M1 - Renal, Fall 2007

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Folate and AdoMet One-Carbon Pools  

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See: http://seqcore.brcf.med.umich.edu/mcb500 for supplementary course materials.

Medical relevance of the one-carbon pathways
Mechanism of antibiotics
   Sulfa drugs - antibacterial
   Trimethoprim, pyrimethamin - antibacterial, antimalarial
Pathologies
   VitB₁₂ deficiency/pernicious anemia
   dietary folate deficiency
   sprue
   (See also the Nucleic Acid lectures for anti-cancer chemotherapies)

I. Tetrahydrofolate as a carrier of one-carbon units

A. Obtaining folate - an essential vitamin

1. Dietary sources (green veggies, fortified cereals, liver) provide folic acid. Cleaved by enzyme 'conjugase' to remove extra glutamate residues, absorbed, reduced to dihydrofolate, then to tetrahydrofolate by Dihydrofolate Reductase (DHFR). DHFR inhibitors are useful antibiotics if they affect other organisms but not humans.

2. Inhibitors of DHFR are used therapeutically: e.g. methotrexate (cancer chemotherapy). Tumors that resist methotrexate sometimes have amplified the DHFR gene to compensate for the inhibitor.
3. Compounds that inhibit bacterial folate biosynthesis can be excellent antibiotics. Example: sulfa drugs like sulfanilamide:

\[
\text{Para-aminobenzoic acid (PABA)} \quad \text{sulfanilamide}
\]

**B. Main entry of one-carbon units - N⁵, N¹⁰ methylene tetrahydrofolate**

1) Serine conversion to glycine:

\[
\text{Tetrahydrofolate} + \text{serine} \rightarrow \text{glycine} + \text{N⁵, N¹⁰ methylene tetrahydrofolate}
\]

2) Glycine conversion to CO₂ and NH₄⁺:

\[
\text{Tetrahydrofolate} + \text{glycine} \rightarrow \text{N⁵, N¹⁰ methylene tetrahydrofolate}
\]

**C. Oxidation states of the one-carbon unit and inter-conversions**

(reversible reactions indicated by double-ended arrows)

\[
\text{N⁵ methyl tetrahydrofolate} \leftrightarrow \text{N⁵ formyl tetrahydrofolate} \leftrightarrow \text{Bioynthesis of methionine}
\]

\[
\text{N⁵, N¹⁰ methylene tetrahydrofolate} \leftrightarrow \text{Bioynthesis of thymidylate}
\]

\[
\text{N⁵, N¹⁰ methenyl tetrahydrofolate} \leftrightarrow \text{Bioynthesis of purines}
\]

\[
\text{Gly} \quad \text{Ser} \quad \text{N⁵ methyl tetrahydrofolate} \quad \text{NAD⁺} \quad \text{NADH} + \text{H}
\]
II. S-adenosylmethionine ('SAM', aka 'AdoMet') Overview:

\[
\begin{align*}
\text{Methionine} & : \text{CH}_3\text{S-CH}_2\text{CH}_2\text{C}(-)\text{COO}^+ \\
\text{S-Adenosyl Methionine} & : \text{CH}_3\text{S-CH}_2\text{CH}_2\text{C}(-)\text{COO}^+ \\
\text{Homocysteine} & : \text{HS-CH}_2\text{CH}_2\text{C}(-)\text{COO}^+ \\
\end{align*}
\]
A. Biosynthesis of methionine
(see also the Amino Acid Metabolism handout)

\[
\text{Homocysteine} \xrightarrow{N^5\text{-methyl THF}} \text{Methionine}
\]

B. Re-utilization of folates:

\[
\text{Tetrahydrofolate} \xrightarrow{\text{Carbon donor}} \text{Methylene tetrahydrofolate}
\]

\[
\text{Methionine} \xrightarrow{\text{NADH} + H^+} \text{Homocysteine}
\]

C. Synthesis of S-Adenosyl Methionine

\[
\text{Methionine} \xrightarrow{\text{ATP}} \text{S-Adenosyl methionine}
\]

D. Uses of SAM - biological methylator
Example: Conversion of norepinephrine to epinephrine:

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\[
\begin{align*}
\text{Norepinephrine} & \quad \text{SAM} \quad \text{SAH} \\
\text{Epinephrine} & \\
\end{align*}
\]
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Others: Conversion of phosphatidylethanolamine to phosphatidylcholine, methylation of mRNA and DNA

E. AdoMet cycle

III. Pathologies:
A. Folate deficiency is common. symptom: megaloblastic anemia
   weakness, anemia, anorexia
   Appearance of large, immature erythrocytes ('megaloblasts') in the blood

B. several causes:
   - dietary deficiency common
   - alcoholism may compound folate deficiency
   - inability to absorb folates (e.g. tropical sprue and non-tropical or celiac sprue)

Dietary folates are typically poly-glutamated (up to 6 $\gamma$-glutamyl residues)
We can absorb only the mono-glutamyl form
An enzyme 'conjugase' secreted by the brush border cells of the intestine
   hydrolytically removes the extra glu residues so we can absorb the folate
Intestinal irritation can compromise production of conjugase

- possibly secondary to B12 deficiency: pernicious anemia

'Methyl trap' hypothesis and deficiency of vitamin B12:

B12 deficiency can be caused by autoimmune response to 'Intrinsic Factor', a product of the gut that aids in the absorption of B12.