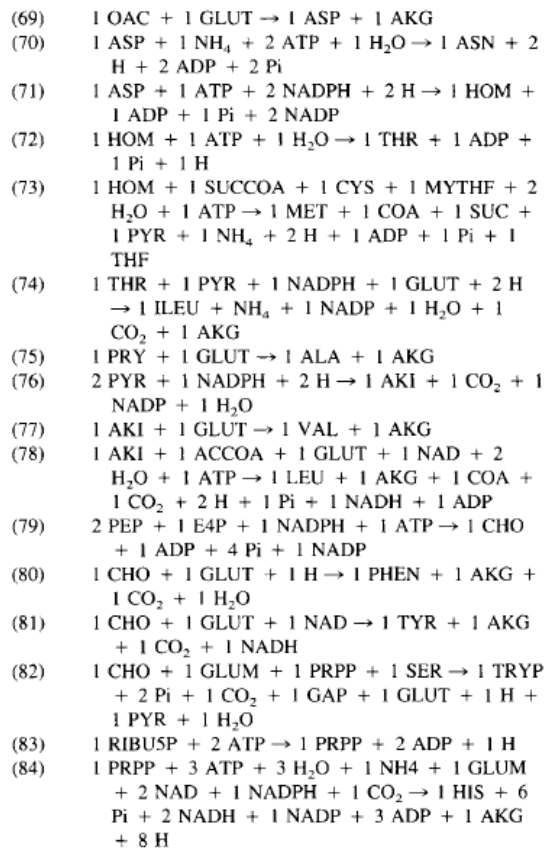


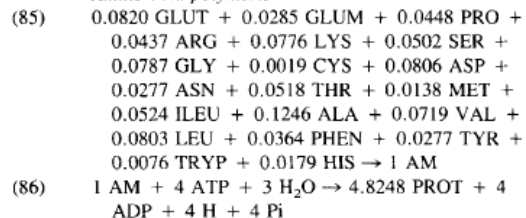
Biochemical reactions

Reactions indexed with an asterisk (*) are omitted in the applied metabolic networks.

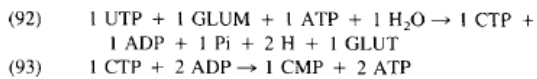
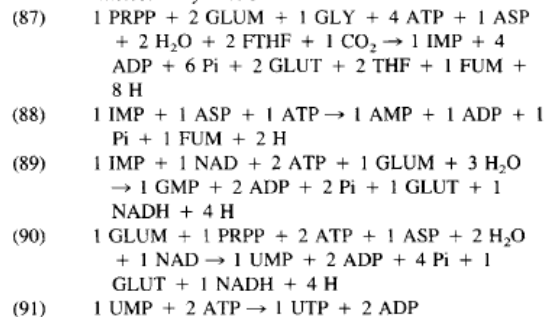
- Glycolysis and citric acid cycle*
- (1) 1 GLUC + 1 ATP → 1 GLUC6P + 1 ADP + 1 H
 (2) 1 GLUC6P → 1 FRUC6P
 (3) 0.5 FRUC6P + 0.5 ATP → 1 GAP + 0.5 ADP + 0.5 H
 (4) 1 GAP + 0.5 H₂O → 0.5 FRUC6P + 0.5 Pi
 (5) 1 GAP + 1 NADH + 1 H₂O + 1 H → 1 GOH + 1 NAD + 1 Pi
 (6) 1 GAP + 1 NAD + 1 Pi + 1 ADP → 1 G3P + 1 ATP + 1 NADH + 1 H
 (7) 1 G3P → 1 PEP + 1 H₂O
 (8) 1 PEP + 1 ADP + 1 H → 1 PYR + 1 ATP
 (9)* 1 PYR + 2 ATP + 1 H₂O → 1 PEP + 2 ADP + 1 Pi + 2 H
 (10) 1 PYR + 1 NAD + 1 COA → 1 ACCOA + 1 NADH + 1 CO₂
 (11) 1 PYR + 1 H → 1 ACET + 1 CO₂
 (12) 1 PYR + 1 ATP + 1 H₂O + 1 CO₂ → 1 OAC + 1 ADP + 1 Pi + 2 H
 (13) 1 ACET + 1 NAD + 1 H₂O → 1 AC + 1 NADH + 2 H
 (14) 1 ACET + 1 NADP + 1 H₂O → 1 AC + 1 NADPH + 2 H
 (15) 1 OAC + 1 ACCOA + 1 H₂O → 1 ISOCIT + 1 COA + 1 H
 (16) 1 OAC + 1 ATP → 1 PEP + 1 CO₂ + 1 ADP
 (17) 1 ISOCIT + 1 NAD → 1 AKG + 1 NADH + 1 CO₂
 (18) 1 ISOCIT + 1 NADP → 1 AKG + 1 NADPH + 1 CO₂
 (19) 1 AKG + 1 COA + 1 NAD + 1 H → 1 SUCCOA + 1 NADH + 1 CO₂ + 1 H
 (20) 1 SUCCOA + 1 ADP + 1 Pi → 1 SUC + 1 ATP + 1 COA
 (21) 1 SUC + 1 FAD → 1 FUM + 1 FADH₂
 (22) 1 FUM + 1 H₂O → 1 MAL
 (23) 1 MAL + 1 NAD → 1 OAC + 1 NADH + 1 H
 (24) 1 FADH₂ + 1 NAD → 1 NADH + 1 H + 1 FAD
- PEP phosphotransferase*
- (25) 1 GLUC(E) + 1 PEP → 1 GLUC6P + 1 PYR
- Pentose phosphate pathway*
- (26) 1 GLUC6P + 2 NADP + 1 H₂O → 1 RIBU5P + 2 NADPH + 1 CO₂ + 2 H
 (27) 1 RIBU5P → 1 RIB5P
 (28) 1 RIBU5P → 1 XYL5P
 (29) 1 RIB5P + 1 XYL5P → 1 SED5P + 1 GAP
 (30) 1 SED5P + 1 GAP → 1 FRUC6P + 1 E4P
 (31) 1 XYL5P + 1 E4P → 1 FRUC6P + 1 GAP
- Glyoxylate shunt*
- (32) 1 ISOCIT → 1 GLYO + 1 SUC
 (33) 1 GLYO + 1 ACCOA + 1 H₂O → 1 MAL + 1 COA + 1 H
- Oxidative phosphorylation*
- (34) 1 NADH + 0.5 O₂ + δ₁ADP + δ₁ Pi + (1 + δ₁) H → (1 + δ₁) H₂O + 1 NAD + δ₁ ATP
 (35) 1 NADH + 0.5 O₂ + 1 H → 1 H₂O + 1 NAD
 (36) 1 FADH₂ + 0.5 O₂ + δ₂ ADP + δ₂ Pi + δ₂ H → (1 + δ₂) H₂O + 1 FAD + δ₂ ATP
 (37)* 1 FADH₂ + 0.5 O₂ + 3/5 δ₁ ADP + 3/5 δ₁ Pi + 3/5 δ₁ H → (1 + 3/5 δ₁) H₂O + 1 FAD + 3/5 δ₁ ATP
- (38)* 1 NADPH + 0.5 O₂ + δ₁ ADP + δ₁ Pi + (1 + δ₁) H → (1 + δ₁) H₂O + 1 NADP + δ₁ ATP
- Carbon substrates other than glucose*
- (39) 1 CIT → 1 ISOCIT
 (40) 1 LAC + 1 FAD → 1 PYR + 1 FADH₂
 (41) 1 GOH + 1 ATP + 1 FAD → 1 GAP + 1 FADH₂ + 1 ADP + 1 H
 (42) 1 GLUCON + 1 ATP → 1 PYR + 1 GAP + 1 ADP + 1 H₂O + 1 H
 (43) 1 ETOH + 1 NAD → 1 ACET + 1 NADH + 1 H
 (44) 1 AC + 1 COA + 2 ATP + 1 H₂O → 1 ACCOA + 2 ADP + 2 Pi + 1 H
- Transfer of 1-carbon compounds*
- (45) 1 THF + 1 ATP + 1 NADH + 1 CO₂ → 1 FTTHF + 1 ADP + 1 Pi + 1 NAD
 (46) 1 THF + 1 CO₂ + 3 NADH + 3 H → 1 MYTHF + 3 NAD + 2 H₂O
 (47) 1 THF + 1 CO₂ + 2 NADH + 2 H → 1 MYTHF + 2 NAD + 2 H₂O
- Transport*
- (48) 1 Pi(E) + 2 H(E) → 1 Pi + 2 H
 (49) 1 NH₄(E) + 1 H(E) → 1 NH₄ + 1 H
 (50) 1 GLUC(E) + 1 H(E) → 1 GLUC + 1 H
 (51) 1 SO₄(E) + 3 H(E) → 1 SO₄ + 3 H
 (52) 1 AC(E) + 1 H(E) → 1 AC + 1 H
 (53) 1 LAC(E) + 1 H(E) → 1 LAC + 1 H
 (54) 1 PYR(E) + 1 H(E) → 1 PYR + 1 H
 (55) 1 GLUCON(E) + 1 H(E) → 1 GLUCON + 1 H
 (56) 1 SUC(E) + 2 H(E) → 1 SUC + 2 H
 (57) 1 CIT(E) + 3 H(E) → 1 CIT + 3 H
- H⁺ ATPase*
- (58) 1 ATP + 1 H₂O → 1 ADP + 1 H(E) + 1 Pi
- Amino acid synthesis*
- (59) 1 AKG + 1 NH₄ + 1 NADPH + 1 H → 1 GLUT + 1 NADP + 1 H₂O
 (60) 1 GLUT + 1 NH₄ + 1 ATP → 1 GLUM + 1 ADP + 1 Pi + 1 H
 (61) 1 GLUT + 1 ATP + 2 NADPH + 2 H → 1 PRO + 1 ADP + 1 Pi + 1 H₂O + 2 NADP
 (62) 1 ATP + 1 NH₄ + 1 CO₂ → 1 CARP + 1 ADP + 2 H
 (63) 2 GLUT + 1 ACCOA + 4 ATP + 1 NADPH + 1 CARP + 1 ASP + 3 H₂O → 1 ARG + 1 COA + 1 AKG + 1 AC + 4 ADP + 1 FUM + 5 Pi + 1 NADP + 4 H
 (64) 2 GLUT + 1 ACCOA + 3 ATP + 2 NADPH + 2 NAD + 3 H₂O → 1 LYS + 1 COA + 1 AKG + 1 CO₂ + 3 ADP + 3 Pi + 2 NADP + 2 H + 2 NADH
 (65) 1 ASP + 1 PYR + 2 NADPH + 1 SUCCOA + 1 GLUT + 1 ATP + 2 H → 1 LYS + 1 SUC + 1 AKG + 1 CO₂ + 2 NADP + 1 COA + 1 ADP + 1 Pi
 (66) 1 G3P + 1 GLUT + 1 NAD + 1 H₂O → 1 SER + 1 AKG + 1 Pi + 1 H + 1 NADH
 (67) 1 SER + 1 THF → 1 GLY + 1 METHF + 1 H₂O
 (68) 1 SER + 1 ACCOA + 1 SO₄ + 4 NADPH + 4 H + 1 ATP → 1 CYS + 1 AC + 1 COA + 4 NADP + 1 ADP + 3 H₂O + 1 Pi



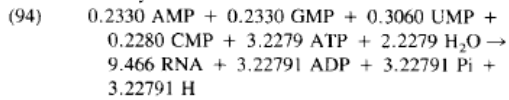
Amino acid polymerization



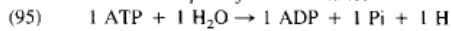
Nucleotide synthesis



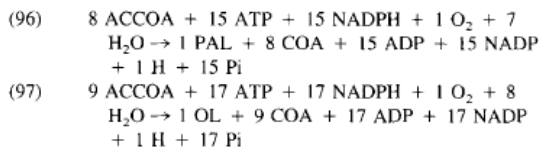
RNA synthesis



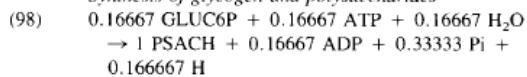
ATP consumption for maintenance



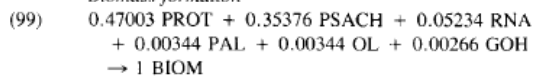
Synthesis of fatty acids



Synthesis of glycogen and polysaccharides



Biomass formation



NOMENCLATURE

C_i	concentration of compound i [(C)mol · L ⁻¹]
D	dilution rate (h ⁻¹)
df	degree of freedom (-)
f	ethanol fraction of the feed (C-mol · C-mol ⁻¹ total carbon)
K	growth-associated maintenance coefficient (mol ATP · C-mol ⁻¹ biomass)
K'	growth-associated maintenance coefficient (mol ATP · C-mol ⁻¹ protein)
m_{ATP}	non-growth-associated maintenance coefficient (mol ATP · C-mol ⁻¹ biomass h ⁻¹)
m'_{ATP}	non-growth-associated maintenance coefficient (mol ATP · C-mol ⁻¹ protein h ⁻¹)
m	total number of compounds (-)
n	number of reactions (-)
p	number of compounds exchanged between the system and the environment (-)
q_i	specific conversion rate of compound i [(C)mol · C-mol ⁻¹ · h ⁻¹]
r_{A_i}	net conversion rate of compound i [(C)mol · L ⁻¹ · h ⁻¹]
r_j	volumetric rate of biochemical reaction j [(C)mol · L ⁻¹ · h ⁻¹]
V	volume (L)
X_p	protein content of the biomass (C-mol · C-mol ⁻¹)
Y_{SP}	apparent yield of product on carbon substrate (C-mol · C-mol ⁻¹)
Y_{SP}^{lim}	limit to product yield on carbon substrate due to biochemical constraint (C-mol · C-mol ⁻¹)
Y_{SP}^{max}	product yield parameter in linear equation for consumption of carbon substrate (C-mol · C-mol ⁻¹)
Y_{SX}	apparent yield of biomass on carbon substrate (C-mol · C-mol ⁻¹)
Y_{SX}^{max}	biomass yield parameter in linear equation for consumption of carbon substrate (C-mol · C-mol ⁻¹)