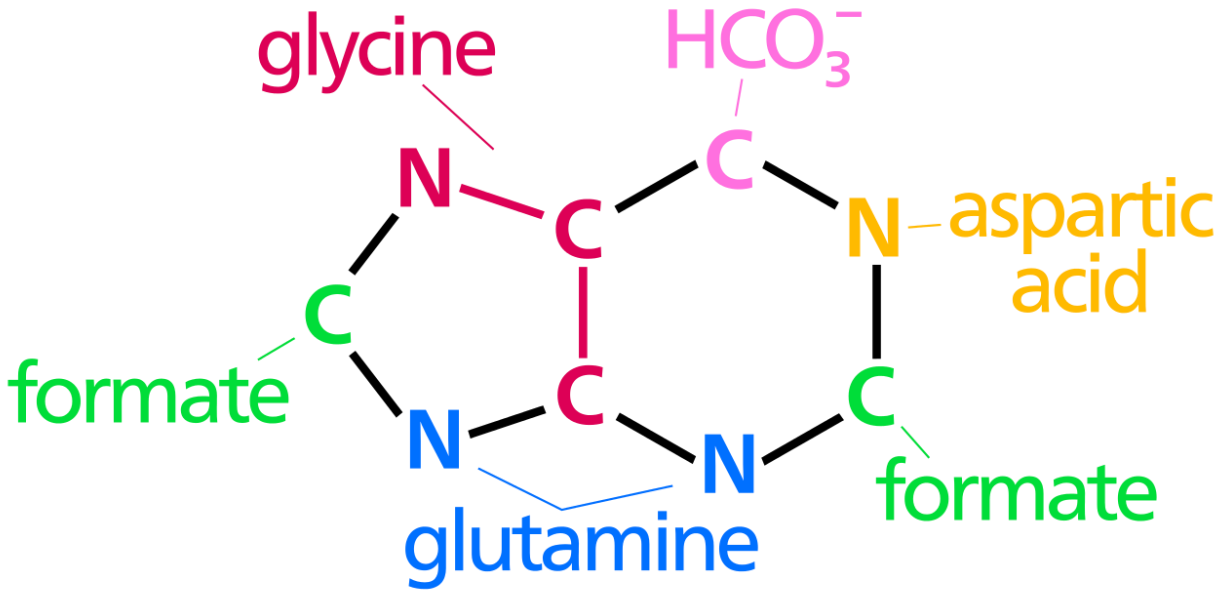
1. Purine synthesis

Adenine and guanine are the two nucleotides classified as purines. In purine synthesis, PRPP is turned into inosine monophosphate, or IMP. Production of IMP from PRPP requires glutamine, glycine, aspartate, and 6 ATP, among other things. IMP is then converted to AMP (adenosine monophosphate) using GTP and aspartate, which is converted into fumarate. While IMP can be directly converted to AMP, synthesis of GMP (guanosine monophosphate) requires an intermediate step, in which NAD+ is used to form the intermediate xanthosine monophosphate, or XMP. XMP is then converted into GMP by using the hydrolysis of 1 ATP and the conversion of glutamine to glutamate. AMP and GMP can then be converted into ATP and GTP, respectively, by kinases that add additional phosphates.

ATP stimulates production of GTP, while GTP stimulates production of ATP. This cross regulation keeps the relative amounts of ATP and GTP the same. Excess of either nucleotide could increase the likelihood of DNA mutations, where the wrong purine nucleotide is inserted.

Lesch–Nyhan syndrome is caused by a deficiency in hypoxanthine-guanine phosphoribosyltransferase or HGPRT, the enzyme that catalyzes the reversible reaction of producing guanine from GMP. This is a sex-linked congenital defect that causes overproduction of uric acid along with mental retardation, spasticity, and an urge to self-mutilate.



the origin of atoms that make up purine bases.

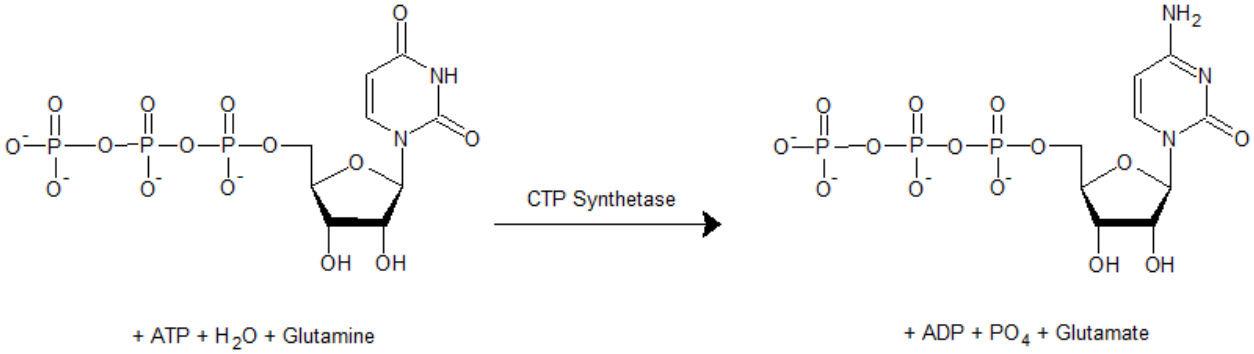
Pyrimidine synthesis

Pyrimidine nucleotides include cytidine, uridine, and thymidine. The synthesis of any pyrimidine nucleotide begins with the formation of uridine.

This reaction requires aspartate, glutamine, bicarbonate, and 2 ATP molecules (to provide energy), as well as PRPP which provides the ribose-monophosphate. Unlike in purine synthesis, the sugar/phosphate group from PRPP is not added to the nitrogenous base until towards the end of the process. After uridine-monophosphate is synthesized, it can react with 2 ATP to form uridine-triphosphate or UTP. UTP can be converted to CTP (cytidine-triphosphate) in a reaction catalyzed by CTP synthetase. Thymidine synthesis first requires reduction of the uridine to deoxyuridine (see next section), before the base can be methylated to produce thymidine.

ATP, a purine nucleotide, is an activator of pyrimidine synthesis, while CTP, a pyrimidine nucleotide, is an inhibitor of pyrimidine synthesis. This regulation helps to keep the purine/pyrimidine amounts similar, which is beneficial because equal amounts of purines and pyrimidines are required for DNA synthesis.

Deficiencies of enzymes involved in pyrimidine synthesis can lead to the genetic disease Orotic aciduria which causes excessive excretion of orotic acid in the urine.



Uridine-triphosphate (UTP), at left, reacts with glutamine and other chemicals to form cytidine-triphosphate (CTP), on the right.

Converting nucleotides to deoxynucleotides

Nucleotides are initially made with ribose as the sugar component, which is a feature of RNA. DNA, however, requires *deoxy*ribose, which is missing the 2'-hydroxyl (-OH group) on the ribose. The reaction to remove this -OH is catalyzed by ribonucleotide reductase. This enzyme converts NDPs (nucleoside-diphosphate) to dNDPs (deoxynucleoside-diphosphate). The nucleotides must be in the diphosphate form for the reaction to occur.

In order to synthesize thymidine, a component of DNA which only exists in the deoxy form, uridine is converted to deoxyuridine (by ribonucleotide reductase), and then is methylated by thymidylate synthase to create thymidine.

2. What is a Bioreactor

A bioreactor is a closed system used for the processing of a biochemical reaction. It supports either the growth of cells such as mammalian or insect in a culture or production of a secondary metabolite such as pharmaceutical products, antibodies or vaccines. Fermentor is a type of bioreactor that uses fungal or bacterial cells for fermentation. Thus, depending on the purpose, bioreactors can be classified into two types; **suspended growth bioreactors**, which produce secondary metabolites, and **biofilm bioreactors**, which process cell cultures.

What is a Fermentor

Fermentor is a type of bioreactor, which uses fungi or bacteria for the fermentation of ethanol or lactic acid. Hence, a fermentor operates under anaerobic conditions. Also, fermentor is capable of providing the optimal growth conditions such as temperature to microorganisms.

Based on the type of cultures (such as batch or continuous culture) used in a fermentor, it can be classified into three as batch, fed-batch or continuous. Also, two type of fermentations can occur in a fermentor: **surface fermentation** by microorganisms in a solid medium and **submerged fermentation** by microorganisms in a liquid medium.

Difference Between Bioreactor and Fermentor

Definition

Bioreactor refers to an apparatus in which a biological reaction or process is carried out, especially on an industrial scale whereas fermentor refers to the container in which fermentation takes place.

Type of Biochemical Reaction

Bioreactor allows any type of biochemical reactions to occur while the type of biochemical reaction facilitated by the fermentor is fermentation.

Correspondence

A bioreactor is a vessel that facilitates a biochemical reaction while fermentor is a type of bioreactor.

Type of Substrate

Various types of substrates can be used in a bioreactor based on the desired reaction while glucose or glucose-containing compounds are used in a fermentor.

Microorganisms

Bioreactors may use either microorganisms or biochemically active substances such as enzymes or catalysts while fermentor always uses microorganisms to carry out the reaction.

Types of Microorganisms

Bioreactors can use mammalian or insect cell populations while fermentors use fungal or bacterial cell populations.

Origin of Microorganisms

Microorganisms are introduced into the bioreactors while microorganisms in the air are used in the fermentors.

Aerobic/Anaerobic

Bioreactors may use either aerobic or anaerobic conditions while fermentors use anaerobic conditions.

Height of the Vessel

Short vessels can be used for mammalian cell cultures, which improve mixing while taller vessels are used for bacterial cultures, which improve the oxygen mass transfer.

Volume

The volume of the bioreactor can be up to several litres while the volume of the fermentor can be up to 2 L.

Agitation RPM

A preferable agitation RPM has to be maintained in a bioreactor due to the presence of cells without cell walls while a considerable agitation RPM can be used in a fermentor since both bacteria and fungi have cell walls.

Doubling Time

The doubling time of a bioreactor is long (14, 17 or 24 hours) while the doubling time of a fermentor is 20 mins.

Purpose

The bioreactors can either be used to produce a cell mass or a particular metabolite while fermentors are used to produce a metabolite.

Metabolites

Bioreactors can produce secondary metabolites while fermenters can only produce primary metabolites.

Types of Metabolites

Furthermore, bioreactors are used in the production of medicines, pharmaceutical liquids, antibodies or vaccines while fermenters are used to produce lactic acid or ethanol.

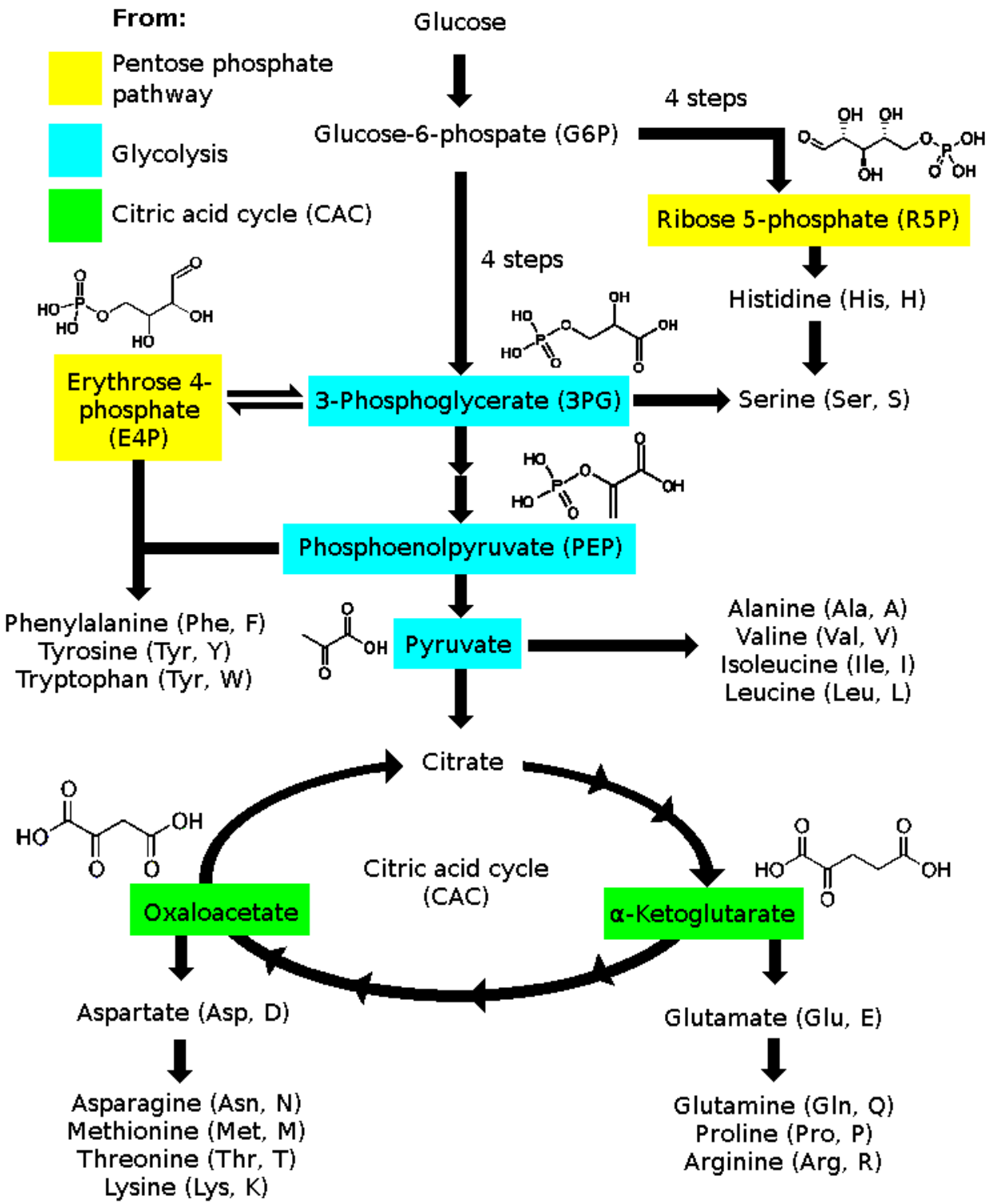
Viral Infections

Bioreactors tend to be infected by viruses while fermenters generally are not infected by viruses.

Types of designs

Bioreactors can be packed bed, fluidized bed, IVFR or Airlift bioreactor while fermentors can be batch, fed-batch or continuous.

3. Amino acid synthesis is the set of biochemical processes (metabolic pathways) by which the amino acids are produced. The substrates for these processes are various compounds in the organism's diet or growth media. Not all organisms are able to synthesize all amino acids. For example, humans can only synthesize 11 of the 20 standard amino acids (a.k.a. non-essential amino acid), and in time of accelerated growth, histidine can be considered an essential amino acid


From:
Pentose phosphate pathway
Glycolysis
Citric acid cycle (CAC)
Glucose
Glucose-6-phospate (G6P)
4 steps
Ribose 5-phosphate (R5P)
Histidine (His, H)
4 steps
Erythrose 4-phosphate (E4P)
3-Phosphoglycerate (3PG)
Serine (Ser, S)
Phosphoenolpyruvate (PEP)
Phenylalanine (Phe, F)
Tyrosine (Tyr, Y)
Tryptophan (Tyr, W)
Pyruvate
Alanine (Ala, A)
Valine (Val, V)
Isoleucine (Ile, I)
Leucine (Leu, L)
Citrate
Citric acid cycle (CAC)
Oxaloacetate
α-Ketoglutarate
Aspartate (Asp, D)
Glutamate (Glu, E)
Asparagine (Asn, N)
Methionine (Met, M)
Threonine (Thr, T)
Lysine (Lys, K)
Glutamine (Gln, Q)
Proline (Pro, P)
Arginine (Arg, R)