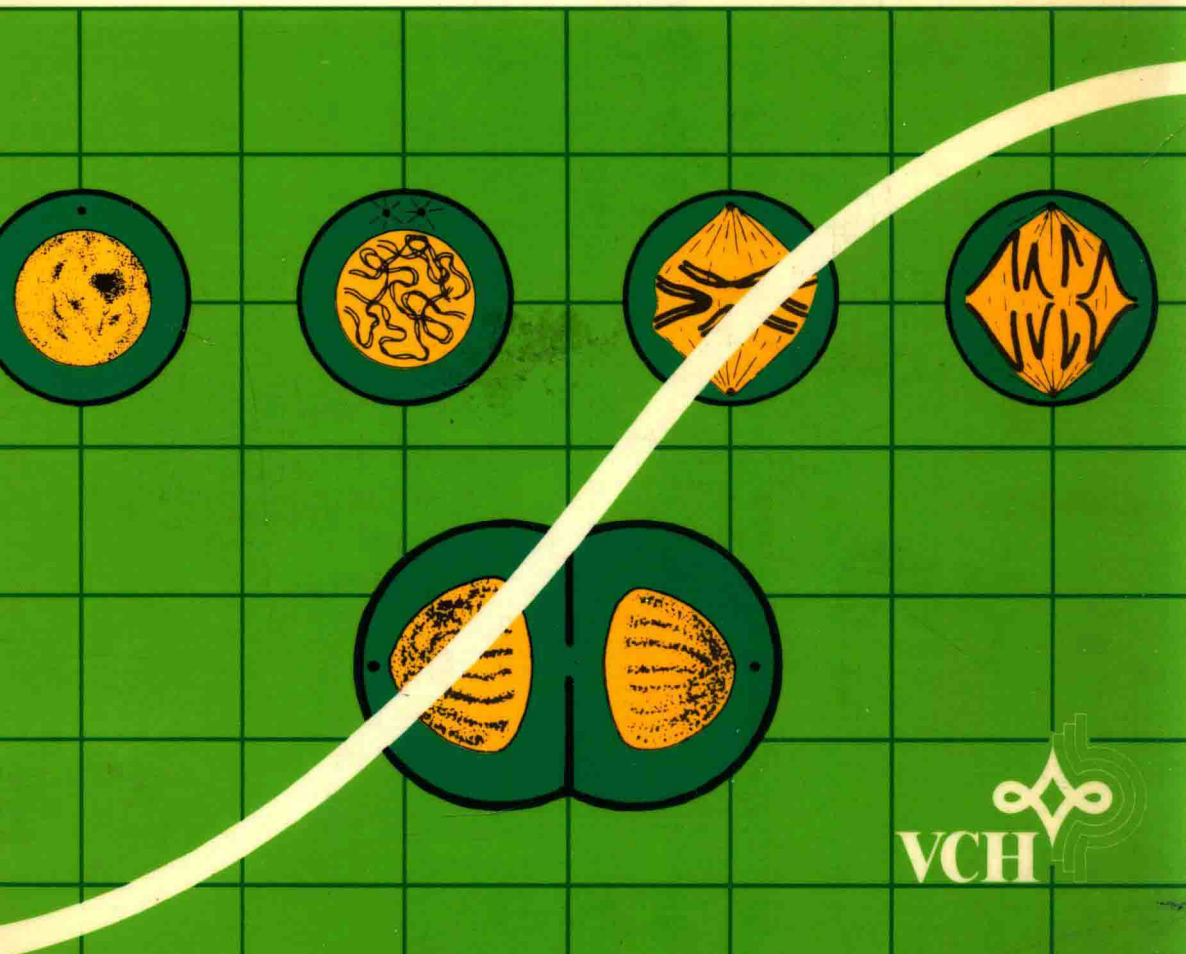
Basic Biotechnology

A Student's Guide

Edited by
P. Präve, U. Faust, W. Sittig, D. A. Sukatsch



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Preface

In recent years biotechnology has undergone exciting advancements. A comprehensive survey of this diverse field was provided by *Fundamentals of Biotechnology*, a 750-page treatise written by a group of recognized experts from both university and industry. While preparing this major work, we were struck by the idea of segregating the chapters covering basic concepts of biotechnology and presenting them in a smaller book to be used as a student text. The result is the present book, *Basic Biotechnology – A Student's Guide*. We were encouraged to prepare this new textbook by biotechnology teachers in Europe and U.S.A.

Basic Biotechnology is intended as recommended reading for biotechnology courses – in whichever department they are taught: chemical engineering, agricultural engineering, biochemistry, or microbiology. We hope that it will be useful to both professors teaching such courses and to their students.

January 1987 The Editors

Contents

Technical Terms at the Fermenter

Term	Abbreviation	Unit
Bodenstein number $\left(B_o = \frac{w \cdot L}{D_{eff}}\right)$ (flow related to diffusion)	*Bo*	—
Bubble diameter	d_B	mm
Diameter of the bioreactor (tank)	D_t	m
Diameter of the stirrer (impeller)	D_i	m
Diffusion constant	D	—
Efficiency	η	%
Height of the fermenter	H_T	m
Henry's constant	*He*	$m^3 \cdot bar \cdot kmol^{-1}$
Level of liquid in the bioreactor	H_L	m
Mass exchange area (interface)	a	m^2
Mass transfer number	$K_L \cdot a$	s^{-1}, h^{-1}
Mass transport coefficient	K_L	$m \cdot s^{-1}$
Mixing time	t_m, Θ	s
Osmotic pressure	π	bar
Peripheral speed of the stirrer (tip speed)	v_{tips}	$m \cdot s^{-1}$
Position of the stirrer on the shaft	S_m	m
Power demand with aeration	P_g	W
Power demand without aeration	P_0	W
Proportion of gas volume	ε_G	%
Rate of mass transport	N_A	$mol \cdot h^{-1}$
Rate of rotation	n	s^{-1}
Reynolds number (characterizes the flow) ($Re = v \cdot L \cdot \nu^{-1}$)	*Re*	—
Schmidt number* ($Sc = \nu \cdot D^{-1}$)	*Sc*	—
Sherwood number** ($Sh = K_L \cdot d_B \cdot D^{-1}$)	*Sh*	—
Specific power input	$P \cdot V^{-1}$	$W \cdot L^{-1}$
Superficial rate of flow (empty-tube velocity)	v_s	$m \cdot s^{-1}$
Velocity gradient	$\frac{dv}{dx}$	s^{-1}
Volume of the fermenter	V_F	m^3

* Characterizing oxygen diffusion in solution.

** Characterizing oxygen transfer into the culture solution.

Basic Physical Magnitudes

(SI system) based on:

Length	(meter, m)	Temperature	(kelvin, K)
Mass	(kilogram, kg)	Luminous intensity	(candela, cd)
Time	(second, s)	Amount of substance	(mole, mol)
Current strength, electrical	(ampere, A)		

Magnitude	Symbol	Unit, Abbreviation, Relationship
Volume	V	L, m^3
Frequency	f	hertz, $Hz = s^{-1}$
Rate of rotation	n	$rpm = s^{-1}$
Velocity	v	$m \cdot s^{-1}$
Acceleration	a	$m \cdot s^{-2}$
Angular velocity	ω	$rad \cdot s^{-1}$
Angular acceleration	α	$rad \cdot s^{-2}$
Density	ρ	$kg \cdot m^{-3}$
Force	F	newton, $N = kg \cdot m \cdot s^{-2}$
Work, energy	W, E	joule, $J = N \cdot m = kg \cdot m^2 \cdot s^{-2}$ (kilowatt hour, kW h = 3.6 MJ)
Power	P	watt, $W = J \cdot s^{-1} = kg \cdot m^2 \cdot s^{-3}$
Pressure	p	pascal, $Pa = N \cdot m^{-2} = kg \cdot s^{-2} \cdot m^{-1}$ technical atmosphere, at = 0.980665 bar physical atmosphere, atm = 760 torr torr = 133.3 Pa bar = 10^5 Pa meter water column, m H_2O = 0.1 at
Surface tension	σ	$N \cdot m^{-1} = kg \cdot s^{-2}$
Viscosity, dynamic	η	pascal-second, $Pa \cdot s = N \cdot m^{-2} \cdot s$
kinematic	ν	stokes, $St = 10^{-4}\ m^2 \cdot s^{-1}$
Amount of heat Q	Q	joule, $J = W \cdot s = N \cdot m$ calorie, cal = 4.1868 J
Coefficient of heat transmission	k	$cal \cdot m^{-2} \cdot h^{-1} \cdot K^{-1} = 4.868\ J \cdot m^{-2} \cdot h^{-1} \cdot K^{-1}$ $= 1.163 \cdot 10^{-3}\ Wm^{-2}\ K^{-1}$
Thermal conductivity	λ	$W \cdot (m \cdot K)^{-1} = kg \cdot m \cdot s^{-3} \cdot K^{-1}$
Current strength, electrical	I	ampere, A
Amount of electricity, charge	Q	coulomb, $C = A \cdot s$
Tension, electrical	U	volt, $V = W \cdot A^{-1} = kg \cdot m^2 \cdot s^{-3} \cdot A^{-2}$
Resistance, electrical	R	ohm, $\Omega = V \cdot A^{-1} = kg \cdot m^2 \cdot s^{-3} \cdot A^{-2}$
Capacity	C	farad, $F = C \cdot V^{-1} = A \cdot s \cdot V^{-1}$

Part I: Introduction

Chapter 1

Biotechnology – History, Processes, and Products

Hans-Jürgen Rehm and Paul Präve

1.1 Definition

At the present time, by biotechnology is understood the use of biological processes within the framework of technical operations and industrial production.

It is therefore an application-oriented science of microbiology and biochemistry that is very closely connected with technical chemistry and chemical engineering. Biotechnology always deals with reactions which, in principle, are of biological nature. These reactions are performed either by living microbial cells or plant and animal cells and their tissues, or by enzymes from cells or parts of cells. The production of biomass from the organisms or parts of organisms mentioned is also an area of biotechnology [DECHEMA (German Society for Chemical Apparatus), 1976].

This definition does not include the field of agriculture, which could undoubtedly be regarded as a part of biotechnology. The field of medical technology, which deals with the manufacture of apparatuses for biological purposes, such as heart-lung machines, is not included in this definition, either. This medical technique is often called **biotechnique.**

1.2 Development of Biotechnology

On the basis of this definition it can be seen that biotechnology is a very old field. In prehistoric times, ethanol was probably the first organic substance prepared deliberately, and this by a biotechnological process: alcoholic fermentation. Several stages of development can be recognised in the history of biotechnology, and these are shown in Table 1-1.

1.2.1 Unconscious Use of Biotechnology: Processes in the Manufacture of Foodstuffs

Almost all primitive peoples became acquainted with **alcoholic fermentation** through the fact that sugar-containing fruits underwent spontaneous fermentation on storage. Later, as is still customary today with many peoples, these fermentations were carried out deliberately in earthenware vessels, hollowed-out tree-trunks, nutshells, leather bags, or other vessels. Such was the practical development of the first technological process based on microbiological phenomena.

The production of **wine** from grapes depends on the cultivation of the vine. Evidence for the existence of the vine before 2000 BC in Assyria has been found. As a rule, wine fermentation is left to the yeasts that occur on the grapes. An advanced wine culture developed particularly in the Greek and Roman areas and to some extent this has lasted to the present. The Roman emperor Marcus Aurelius Probus promoted wine growing in Germany on the Moselle and on the Rhine (276 to 282 AD). Wine growing was brought from Europe to South America, especially Chile, Argentina, and Brazil, and also to North America, especially California. For a good 100 years, there have also been significant wine-growing areas in South Africa and Australia.

Beer was mentioned by the Sumerians on a famous clay tablet, the "Monument Bleu," which is kept in the Louvre. There is also a number of documents on the manufacture of beer in the prehistoric era both from Babylonia and from Egypt.

The preparation of beer does not presuppose the cultivation of cereals, since beer can also be made from grass seeds. Greater technical knowledge is necessary for the manufacture of beer than for the simple fermentation of fruits to give wine. This led to the situation that beer was frequently brewed in relatively

Table 1-1. Information on the Historical Development of Biotechnology (Recent period not Included).

Proving bread with leaven	prehistoric period (before 3000 BC)
Fermentation of juices to alcoholic beverages in almost all natural populations	prehistoric period (before 3000 BC)
Knowledge of vinegar formation from fermented juices	prehistoric period (before 3000 BC)
Cultivation of the vine in Assyria	before 2000 BC
Manufacture of beer in Sumer and Babylonia and in Egypt	3rd century BC or even earlier
Wine growing promoted by Marcus Aurelius Probus in Germany	3rd century AD
Manufacture of beer by Celts and Germans	BC and AD
Production of spirits of wine (ethanol)	from 1150 AD, possible indications even earlier
Vinegar manufacturing industry near Orléans	14th century
Artificial growing of mushrooms in France	after about 1650
Visualization of yeast cells by Leeuwenhoek	about 1680
Discovery of the fermentation properties of yeasts by Erxleben	1818
Description of lactic acid fermentation by Pasteur	1857
Assumption of the dependence of fermentation on enzymes by M. Traube	1858
Discovery of Acetobacter by Hansen	1879
Microbiological production of lactic acid	1881
Artificial growth of mushrooms in the USA	after about 1885
Detection of fermentation enzymes in yeast by Buchner	1897
First communal sewage plants in Berlin, Hamburg, Munich, Paris, and other cities	from the end of the 19th century
German process for the manufacture of bakers' yeast	1915
Process for the large-scale production of food and fodder yeast by Delbrück, Hayduck, and Henneberg	1914–1916
Weizmann process for the manufacture of butanol and acetone	1915/1916
Sulfite process for the manufacture of glycerol by Connstein and Lüdecke	1915/16
Manufacture of citric acid in a surface process	from about 1920
Discovery of penicillin by Fleming	1928/29
Microbiological transformations discovered by Mamoli and Vercellone	1937