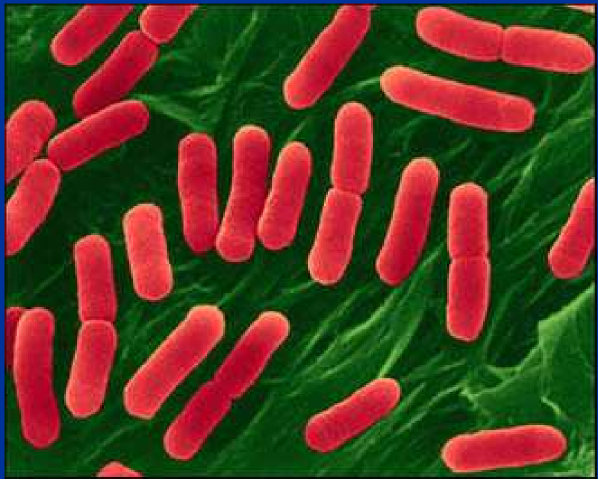
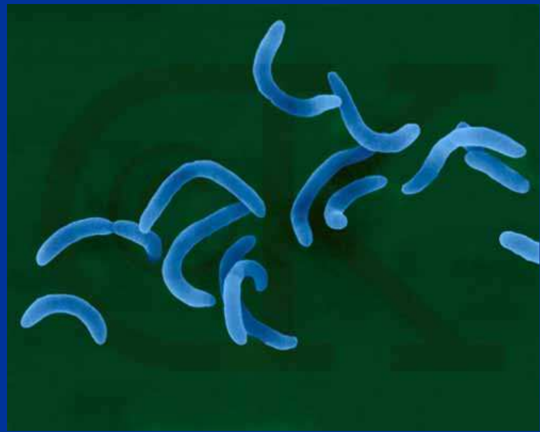
Fermentation up stream and down stream processes

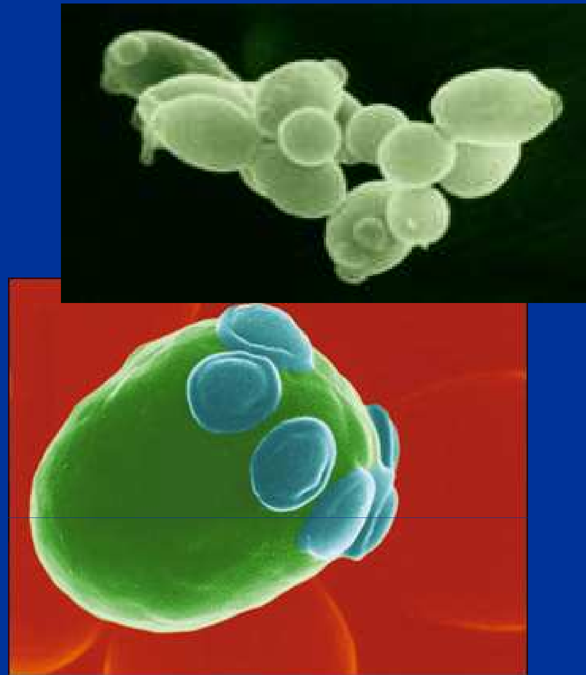


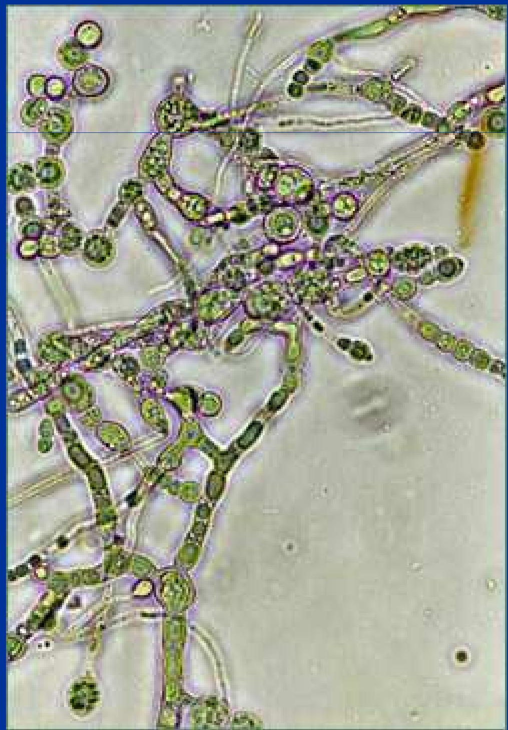
E.coli



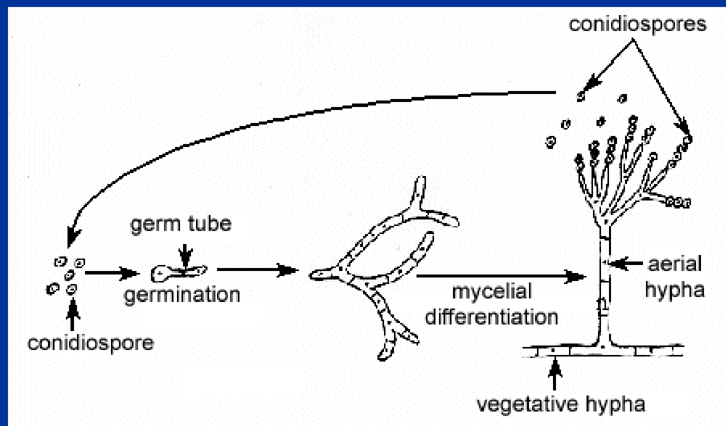
Vibrio cholerae

Saccharomyces cerevisiae



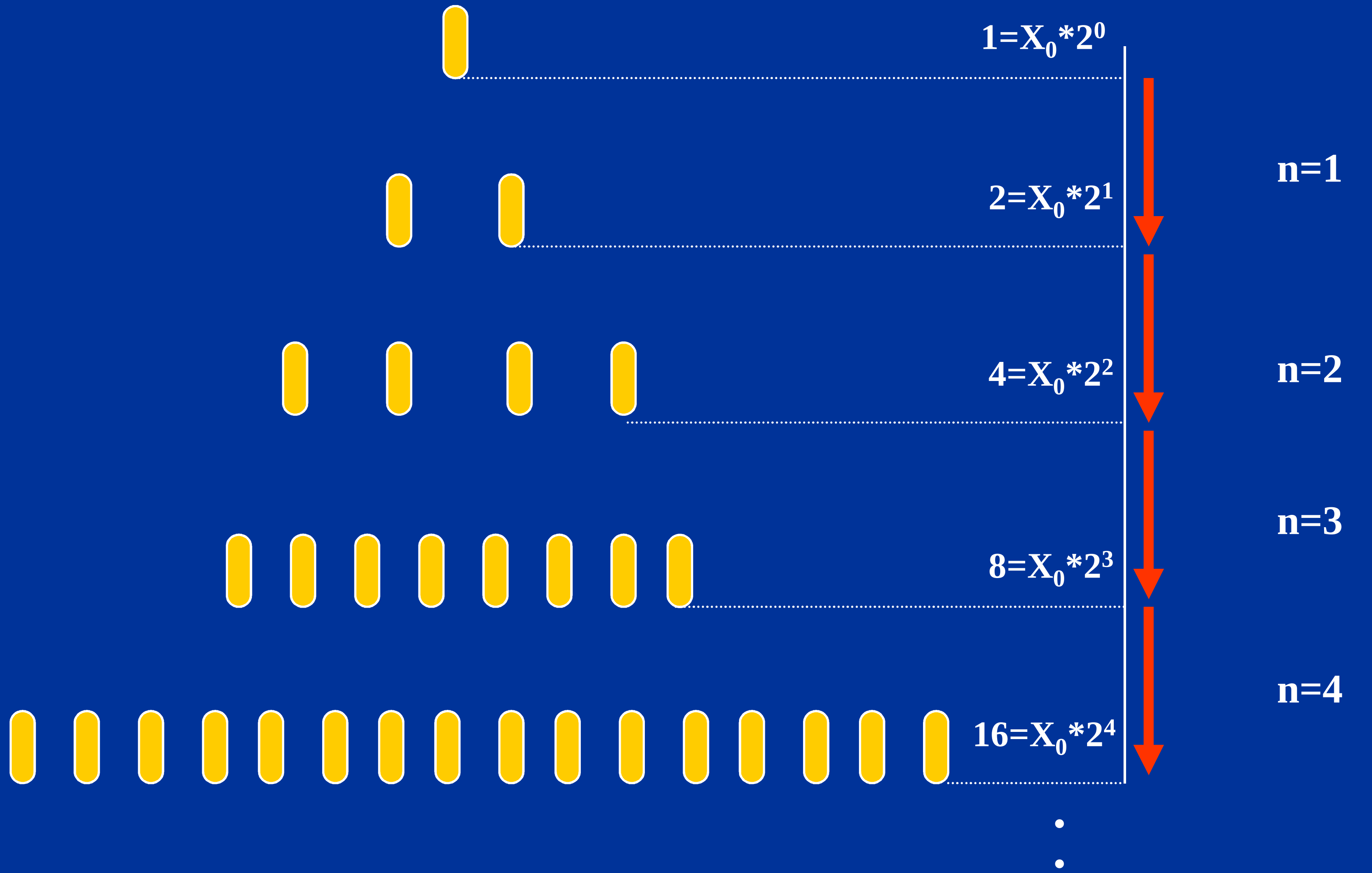


Mucor circenelloides



Aszexuális gombanövekedés

Basic rules of microbial growth



n:no of new generations

$X=X_0 2^n$

Binary dividing microorganisms

Basic rules of microbial growth

Cell number pc/ml

N, x

Cell mass: dw
mg/ml, g/l,kg/m[3]

$$n = \frac{t}{t_g}$$

No of generations

Generációs idő - doubling time
generation time

$$x = x_0 2^{\frac{t}{t_g}} = x_0 2^n$$

MONOD, 1942

$$\frac{dx}{dt} = \mu . x$$

μ: specific growth rate

Basic rules of microbial growth

$$\frac{dx}{dt} = \mu . x$$

Specific growth rate

$$\mu \equiv \frac{1}{x}\frac{dx}{dt}$$

h^{-1}

Basic rules of microbial growth

$$\frac{dx}{dt} = \mu . x$$

$$\frac{dN}{dt} = \nu . N$$

$$x = x_0 e^{\mu t}$$

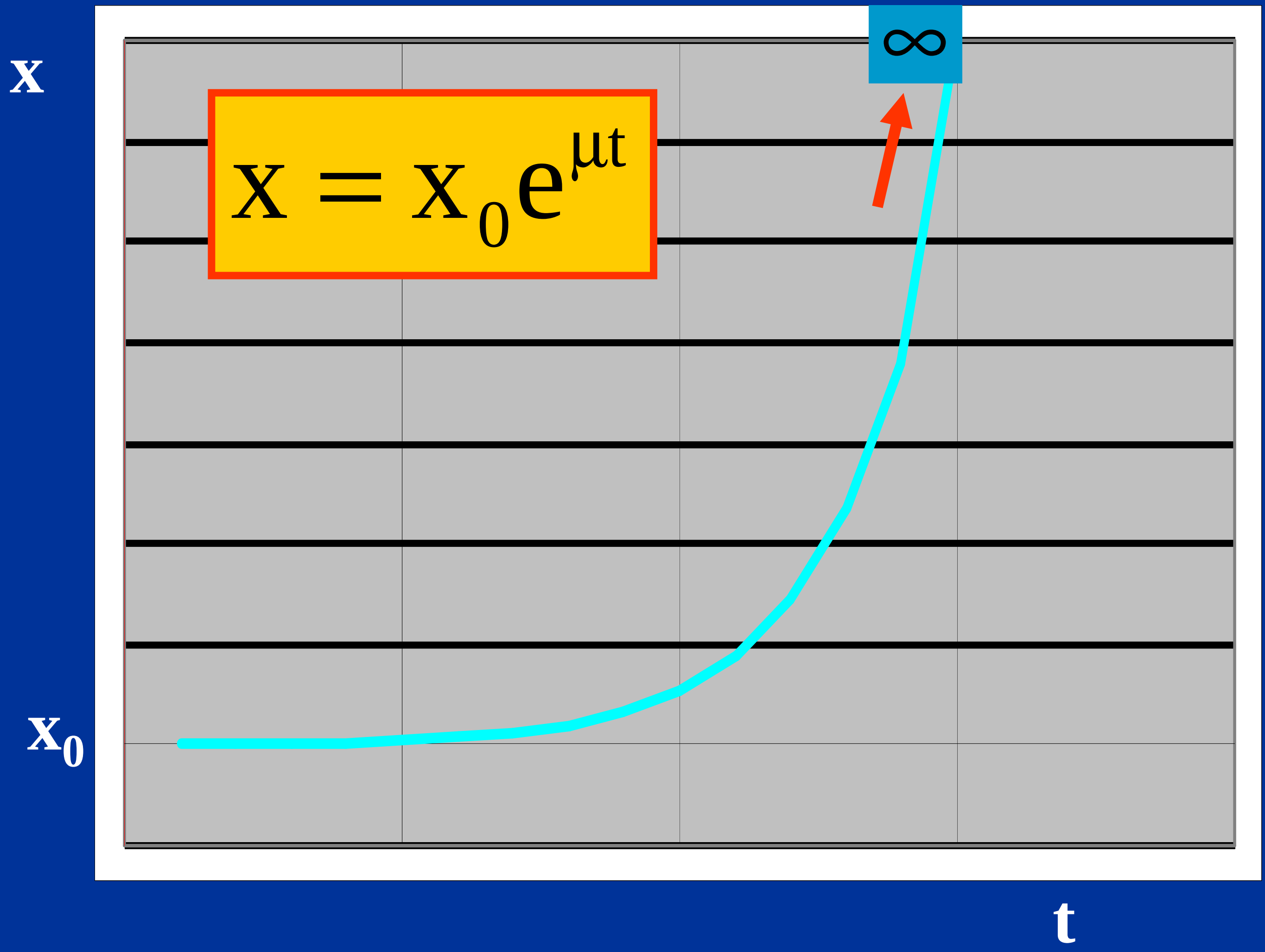
$$N = N_0 e^{\nu t}$$

Relation between μ and tg:

$$t_g = \frac{\ln 2}{\mu}$$

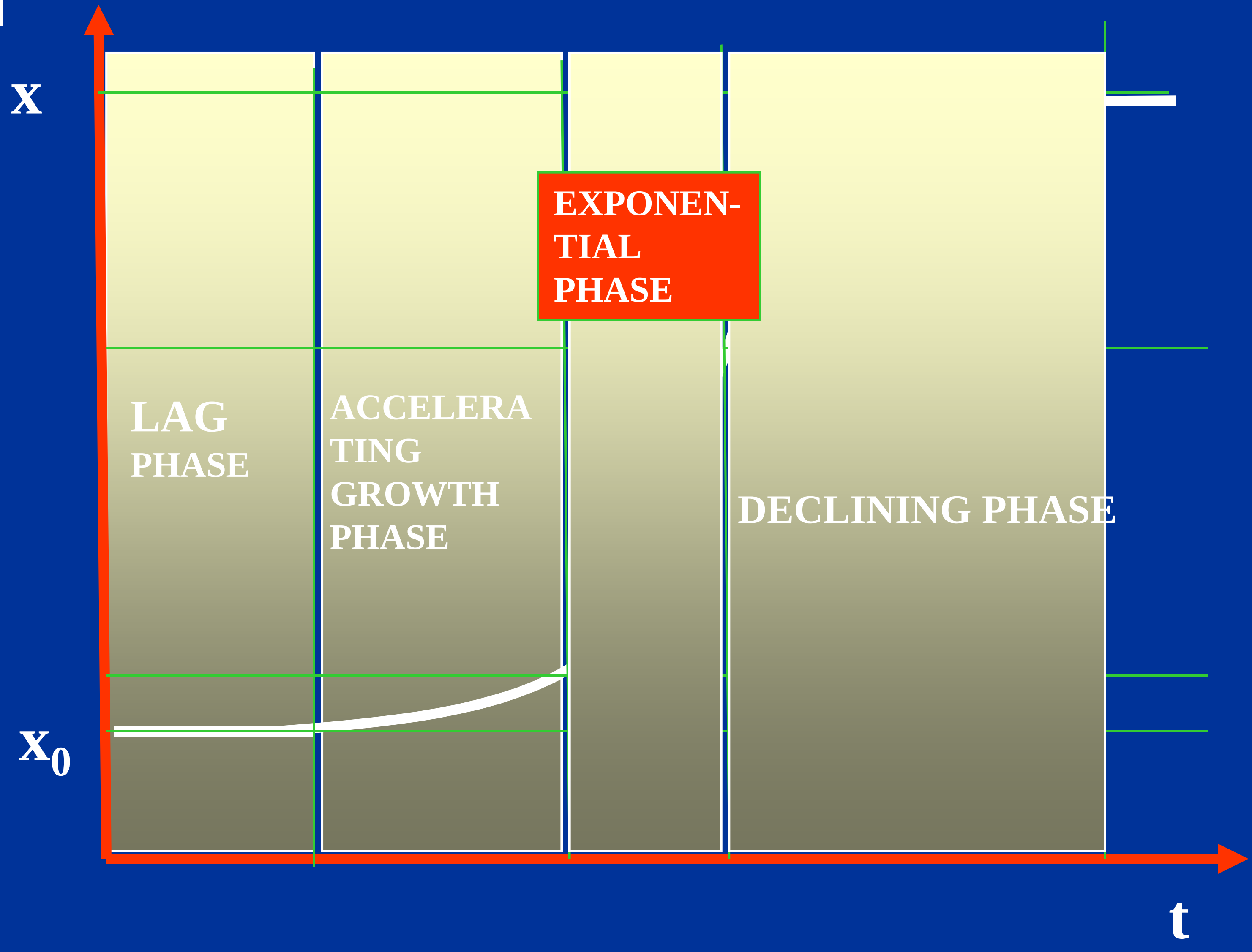
Specific proliferation rate
Spec. Doubling rate

Basic rules of microbial growth

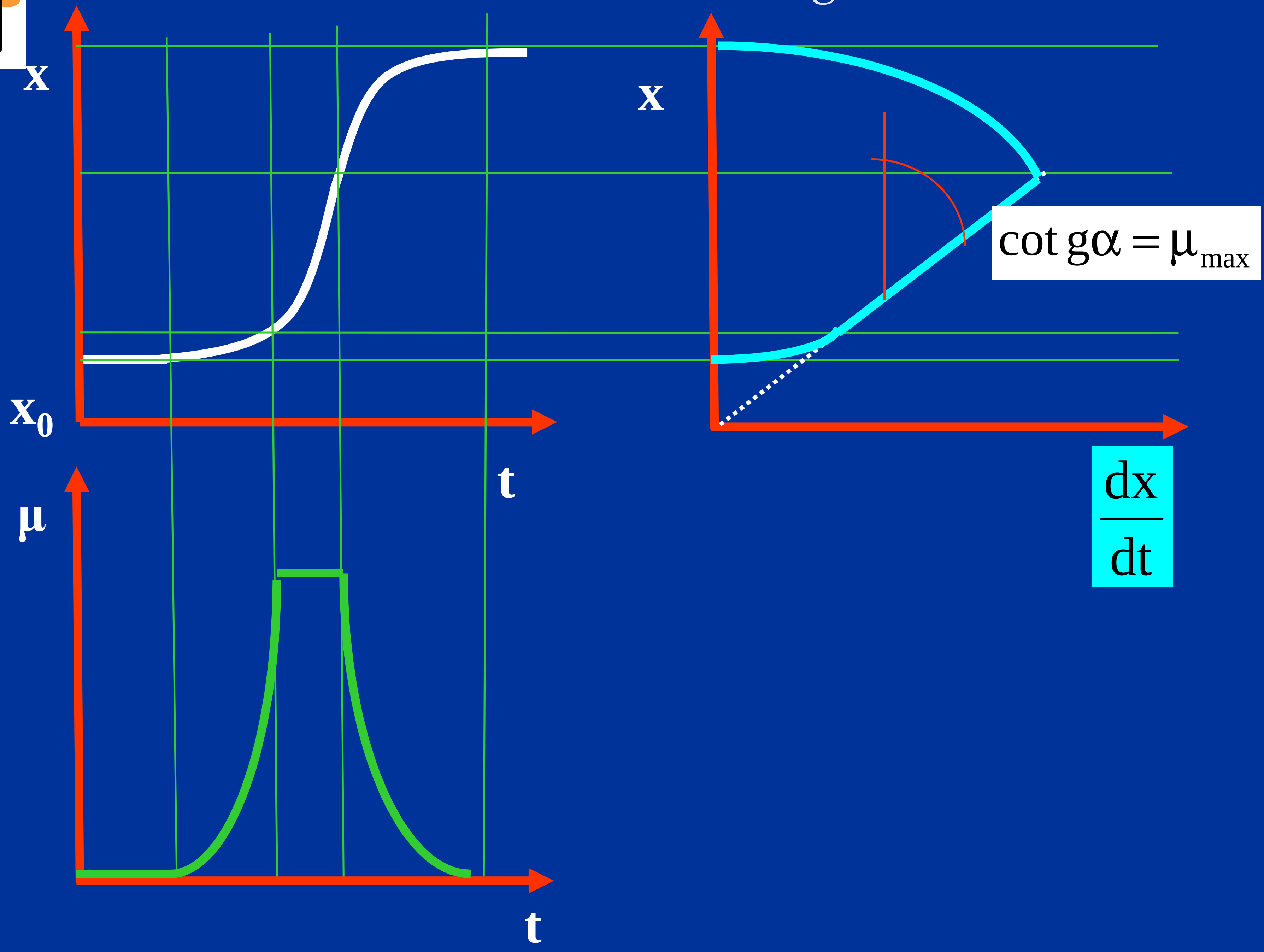


In reality

Basic rules of microbial growth



Basic rules of microbial growth



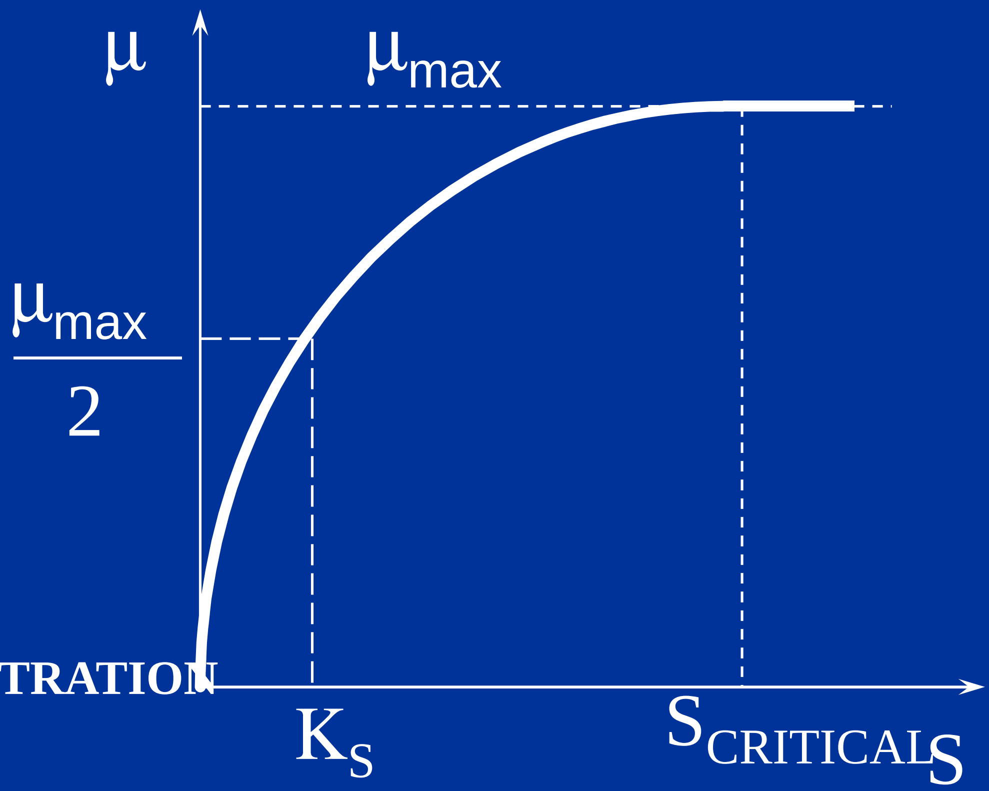
Basic rules of microbial growth

WHAT IS THE REASON OF THE EXISTENCE OD DECLINING PHASE?

1. **NUTRIENT LIMITATION**
2. **TOXIC METABOLIT PRODUCT(S)**
3. **LACK OF SPACE**

MONOD- model

$$\mu = \mu_{max} \frac{S}{K_S + S}$$

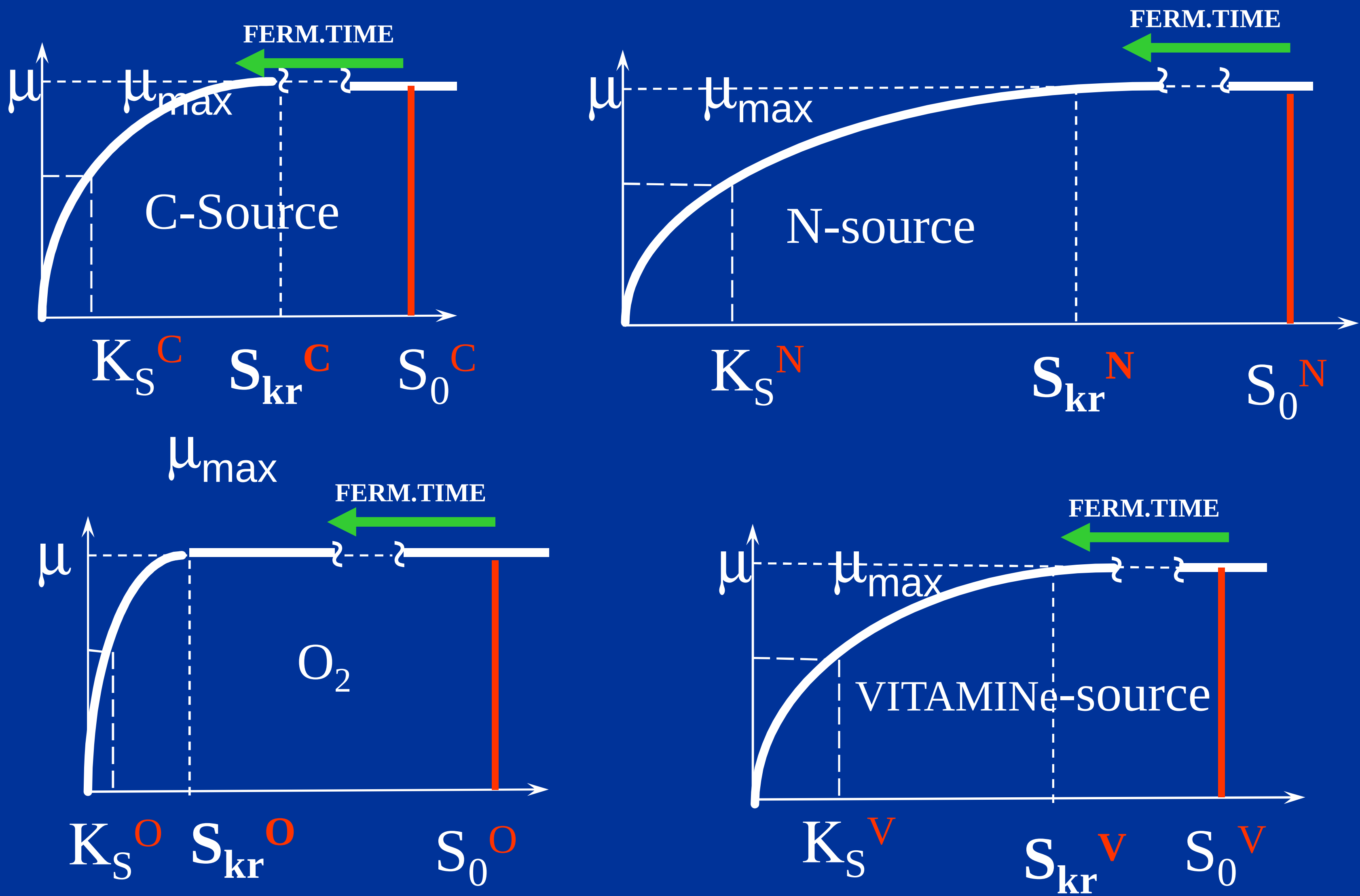


KRITICAL SUBSTRATE CONCENTRATION

<u>LIMITING SUBSTRATE</u>

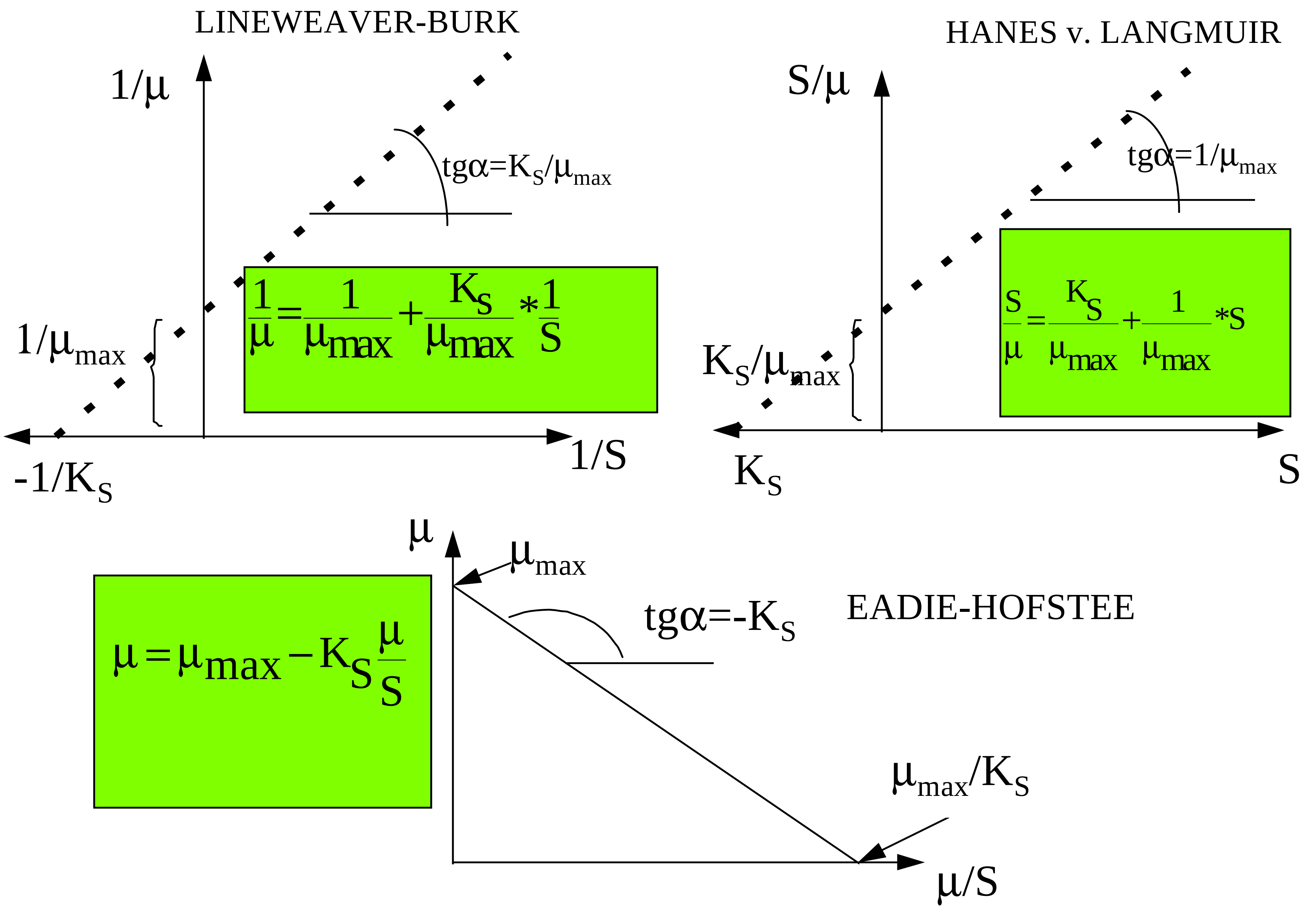
Basic rules of microbial growth

WHICH S WILL BE LIMITING ???



<u>NOTION OF THE LIMITING SUBSTRATE</u>

Basic rules of microbial growth



Basic rules of microbial growth

FOR THE LIMITING S

YIELD COEFF:

$$\frac{dx}{dS} = -Y_{x/s} \qquad = \frac{\Delta x}{\Delta S} = \frac{\frac{1}{x}\frac{dx}{dt}}{\frac{1}{x}\frac{dS}{dt}}$$

EXTENSION

$$\frac{dx}{dS_i} = -Y_{x/s_i} \quad \text{vagy} \; = \text{-}Y_i$$

ALWAYS TRUE:

$$r_x = \frac{dx}{dt} = \mu x$$

In the exponential and declining phase:

$$r_x = \frac{dx}{dt} = \mu \frac{S}{K_S + S} x$$

$$r_S = \frac{dS}{dt} = -\frac{1}{Y_{x/S}} \mu \frac{S}{K_S + S} x$$

Differential equation
Can be solved

MONOD-model

Basic rules of microbial growth

$$\frac{dx}{dS_i} = \frac{\Delta x}{\Delta S} = \frac{\frac{dx}{dt}}{\frac{dS}{dt}} = \frac{\mu_x}{\mu_S} = \frac{\mu_x}{Q_S} - Y_{x/s_i} \quad \text{vagy} \; = -Y_i$$

Basic rules of microbial growth

Utilization of C/en source

What for?

incorporation **energy production**

$$\Delta S = \Delta S_c + \Delta S_E$$

$$\frac{\Delta S}{\Delta x} = \frac{\Delta S_C}{\Delta x} + \frac{\Delta S_E}{\Delta x}$$

$$\frac{1}{Y_{x/s}} = \frac{1}{Y_C} + \frac{1}{Y_E}$$

$$Y_E = \frac{1}{\frac{1}{Y} - \frac{1}{Y_C}} = \frac{YY_C}{Y_C - Y}$$

Overall yield

Yield of incorp. carbon

Energy yield

Basic rules of microbial growth

Material balance for the incorporated carbon

$$\alpha_2 \Delta x = \alpha_1 \Delta S_C$$

C-content of the cell mass

0,46-0,5 50%

C-content of the substráate

Glucose:0,4

$$\frac{\Delta x}{\Delta S_c} = Y_C = \frac{\alpha_1}{\alpha_2}$$

$$Y_E = \frac{Y \cdot \frac{\alpha_1}{\alpha_2}}{\frac{\alpha_1}{\alpha_2} - Y} = \frac{Y . \alpha_1}{\alpha_1 - Y . \alpha_2}$$

Basic rules of microbial growth

Some cases from the product one can estimate the energy production and consumption

EtOH	**yeast, sugar**	
AcOH	***A.aceti*, alcohol**	**NADH !!!**
Glükonsav	***A.suboxydans*, glucose**	

Strain	cult. media	Assimilated ratio of cult. media %	Dissimilated ratio of cult. media %
Streptococcus faecalis			
anaerobic growth	complett	2	98
Saccharomyces cerevisiae	complett		
aerobic growth		10	90
anaerobic growth		2	98
Aerobacter cloaceae	minimal	55	45

1,2,3,

Basic rules of microbial growth

$$\Delta S = \Delta S_c + \Delta S_E$$

?

Cell growth

Maintenance of viability

Cell motion

Osmotic work

Mantenance of orderness

thermodynamics II.law **resyntheses**

$$Y_E = \frac{\Delta x}{\Delta S_E} = \frac{\Delta x}{\Delta S_g + \Delta S_m}$$

$$\frac{1}{Y_E} = \frac{1}{Y_{EG}} + \frac{m}{\mu}$$

Basic rules of microbial growth

$$\frac{dS}{dt} = -\frac{1}{Y}\frac{dx}{dt} = -\frac{\mu x}{Y}$$

!!!

$$\left(\frac{dS}{dt}\right)_E = \frac{\mu_x}{Y_E} = \frac{dS_g}{dt} + \frac{dS_m}{dt}$$

$$\frac{dS_g}{dt} = \frac{\mu x}{Y_{EG}}$$

$$\frac{dS_m}{dt} = mx$$

modell

$$\frac{\mu x}{Y_E} = \frac{\mu x}{Y_{EG}} + mx$$

$$\frac{1}{Y_E} = \frac{1}{Y_{EG}} + \frac{m}{\mu}$$

Basic rules of microbial growth

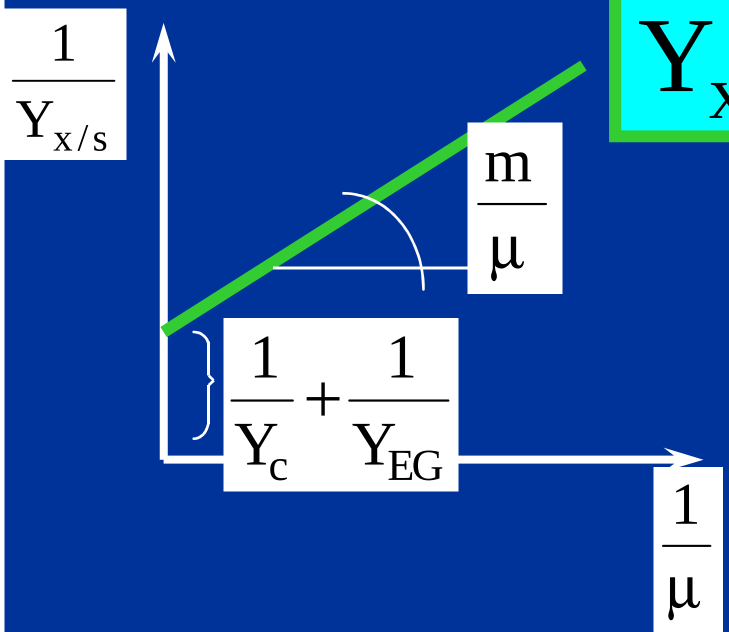
$$\frac{1}{Y_E} = \frac{1}{Y_{EG}} + \frac{m}{\mu}$$

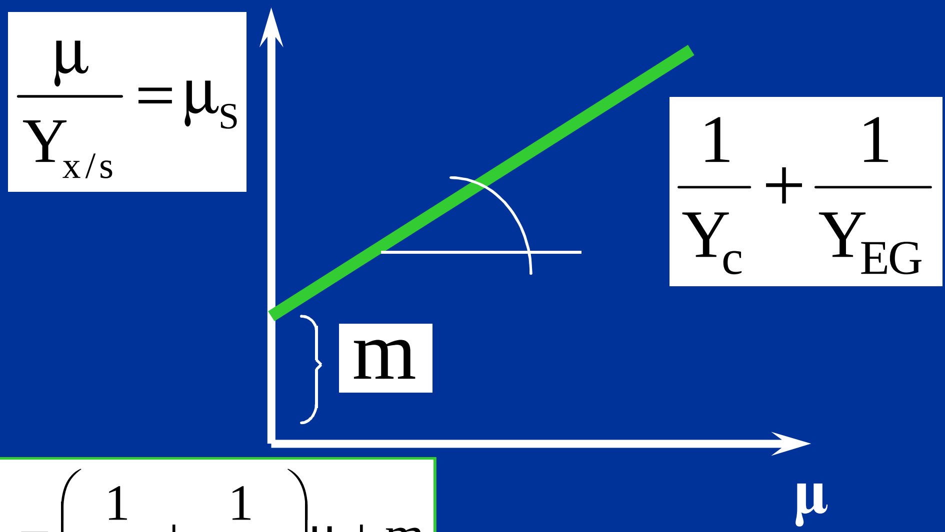
specific maintenance coefficient

g/gh = h^{-1}

For the overall yield:

$$\frac{1}{Y_{x/s}} = \frac{1}{Y_c} + \frac{1}{Y_{EG}} + \frac{m}{\mu}$$





$$\mu_S = \left(\frac{1}{Y_C} + \frac{1}{Y_{EG}}\right)\mu + m$$

Basic rules of microbial growth

ATP-yield

$$Y_{ATP} = \frac{\Delta x}{\Delta ATP} = \frac{Y'_{x/s}}{Y_{ATP/s}}$$

g/mol (for Y_{ATP})

g/mol (for $Y'_{x/s}$)

mol/mol (for $Y_{ATP/s}$)

$$Y'_{x/s} = MY_{x/s}$$

10,5 g/mol

(8,3-32)

$$\Delta ATP = (\Delta ATP)_g + (\Delta ATP)_m$$

$$\frac{1}{Y_{ATP}} = \frac{1}{Y_{ATP}^{max}} + \frac{m_{ATP}}{\mu}$$

$$Q_{ATP} = \frac{\mu}{Y_{ATP}} = \frac{\mu}{Y_{ATP}^{max}} + m_{ATP}$$

culture conditions		specific mentenance coefficients m	m_{ATP}
Aerobacter cloaceae	aerobic, glucose	0,094	14
Saccharomyces cerevisiae	anaerobic glucose + 0,1 mol/dm^3 NaCl	0,036	0,52
Saccharomyces cerevisiae	anaerobic, glucose +1,0 mol/dm^3 NaCl	0,360	2,2
Penicillium chrysogenum	aerobic	0.,022	3,2
Lactobacillus casei	aeroic, glucose	0,135	1,5

Basic rules of microbial growth

$$\frac{P}{O}$$

Effectivity of oxidatíve phosphorilation

mol/gatom

„P/O ratio”

3/1=3

$$NADH + H^{+} + 1/2O_2 + 3\,ADP + 3\,H_3PO_4 \longrightarrow NAD^{+} + 3\,ATP + 4\,H_2O$$

$$Y_{\frac{p}{s}} = \frac{\Delta P}{\Delta S} \qquad Y_{\frac{p}{x}} = \frac{\Delta P}{\Delta x}$$

Basic rules of microbial growth

METABOLIC
HEAT PRODUCTION

$$Y_H = Y_{kcal} = \frac{\Delta x}{-\Delta H_x . \Delta x + \Delta H_S . \Delta S} = \frac{\Delta x}{\Delta Q}$$

HEAT PROD. YIELD

ENTHALPY OF
CELL MASS

ENTHALPY OF SUBSTRATE

$$Y_H = Y_{kcal} = \frac{\Delta x / \Delta S}{-\Delta H_x . \Delta x / \Delta / \ + \Delta H_S . \Delta \Delta S / \Delta} = \frac{Y_{x/S}}{\Delta H_S - Y_{x/S} \Delta H_x}$$

IF THERE IS NO SIGNIFICANT EXTRACELLULAR PRODUCTION

RQ respiration quotient

$$\frac{\Delta CO_2}{\Delta O_2} = \frac{\frac{dCO_2}{dt}}{\frac{dO_2}{dt}} = \frac{q_{CO_2}}{q_{O_2}}$$

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6\,H_2O$ $RQ_{max} = 1$

$2C_2H_5OH + 6\,O_2 \longrightarrow 4\,CO_2 + 6\,H_2O$ $RQ_{max} = 4/6 = 0{,}67$

$C_6H_{12}O_6 \longrightarrow C_2H_5OH + CO_2$ $RQ_{max} = \infty$

$2\,CH_3OH + 3\,O_2 \longrightarrow 2\,CO_2 + 4H_2O$ $RQ_{max} = 2/3 = 0{,}67$

$C_2H_2O_4 + ½\,O_2 \longrightarrow 2CO_2 + H_2O$ $RQ_{max} = 2/½ = 4$

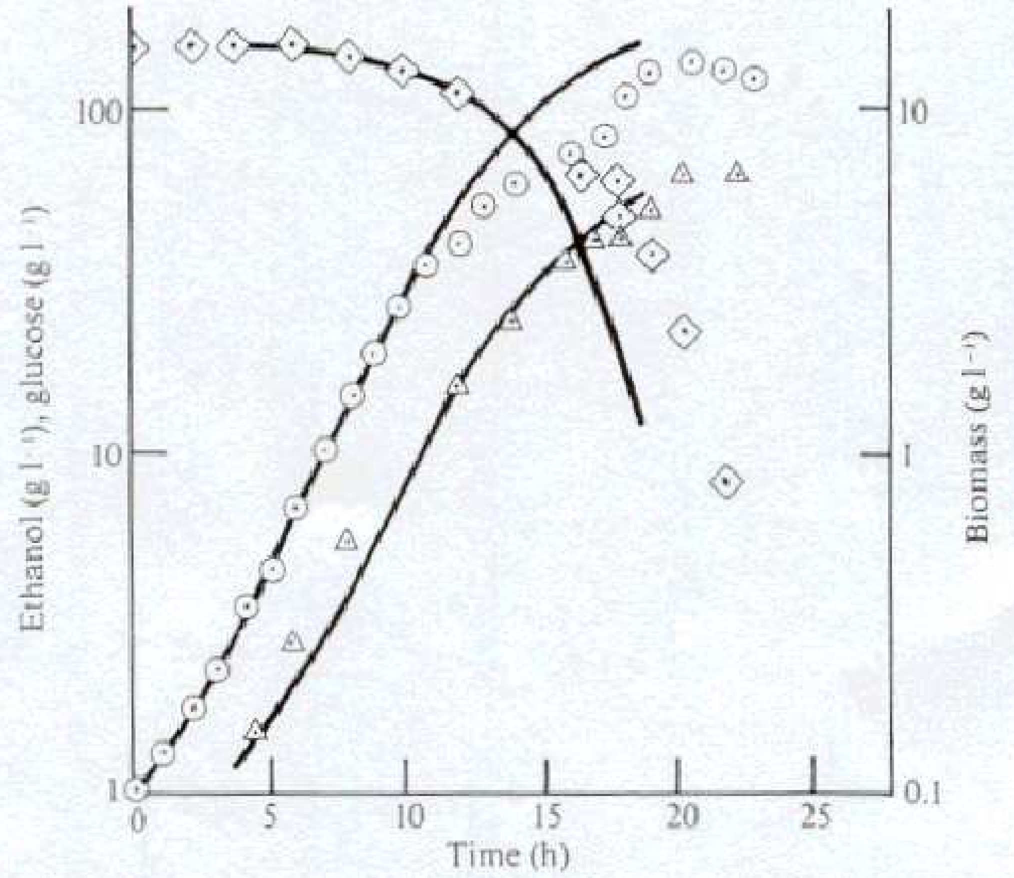


Fig. 6.59. Batch ethanol fermentation by *Saccharomyces cerevisiae*. Observed values; ⊙, biomass; △, ethanol; ◇, glucose (Aiba et al., 1968).

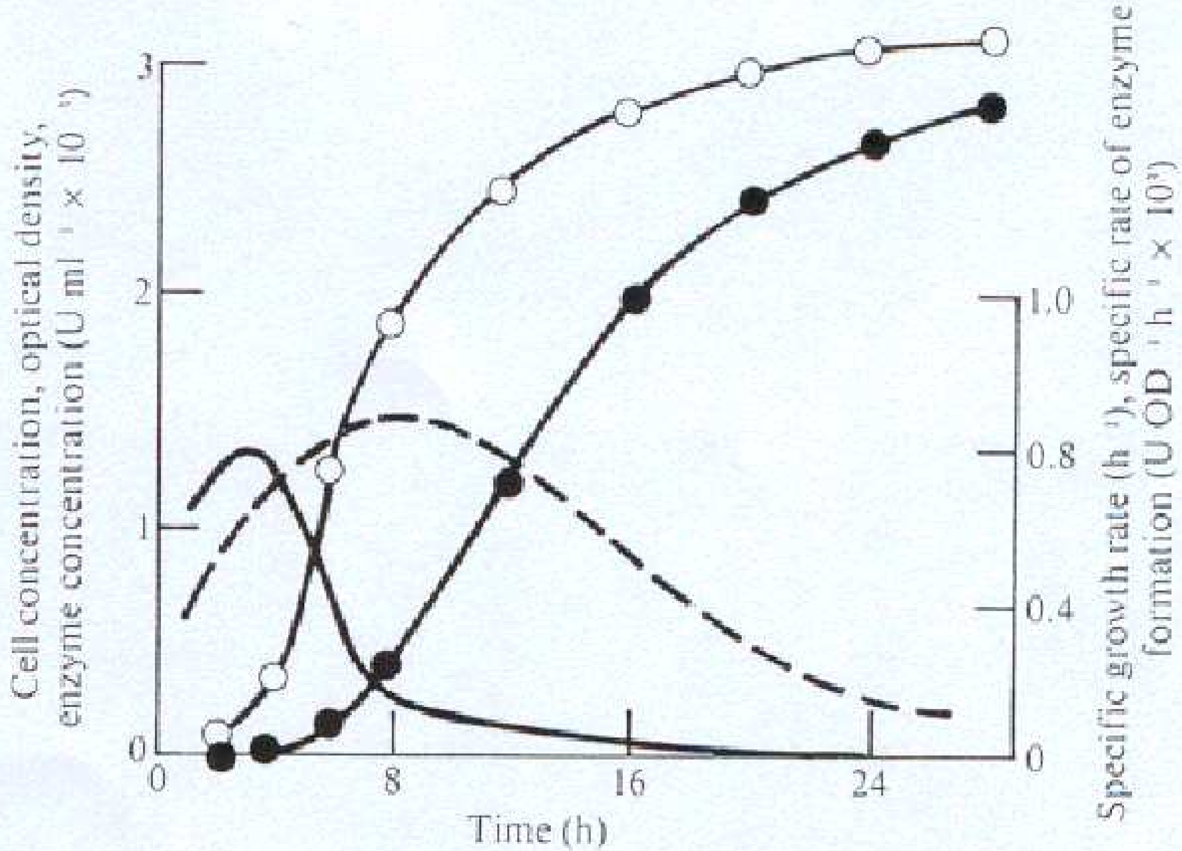
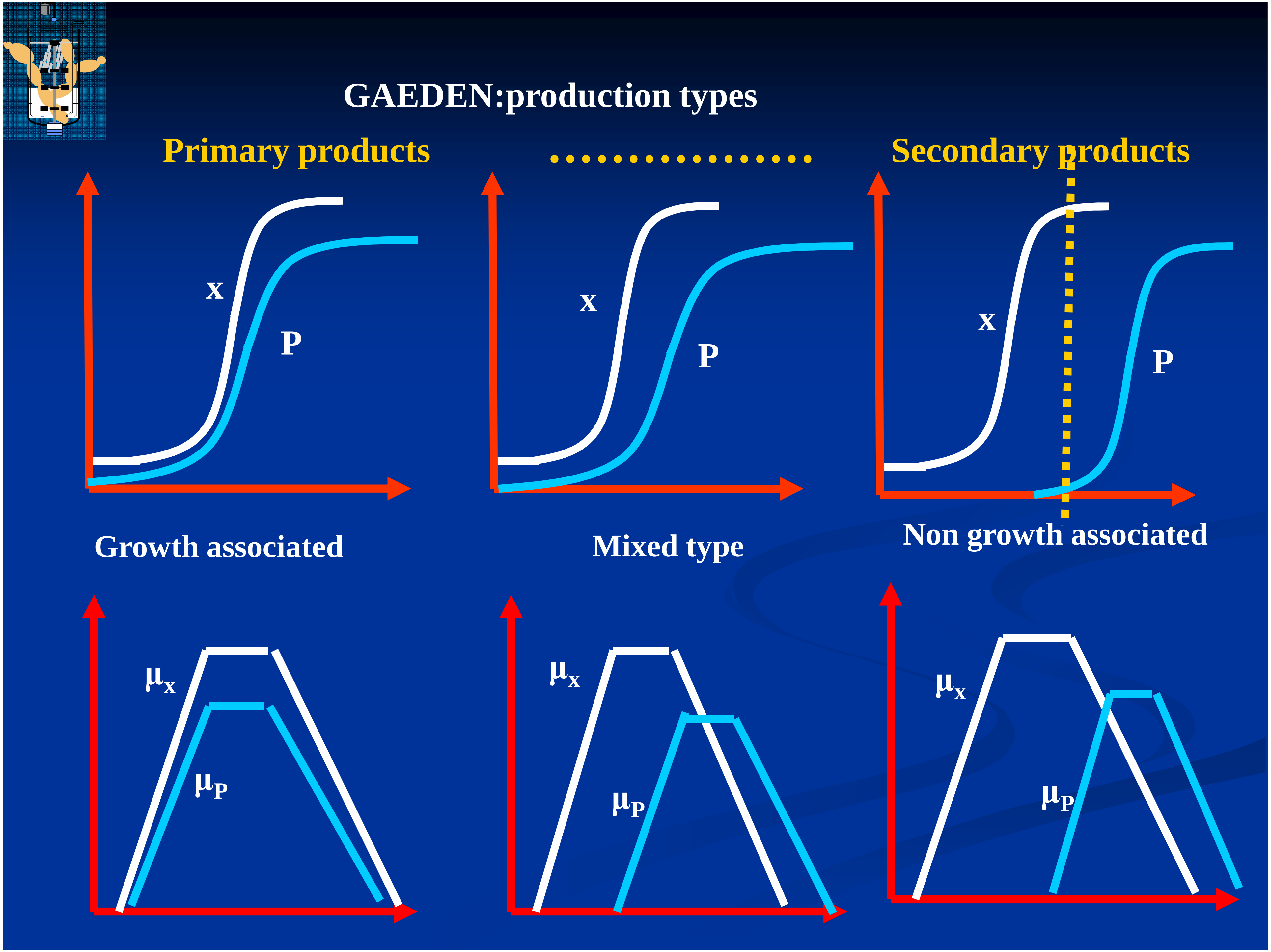


Fig. 6.53. Time course of α-amylase formation by *Bacillus amyloliquefaciens*. ——, specific growth rate (μ); ...., specific rate of enzyme formation (ε); —○—, cell concentration (x); —●—, enzyme concentration (E).

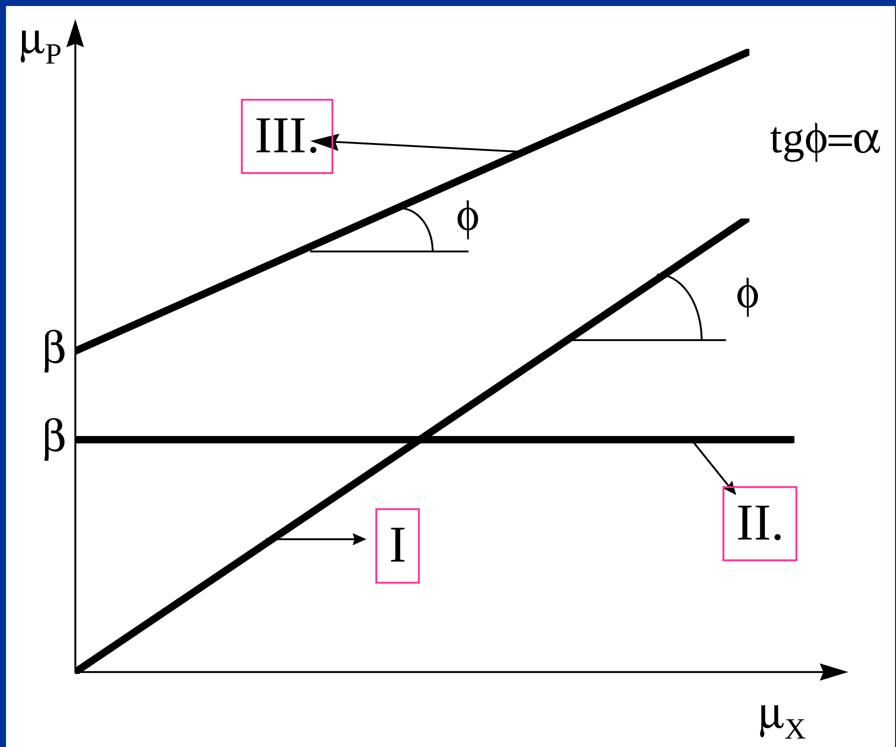

GAEDEN:production types
Primary products
....
Secondary products
x
P
x
P
x
P
Growth associated
Mixed type
Non growth associated
μ_x
μ_P
μ_x
μ_P
μ_x
μ_P

KINETICS OF PRODUCT FORMATION

LUEDEKING – PIRET MODEL

$$r_P = \frac{dP}{dt} = \alpha \frac{dx}{dt} + \beta x$$

$$\frac{1}{x}\frac{dP}{dt} = \mu_P = \alpha\mu_x + \beta$$



I: $\alpha>0$ **és** $\beta = 0$ **GROWTH ASSOC.**

II: $\alpha = 0$ **és** $\beta>0$ **NONGROWTH ASSOC**

III: $\alpha>0$ **és** $\beta>0$ **MIXED TYPE**