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M1 - Renal, Fall 2007

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<http://hdl.handle.net/2027.42/64946>
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Nucleic Acid metabolism
Click on any blue rectangle to see details.
Formation of PRPP: Phosphoribose pyrophosphate

PRPP Use in Purine Biosynthesis:
The First Purine: Inosine Monophosphate
(folates are involved in this synthesis)

Conversion to Adenosine:

Inosine monophosphate

Conversion to Guanosine:

Inosine monophosphate

Xanthosine monophosphate

Guanosine monophosphate
Nucleoside Monophosphate Kinases

AMP + ATP $\leftrightarrow$ 2ADP  \hspace{1cm} \text{(adenylate kinase)}

GMP + ATP $\leftrightarrow$ GDP + ADP \hspace{1cm} \text{(guanylate kinase)}

- similar enzymes specific for each nucleotide
- no specificity for ribonucleotide vs. deoxyribonucleotide
Ribonucleotide Reductase

Hydroxyurea inhibits this enzyme: chemotherapeutic use

\[ \text{HONH}^- \text{C}^- \text{NH}_2 \]
Regulation of Ribonucleotide Reductase
Nucleoside Diphosphate Kinase

\[ N_1DP + N_2TP \leftrightarrow N_1TP + N_2DP \]

\[ dN_1DP + N_2TP \leftrightarrow dN_1TP + N_2DP \]

- No specificity for base
- No specificity for ribo vs deoxy
Feed-forward regulation by PRPP

PRPP

IMP

GMP

AMP

GTP

ATP
Feed-forward regulation by PRPP

PRPP

+ 

IMP

GMP

ATP

GTP

AMP

GTP

ATP
Feed-forward regulation by PRPP

PRPP

↓

IMP

↓

AMP

GTP +

GMP

ATP +

GTP

ATP
Feed-forward regulation by PRPP

Diagram showing the regulatory pathway involving PRPP, IMP, GMP, ATP, GTP, AMP, and ATP.
Degradation of the Purine Nucleosides:

Adenosine → NH₄⁺ + H₂O → Adenosine deaminase (ADA) → Inosine → pi ribose - 1 - P → putine nucleoside phosphorylase → Hypoxanthine → xanthine oxidase → Xanthine → uric acid

Guanosine → pi ribose - 1 - P → putine nucleoside phosphorylase → Guanine → xanthine oxidase → Xanthine → uric acid
“Salvage” Pathways for Purine Nucleotides

APRT - Adenine phosphoribosyl transferase - performs a similar function with adenine.
Adenosine Deaminase Deficiency:

Deoxyadenosine → dAMP → dADP → dATP

Adenosine deaminase (ADA)

2-deoxyribosyl Deoxyinosine

Hypoxanthine

Guanine → Xanthine → Uric acid
Hyperuricemia can be caused by:

Accelerated degradation of purines:

- Accelerated synthesis of purines
- Increased dietary intake of purines

Impaired renal clearance of uric acid

Gout: deposition of urate crystals in joints, “tophi” in cooler periphery

Allopurinol inhibits xanthine oxidase and reduces blood uric acid levels:
The hands of a patient with a long history of gout, including high serum urate levels.
Lesch-Nyhan Syndrome: Defective HGPRT

- hyperuricemia
- spasticity
- mental retardation
- self-mutilation behavior

A defect in APRT does NOT have similar consequences
Myoadenylate Deaminase ‘Fills’ the TCA Cycle in Muscle
Carbamoyl phosphate synthetase II - a *cytoplasmic* enzyme...

\[
2\text{ATP} + \text{HCO}_3^- + \text{glutamine} + \text{H}_2\text{O} \rightarrow \text{NH}_2\text{C} - \text{O}^\text{P}^\text{2-} + \text{glutamate} + 2\text{ADP} + \text{P}_i
\]

*carbamoyl phosphate*

...used for pyrimidine synthesis

\[
\begin{align*}
\text{carbamoyl phosphate} & \quad + \quad \text{aspartate} \\
& \rightarrow \quad \text{orotate}
\end{align*}
\]
Orotate is linked to PRPP to form Uridine monophosphate:
Newly-synthesized uridine monophosphate will be phosphorylated to UDP and UTP, as described for the purine nucleotides.

UTP can be converted to CTP by CTP Synthetase:
Some UDP is converted to dUDP via ribonucleotide reductase.

The Thymidylate Synthase Reaction:
Methotrexate Inhibits Dihydrofolate Reductase:

Dihydrofolate builds up, levels of THF become limiting, thymidylate synthase is unable to proceed. Follow it with a dose of Leucovorin, a.k.a. formyl-THF.
FdUMP Inhibits The Thymidylate Synthase Reaction:
Complicated Pathways for Pyrimidine Production:

This figure is primarily a study aid; you do not need to memorize it or reproduce it. The information here merely summarizes material from previous sections.
Pathologies of pyrimidine nucleotide biosynthesis:

Orotic acidurea due to OTC deficiency - please review your Urea Cycle notes.

Hereditary orotic acidurea - deficiency of the enzyme that convert orotate to OMP to UMP. Not common.
Pyrimidine degradation:

Cytidine deaminase converts cytidine to uridine

A phosphorylase removes the sugar

Degradation of the base proceeds (products are unimportant here)
Pyrimidines can be salvaged as well:

Enzyme: Pyrimidine nucleoside phosphorylases
Thymine + deoxyribose-1-phosphate  --> thymidine
(NOT thymidine monophosphate!)

Enzyme: Thymidine kinase - adds the monophosphate back
Thymidine + ATP  --> thymidine monophosphate

Herpes Simplex Virus carries its own tk gene
Certain drugs act via the pyrimidine salvage pathway:

\[ \text{Acyclovir} \xrightarrow{\text{HSV thymidine kinase}} \text{AcycloGMP} \]

\[ \text{5-fluorouracil} + \text{deoxyribose-1-phosphate} \xrightarrow{\text{pyrimidine phosphorylase}} \text{fluorodeoxyuridine} \xrightarrow{\text{uridine kinase}} \text{fluorodeoxyuridine monophosphate (FdUMP)} \]
5-FU efficacy depends on rate of degradation vs activation

5-FU \rightarrow \rightarrow FdUMP
+ methylene-THF + Thymidylate Synthase
\rightarrow \text{inactivation of TS}

Degradation
(via dihydropyrimidine dehydrogenase, DPD)

DPD inhibitors can potentiate 5FU activity
Capecitabine mode of action:

Cytosine arabinoside (araC) activation and inactivation: