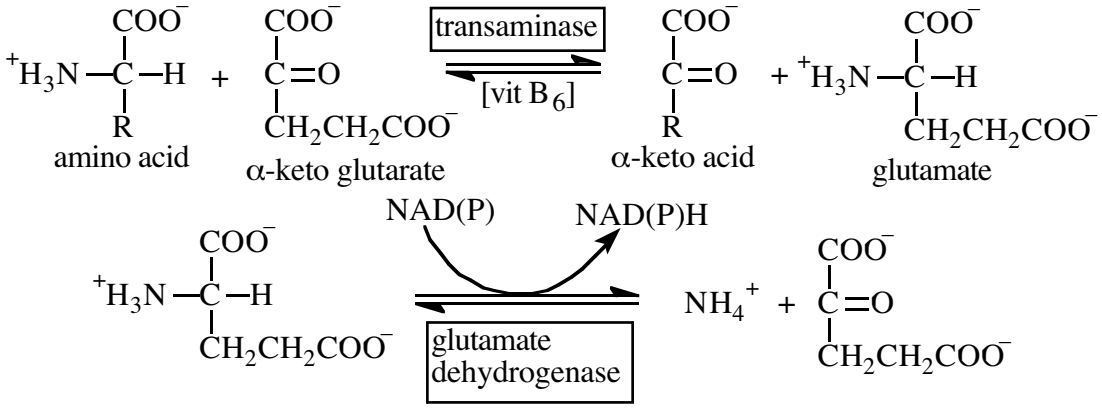
Amino Acid Metabolism: The primary purpose for amino acids in the body is to provide the building blocks for proteins OR other amino acids. However, if there is no protein synthesis occurring, the amino acids can be broken down (i.e. catabolized) to yield ATP. In this section we will talk about what happens to amino acids during catabolism and **transmutation**. But first, we must discuss how proteins are degraded, since they are the source of amino acids in our diet.

Polypeptides, as we recall, are denatured in acid. Since the stomach is a highly acidic place, the ingested protein is first denatured in the stomach before doing anything else. Once denatured, the **protease** enzymes come by and start cutting up the polypeptide. There are three common types of proteases:

endopeptidases	**aminopeptidases**	**carboxypeptidases**
hydrolyzes a peptide bond somewhere in the middle of the polypeptide	hydrolyzes the peptide bond of the N-terminal amino acid	hydrolyzes the peptide bond of the C-terminal amino acid

The endopeptidases start the process by making the polypeptides into shorter peptide chains (generally, this occurs in the stomach), the **exopeptidases** take over in the small intestine. Many different enzymes are used to break down a protein, since each peptidase is best suited for a specific amino acid. Once the amino acids are freed from the polypeptide chain, the actual catabolism can take place.

Deamination: The first step in dealing with amino acids is to remove the ammonium portion of the amino acid. This is done in two steps: First the amino group is transferred to α-keto glutarate (to form glutamate); secondly, the amino group is removed as an ammonium ion to regenerate the α-keto glutarate:

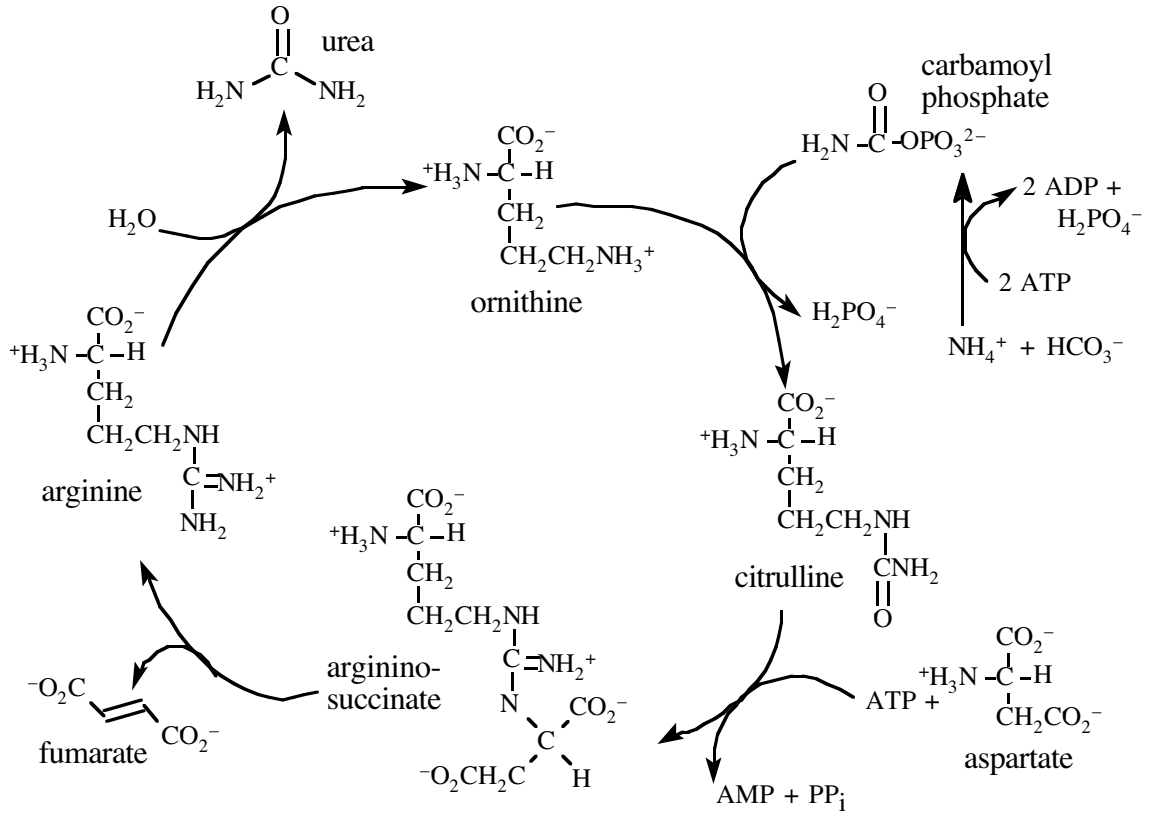


In the second step, NAD is used in the forward reaction, and NADPH is used in the reverse reaction.

The ammonium ion is toxic in large quantities, so the body must get rid of it somehow. There are three pathways by which this is done. The first, which is employed by fish, is to pump the ammonium out directly into water, where it can be diluted. This is not a viable method for non-aquatic species, since the ammonium would have to stay in the

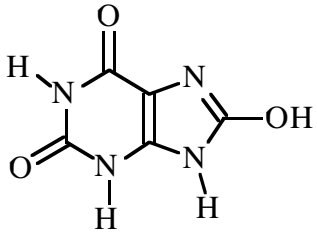
body until a suitable amount of water is located. Instead, one of the other two pathways are employed.

Urea and Uric Acid Syntheses: The method of choice in ammonium removal in mammals is by producing **urea**, $H_2N\text{-}CO\text{-}NH_2$. The urea is excreted in the urine of the animal. The question that still remains is how does this occur?
The process, which takes place in the liver, occurs as follows. The ammonium is transported to the liver in the form of glutamine. Once in the liver, the free ammonium ion is reproduced, and is added, along with HCO_3^- to ornithine to produce citrulline. The citrulline binds with aspartate to produce argininosuccinate. This gives off fumarate and arginine. The arginine is hydrolyzed to give ornithine and urea:



The enzymes were omitted for the sake of brevity.

In birds and reptiles, urea is not formed. Instead, uric acid:



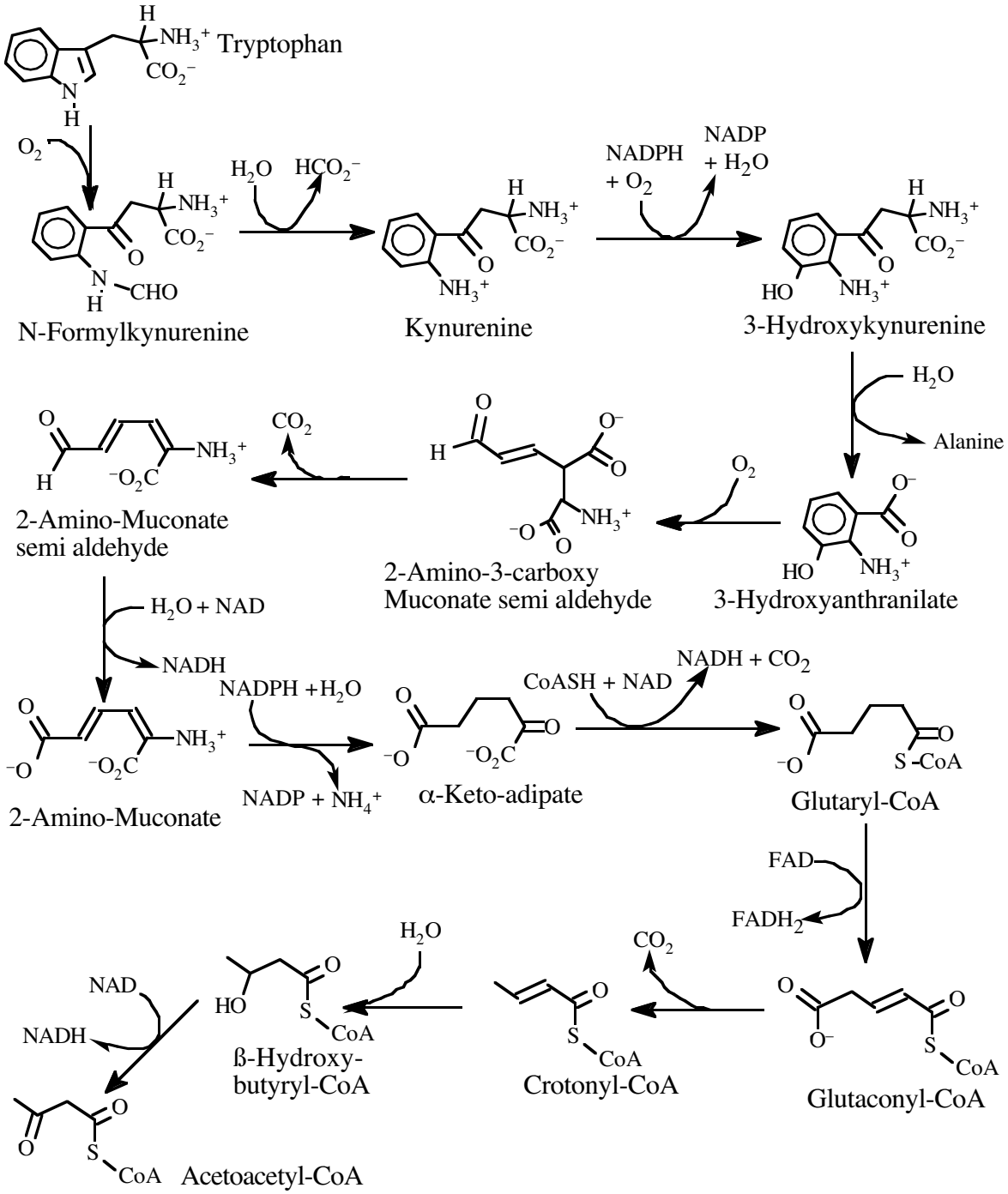
is produced. We will discuss this in more detail in the nucleic acid chapter.

The rest of the amino acid: Once the amino group is removed, the rest of the amino acid molecule can be broken down further into one of the following molecules: α-ketoglutartate {glu, gln, his, arg, pro}, succinyl-CoA {met, val, ile}, oxaloacetate {asn, asp}, fumarate {asp, tyr, phe}, pyruvate {thr, trp, gly, ser, cys, ala}, acetyl-CoA {ile, leu, trp}, and aceto-acetyl-CoA {phe, tyr, trp, lys, leu}.
These can be used to get ATP (Krebs cycle), make sugars (glucogenesis){ala, arg, asp, asn, cys, glu, gln, gly, his, met, pro, ser, thr, val}, make fats {lys, leu}, or both {ile, phe, trp, tyr}.

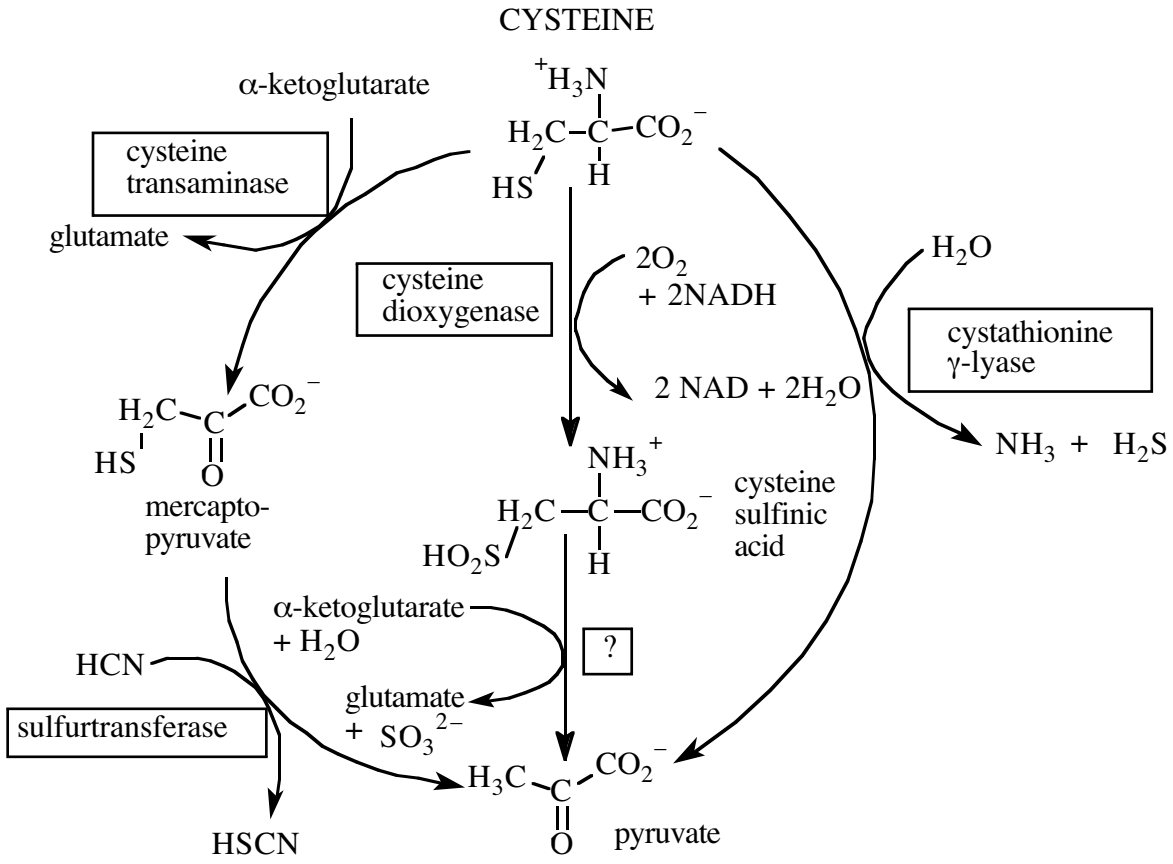
Amino Acid Degradation: The breakdown of the amino acids is kind of complicated. Instead of looking at all of them, we will concentrate on a few of the most "unusual" of them. The first one we will look at is:

TRYPTOPHAN

This has the most odd shape and size, thus this will illustrate the complexity of the process.



A couple of interesting steps occur along the way. In step 4 of the process, the amino acid alanine is produced. At step 8, the ammonium ion that is involved in the urea cycle is produced. Also, the product, α-keto-adipate, is also a product in the decomposition of lysine.



Amino Acid Anabolism: Not all catabolic pathways are as involved as the one shown for Tryptophan, and not all anabolic pathways are as difficult. However, the formation of amino acids is much more difficult than obtaining them through diet. One reason for this is that nitrogen (in the form of ammonium ions) cannot be stored in the body. Therefore, most "higher" organisms obtain the amino acids through diet and not through anabolism. The lower organisms, namely bacteria, where the amino acids ultimately come from, have the ability to form NH_4^+ from either nitrogen gas (N_2) in the air - called **nitrogen fixing bacteria** - or from the reduction of nitrates and nitrites. If all else fails, the body is prepared to make several amino acids. Generally, the carbon skeletons are intermediates of the TCA cycle (e.g. oxaloacetate).