

List of symbols.

Symbol	Unit	Description
Θ	-	unit step function
\mathcal{E}	-	unit step function
$\Phi_{1,...,3}$	-	exponential step function
$\rho_{1,...,3}$	-	constant to adjust the exponential step function
ω	-	constant to adjust ammonium release from amino acid degradation
μ_{\max}	1/min	maximum cell-specific growth rate
μ	1/min	cell-specific growth rate
α	-	constant adjusting inhibition factor
β	1/min	switch constant for cell death rate
\overline{d}	μm	mean cell diameter
b_{NAD}	-	adjustable parameter for influence of NAD/NADH
d_c	μm	critical cell diameter
d_m	μm	minimum cell diameter
f	-	growth inhibition factor
N^c	-	number of cell classes
v_e^{\max}	L/cell/min	cell number-specific activity of enzyme e

List of symbols (continued).

Symbol	Unit	Description
$v_{Glu_{trans}}^x$	mmol/L/ μ L/min	cell volume-specific transport rate of Glu
v_{HK}^{max}	mmol/cell/min	cell number-specific maximum activity of HK
v_{GPI}^{max}	mmol/cell/min	cell number-specific maximum activity of GPI
v_{G6PDH}^{max}	mmol/cell/min	cell number-specific maximum activity of G6PDH
$v_{Lac_{trans}}^x$	mmol/L/ μ L/min	cell volume-specific transport rate of Lac
$v_{Gln_{trans}}^x$	mmol/L/ μ L/min	cell volume-specific transport rate of Gln
$v_{NH_4^+_{trans}}^x$	mmol/L/ μ L/min	cell volume-specific transport rate of NH ₄
v_{dR5P}^{max}	mmol/cell/min	cell number-specific maximum activity of R5P
v_{UT}^{max}	mmol/cell/min	cell number-specific maximum activity of UT
v_{GLYS}^{max}	mmol/cell/min	cell number-specific maximum activity of GLYS
v_{PFK}^{max}	mmol/cell/min	cell number-specific maximum activity of PFK
$v_{TATKF6P}^{max}$	mmol/cell/min	cell number-specific maximum activity of TATKF6P
$v_{TATK3PG}^{max}$	mmol/cell/min	cell number-specific maximum activity of TATK3GP
v_{ALD}^{max}	mmol/cell/min	cell number-specific maximum activity of ALD
$v_{Pyr_{trans}}^x$	mmol/L/ μ L/min	cell volume-specific transport rate of Pyr

List of symbols (continued).

Symbol	Unit	Description
v_{ENO}^{\max}	mmol/cell/min	cell number-specific maximum activity of ENO
v_{PK}^{\max}	mmol/cell/min	cell number-specific maximum activity of PK
v_{LDH}^{\max}	mmol/cell/min	cell number-specific maximum activity of LDH
v_{ACO}^{\max}	mmol/cell/min	cell number-specific maximum activity of PDH
v_{CL}^{\max}	mmol/cell/min	cell number-specific maximum activity of ACO
v_{ICDH}^{\max}	mmol/cell/min	cell number-specific maximum activity of CL
v_{GS}^{\max}	mmol/cell/min	cell number-specific maximum activity of ICDH
v_{KDH}^{\max}	mmol/cell/min	cell number-specific maximum activity of GS
v_{SDH}^{\max}	mmol/cell/min	cell number-specific maximum activity of SDH
v_{FMA}^{\max}	mmol/cell/min	cell number-specific maximum activity of FMA
v_{MDH}^{\max}	mmol/cell/min	cell number-specific maximum activity of MDH
v_{ATPase}^{\max}	mmol/cell/min	cell number-specific maximum activity of ATPase
v_{AAex}^{\max}	mmol/cell/min	cell number-specific maximum activity of AAex
v_{cUGLC}^{\max}	mmol/cell/min	cell number-specific maximum activity of UGLC
v_{CS}^{\max}	mmol/cell/min	cell number-specific maximum activity of CS
v_{ME}^{\max}	mmol/cell/min	cell number-specific maximum activity of ME

List of symbols (continued).

Symbol	Unit	Description
v_{PECK}^{\max}	mmol/cell/min	cell number-specific maximum activity of PPECK
v_{PC}^{\max}	mmol/cell/min	cell number-specific maximum activity of PC
v_{AlaTA}^{\max}	mmol/cell/min	cell number-specific maximum activity of AlaTA
v_{AspTA}^{\max}	mmol/cell/min	cell number-specific maximum activity of AspTA
v_{GLDH}^{\max}	mmol/cell/min	cell number-specific maximum activity of GLDH
v_{GLNase}^{\max}	mmol/cell/min	cell number-specific maximum activity of GLNase
v_{dNH4}	mmol/cell/min	cell number-specific maximum activity of NH4 degradation
k_{HK}^m	mmol/L	affinity constant of HK
k_{GPI}^m	mmol/L	affinity constant of GPI
k_{GPI}^{eq}	-	equilibrium constant of GPI
k_{G6PDH}^m	mmol/L	affinity constant of G6PDH
k_{UT}^m	mmol/L	affinity constant of UT
$k_{TATKF6P}^{eq}$	-	equilibrium constant of TATKF6P
$k_{TATK3PG}^{eq}$	-	equilibrium constant of TATK3PG

List of symbols (continued).

Symbol	Unit	Description
k_{PFK}^m	mmol/L	affinity constant of PFK
k_{F16P}	mmol/L	affinity constant of ALD for F16P
k_{ENO}^{eq}	-	equilibrium constant of ENO
$k_{PEP_{PK}}$	mmol/L	affinity constant of PK for PEP
$k_{Pyr_{PK}}$	mmol/L	affinity constant of PK for Pyr
$k_{Pyr_{PDH}}$	mmol/L	affinity constant of PDH for Pyr
k_{ACO}^{eq}	-	equilibrium constant of ACO
k_{ACO2}^{eq}	-	equilibrium constant of ACO
k_{Cit}^m	mmol/L	affinity constant of CL for Cit
k_{ICDH}^{eq}	-	equilibrium constant of ICDH
k_{AAex}^{eq}	-	equilibrium constant of AAex
k_{FMA}^{eq}	-	equilibrium constant of FMA
k_{FMA}^m	mmol/L	affinity constant of FMA
k_{MDH}^m	mmol/L	affinity constant of MDH
$k_{x_{ATP}}$	cell/L/min	specific ATP consumption related to growth

List of symbols (continued).

Symbol	Unit	Description
k_{mATP}	cell/L/min	specific ATP consumption related to maintenance
NAD_{basal}	mmol/L	adjustable parameter for influence of NAD/NADH
k_{cUGLC}^m	mmol/L	affinity constant of a general enzyme to UDPGlc
k_{ME}^m	mmol/L	affinity constant of ME
$k_{ATP_{ME}}^i$	mmol ² /L ²	inhibition constant of ME from ATP
k_{μ}^i	mmol/L	growth related inhibition constant of ALD
$k_{Glu_{GS}}^m$	mmol/L	affinity constant of GS for Glu
k_{ICDH}^m	mmol/L	affinity constant of ICDH
k_{OAA}^m	mmol/L	affinity constant of CS for OAA
k_{AcCoA}^m	mmol/L	affinity constant of CS for AcCoA
k_{SDH}^m	mmol/L	affinity constant of SDH
k_{dR5P}^m	mmol/L	affinity constant of a general enzyme to R5P
k_{PEPCK}^m	mmol/L	affinity constant of PEPCK
$k_{Pyr_{PC}}^m$	mmol/L	affinity constant of PC for Pyr

List of symbols (continued).

Symbol	Unit	Description
k_{ME}^{eq}	-	equilibrium constant of ME
k_{KDH}^m	mmol/L	affinity constant of KDH
$k_{OAA_{AspTA}}$	mmol/L	affinity constant of AspTA for OAA
$k_{Glu_{AspTA}}$	mmol/L	affinity constant of AspTA for Glu
$k_{Keto_{AspTA}}$	mmol/L	affinity constant of AspTA for Keto
$k_{Glu_{GLDH}}$	mmol/L	affinity constant of LDH for Glu
k_{Glnase}^m	mmol/L	affinity constant of GLNase
k_{GLDH}^{eq}	-	equilibrium constant of GLDH
k_{ALD}^{eq}	-	equilibrium constant of ALD
k_{PFK}^a	mmol/L	activation constant of PFK
k_{ATPase}^m	mmol/L	affinity constant of ATPase
k_{3PG}	mmol/L	affinity constant of ENO for 3PG
$k_{PEP_{ENO}}$	mmol/L	affinity constant of ENO for PEP
$k_{TATK3PG}^m$	mmol/L	affinity constant of TATK3PG
$k_{TATKF6P}^m$	mmol/L	affinity constant of TATKF6P

List of symbols (continued).

Symbol	Unit	Description
k_{GLDH}^m	mmol/L	affinity constant of GLDH
$k_{ATP_{HK}}^m$	mmol/L	affinity constant of HK for ATP
$k_{ATP_{ALD}}^m$	mmol/L	affinity constant of ALD for ATP
$k_{3PG_{ALD}}^m$	mmol/L	affinity constant of ALD for 3PG
$k_{ATP_{PC}}^m$	mmol/L	affinity constant of PC for ATP
$k_{ATP_{PDH}}^m$	mmol/L	affinity constant of PDH for ATP
k_{Glu^x}	mmol/L	direct binding affinity constant for extracellular Glu
k_{Glu}	mmol/L	direct binding affinity constant for Glu transporter
$k_{Glu_{trans}^x}^{eq}$	-	direct biding equilibrium constant for Glu transporter
k_{Gln^x}	mmol/L	Direct binding (simplified) affinity constant for extracellular Gln
$k_{Pyr_{trans}^x}^m$	mmol/L	affinity constant of extracellular Pyr transporter
k_{AspTA}^m	mmol/L	affinity constant of AspTA
$k_{ATP_{GS}}^m$	mmol/L	affinity constant of GS for ATP
$k_{ATP_{Glnase}}^i$	mmol ² /L ²	inhibition constant of GLNase from ATP

List of symbols (continued).

Symbol	Unit	Description
$k_{OAA_{SDH}}^i$	mmol ² /L ²	inhibition constant of SDH from ATP
k_{GLYS}^m	mmol/L	affinity constant of GLYS
$k_{ATP_{CL}}^m$	mmol/L	affinity constant of CL for ATP
$k_{Lac_{trans}}^{eq}$	-	equilibrium constant of transporter for Lac
$k_{Lac_{trans}}$	mmol/L	affinity constant of transporter for Lac
$k_{Lac_{trans}^x}$	mmol/L	affinity constant of transporter for extracellular Lac
$k_{Pyr_{LDH}}$	mmol/L	affinity constant of LDH for Pyr
$k_{Lac_{LDH}}$	mmol/L	affinity constant of LDH for Lac
k_{cPyr}	mmol ² /L ²	activation constant of LDH from Pyr
$k_{Pyr_{LDH}}^a$	-	activation constant of LDH from Pyr
$k_{Glu_{LDH}}$	mmol ² /L ²	inhibition constant of LDH from Glu
$k_{Glu_{LDH}}^i$	-	inhibition constant of LDH from Glu
k_{LDH}^{eq}	-	equilibrium constant of LDH
k_{dNH4}^m	mmol/L	affinity constant of general enzyme for NH4
$k_{ATP_{dNH4}}^a$	mmol/L	activation constant of NH4 degradation from ATP

List of symbols (continued).

Symbol	Unit	Description
$k_{\text{NH}_4^x}$	mmol/L	direct binding affinity constant for NH_4 transporter
$k_{\text{NH}_4^x_{\text{trans}}}^{\text{eq}}$	-	direct biding equilibrium constant of NH_4 transporter
k_{NH_4}	mmol/L	direct binding affinity constant for NH_4 transporter
k_{AlaTA}^m	mmol/L	affinity constant of AlaTA
$k_{\text{Glu}_{\text{AlaTA}}}^i$	mmol^2/L^2	inhibition constant of AlaTA from Glu
$k_{\text{Glc}^x}^m$	mmol/L	Monod constant for extracellular Glc
k_d^{\min}	1/min	basal cell death rate
k_d^{\max}	1/min	maximum cell death rate
$k_d^{\min\text{inf}}$	1/min	basal cell death rate of infected cells
$k_d^{\max\text{inf}}$	1/min	maximum cell death rate of infected cells
$k_{d\text{Gln}^x}$	1/min	spontaneous glutamine degradation rate
m_{Glc^x}	mmol/L/ $\mu\text{L}/\text{min}$	maintenance related glucose consumption rate
K_e^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme e
K_{HK}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme HK
K_{GPI}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme GPI

List of symbols (continued).

Symbol	Unit	Description
K_{G6PDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme G6PDH
K_{dR5P}^{\max}	mmol/L/min	cell volume-specific reaction rate of general enzyme of R5P degradation
K_{UT}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme UT
K_{GLYS}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme GLYS
K_{PFK}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme PFK
$K_{TATKF6P}^{\max}$	mmol/L/min	cell volume-specific reaction rate of transaldolase and transketolase for F6P
$K_{TATK3PG}^{\max}$	mmol/L/min	cell volume-specific reaction rate of transaldolase and transketolase for 3PG
K_{ALD}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme ALD
K_{ENO}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme ENO
K_{PK}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme PK
K_{LDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme LDH
K_{PDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme PDH
K_{dNH4}^{\max}	mmol/L/min	cell volume-specific reaction rate of general enzyme for NH4 degradation
K_{ACO}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme ACO
K_{CL}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme CL

List of symbols (continued).

Symbol	Unit	Description
K_{ICDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme ICDH
K_{GS}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme GS
K_{KDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme KDH
K_{SDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme SDH
K_{FMA}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme FMA
K_{MDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme MDH
K_{ATPase}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme ATPase
K_{AAex}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme AAex
K_{cUGLC}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme UGLC
K_{CS}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme CS
K_{ME}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme ME
K_{PEPCK}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme PEPCK
K_{PC}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme PC
K_{AlaTA}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme AlaTA
K_{AspTA}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme AspTA

List of symbols (continued).

Symbol	Unit	Description
K_{GLDH}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme GLDH
K_{GLNase}^{\max}	mmol/L/min	cell volume-specific reaction rate of enzyme GLNase
NAD_{basal}	-	adjustable parameter for influence of NAD/NADH
r_i	mmol/L/min	cell-number-specific activity of enzyme i
r_{macro}	-	formula for conversion of macroscopic scale rates to microscopic scale
r_{HK}	mmol/L/min	cell volume-specific reaction rate of HK
r_{GPI}	mmol/L/min	cell volume-specific reaction rate of GPI
r_{G6PDH}	mmol/L/min	cell volume-specific reaction rate of G6PDH
r_{dR5P}	mmol/L/min	cell volume-specific reaction rate of R5P degradation
r_{dNH4}	mmol/L/min	cell volume-specific reaction rate of NH4 degradation
r_{UT}	mmol/L/min	cell volume-specific reaction rate of UT
r_{GLYS}	mmol/L/min	cell volume-specific reaction rate of GLYS
r_{PFK}	mmol/L/min	cell volume-specific reaction rate of PFK
$r_{TATKF6P}$	mmol/L/min	cell volume-specific reaction rate of TATKF6P
$r_{TATK3PG}$	mmol/L/min	cell volume-specific reaction rate of TATK3PG

List of symbols (continued).

Symbol	Unit	Description
r_{ALD}	mmol/L/min	cell volume-specific reaction rate of ALD
r_{ENO}	mmol/L/min	cell volume-specific reaction rate of ENO
r_{PK}	mmol/L/min	cell volume-specific reaction rate of PK
r_{LDH}	mmol/L/min	cell volume-specific reaction rate of LDH
r_{PDH}	mmol/L/min	cell volume-specific reaction rate of PDH
r_{ACO}	mmol/L/min	cell volume-specific reaction rate of ACO
r_{CL}	mmol/L/min	cell volume-specific reaction rate of CL
r_{ICDH}	mmol/L/min	cell volume-specific reaction rate of ICDH
r_{GS}	mmol/L/min	cell volume-specific reaction rate of GS
r_{KDH}	mmol/L/min	cell volume-specific reaction rate of KDH
r_{SDH}	mmol/L/min	cell volume-specific reaction rate of SDH
r_{FMA}	mmol/L/min	cell volume-specific reaction rate of FMA
r_{MDH}	mmol/L/min	cell volume-specific reaction rate of MDH
r_{ATPase}	mmol/L/min	cell volume-specific reaction rate of ATPase
r_{AAex}	mmol/L/min	cell volume-specific reaction rate of AAex

List of symbols (continued).

Symbol	Unit	Description
r_{cUGLC}	mmol/L/min	cell volume-specific reaction rate of UGLC
r_{CS}	mmol/L/min	cell volume-specific reaction rate of CS
r_{ME}	mmol/L/min	cell volume-specific reaction rate of ME
r_{PEPCK}	mmol/L/min	cell volume-specific reaction rate of PEPCK
r_{PC}	mmol/L/min	cell volume-specific reaction rate of PC
r_{AlaTA}	mmol/L/min	cell volume-specific reaction rate of AlaTA
r_{AspTA}	mmol/L/min	cell volume-specific reaction rate of AspTA
r_{GLDH}	mmol/L/min	cell volume-specific reaction rate of GLDH
r_{GLNase}	mmol/L/min	cell volume-specific reaction rate of GLNase
$r_{Lac_{trans}^x}$	mmol/L/min	medium volume-specific transport rate of Lac
$r_{NH_4^+_{trans}}$	mmol/L/min	medium volume-specific transport rate of NH4
$r_{Gln_{trans}^x}$	mmol/L/min	medium volume-specific transport rate of Gln
$r_{Glu_{trans}^x}$	mmol/L/min	medium volume-specific transport rate of Glu
$r_{Pyr_{trans}^x}$	mmol/L/min	medium volume-specific transport rate of Pyr
r_{trans}	1/min	specific transition rate

List of symbols (continued).

Symbol	Unit	Description
r_{m/Glc^x}	mmol/L/min	medium volume-specific uptake rate of Glc for maintenance
r_{x/Glc^x}	mmol/L/min	medium volume-specific uptake rate of Glc for growth
r_{GLUT}	mmol/L/min	cell volume-specific transport rate of Glc
r_{xATP}	mmol/L/min	cell volume-specific ATP consumption rate of cell growth
r_{mATP}	mmol/L/min	cell volume-specific ATP consumption rate of cell maintenance
r_{ATPase}	mmol/L/min	cell volume-specific rate of ATPase
r_{dATP}	mmol/L/min	net ATP consumption rate
r_{CCM}	mmol/L/min	net ATP production rate
r_{NADH}	mmol/L/min	net ATP production from NADH
r_{FADH}	mmol/L/min	net ATP production from FADH
r_{TCA}	mmol/L/min	net ATP production from TCA
$r_{glycolysis}$	mmol/L/min	net ATP production from glycolysis
r_{O_2}	fmol/cell/min	theoretical O ₂ consumption rate
V^c	μL/mL	viable cell volume
V_s^c	L/cell	cell-specific volume

List of symbols (continued).

Symbol	Unit	Description
V_w	-	working volume
X_i	cells/mL	number of viable cells of class i
X_v	cells/mL	viable cell concentration
Y_{x/Glc^x}	mmol/L/cell	cell growth-specific yield coefficient of Glc
E_{level}	-	relative enzyme level
IAV	-	influenza A virus