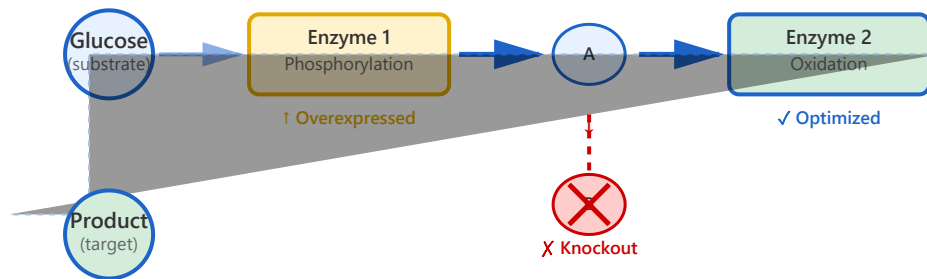


# Metabolic Engineering

## Metabolic Pathway Optimization



## AI-Guided Metabolic Engineering

### Flux Balance Analysis (FBA)

- Identify bottlenecks
- Predict knockouts
- Optimize expression levels

### Machine Learning Models

- Enzyme activity prediction
- Strain design
- Growth prediction

## Flux optimization

Balance metabolic flow

## Enzyme engineering

Improve catalytic efficiency

## Pathway design

Novel biosynthetic routes

## Strain optimization

Host organism engineering

## Scale-up prediction

Lab → production modeling