

# Scale-Up

1. All fermentation processes have their beginning in the research laboratory.
2. For a process to be realized economically, basic research has to be successfully translated into operations on the industrial scale.

Scaling-up is a procedure where the results of small-scale experiments are used as the basis for the design, testing and implementation of a larger scale system.

## Scaling-up

### Translation of microbial results to different scales

	Screen	Pilot Plant	Plant
Size	Slants to 500 mL Shake flasks	5 – 200 L	5000 – 100,000 L
Function	Strain selection Medium development	Optimization of environmental factors	Production scale

## The Requirement For Scaling-up Studies

The physicochemical events in a bioreactor can be analysed and described mathematically, and expressed as constants and coefficients.

These constants and coefficients describe microbial activity which is the sum result of:

1. **Thermodynamic phenomena**  
e.g. gas solubilities; media viscosities.
2. **Intrinsic performance characteristic of the microbe in a given physicochemical environment**  
e.g. maximum rate of substrate conversion; feedback control; generation time.
3. **Transport phenomena**  
e.g. flow and diffusion of substrates and gases.

## The Requirement For Scaling-up Studies 2

**Properties of a Fluid Mixer on Scale-up Illustrating Four Different Constant Scale-up Parameters and Change in Others**  
(Oldshue, 1966)

Scale-up Criterion		80 L volume	10000 L volume			
Energy input	P	1.0	125	3125	25	0.2
Energy input/volume	P/V	1.0	1.0	25	0.2	0.0016
Impeller rotation number	N	1.0	0.34	1.0	0.2	0.04
Impeller diameter	D	1.0	5.0	5.0	5.0	5.0
Pump rate of impeller	F	1.0	42.5	125	25	5.0
Pump rate of impeller/volume	F/V	1.0	0.34	1.0	0.2	0.04
Max. impeller speed	N/D	1.0	1.7	5.0	1.0	0.2
Reynolds number	$ND^2\rho/\eta$	1.0	8.5	25.0	5.0	1.0

Thus, in moving from small scale to large scale fermentations, the operating conditions determined in the former must be altered for use in the latter to maintain the productivity obtained in small scale.

# Scale-up Methods

Scale-up based on fixed:

1. Power input
2. Mixing time
3. Oxygen transfer rate
4. Environment e.g. dissolved oxygen
5. Impeller tip speed

Methodology assumes that for the fixed parameter, productivity is high and that everything else is constant or of little importance for process yield.

## Scale-up procedure

**General Procedure** (After Derman & Solomon, 1986)

1. Define a set of target values on the basis of small-scale experiments.
2. Compare with limit (i.e. maximal or minimal) values obtainable on production scale, calculated by means of published relationships and experimental small-scale data.
3. Combine steps 1 and 2 to obtain a final target set of values.
4. Define operating conditions for smaller pilot fermentors.

5. Carry out experiments in smaller pilot fermentors

