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M1 - Renal, Fall 2007

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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:

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

\[
\text{sulfanilamide}
\]

B. Main entry of one-carbon units - \(N^5, N^{10}\) methylene tetrahydrofolate

1) Serine conversion to glycine:

\[
\text{Tetrahydrofolate} + \text{serine} \rightarrow \text{glycine} + \text{Tetrahydrofolate}
\]

2) Glycine conversion to \(\text{CO}_2\) and \(\text{NH}_4^{(+)}\):

\[
\text{Tetrahydrofolate} + \text{glycine} \rightarrow \text{NAD}^+ + \text{NADH} + \text{H} + \text{CO}_2 + \text{NH}_4^{(+)}
\]

C. Oxidation states of the one-carbon unit and inter-conversions (reversible reactions indicated by double-ended arrows)
II. S-adenosylmethionine ('SAM', aka 'AdoMet') Overview:

\[
\text{CH}_3 - \text{S} - \text{CH}_2 - \text{CH}_2 - \text{C} - \text{COO}^{(-)} \quad \text{Methionine}
\]

\[
\text{HS} - \text{CH}_2 - \text{CH}_2 - \text{C} - \text{COO}^{(-)} \quad \text{Homocysteine}
\]

\[
\text{CH}_3 - \text{S} - \text{CH}_2 - \text{CH}_2 - \text{C} - \text{COO}^{(+)}
\]

S-Adenosyl Methionine

\[
\text{HS} - \text{CH}_2 - \text{CH}_2 - \text{C} - \text{COO}^{(+)}
\]

S-Adenosyl Homocysteine

**Biological Reaction**

\[
\text{ATP} + \text{H}_2\text{O} \rightarrow \text{PP}_i + \text{Pi} + \text{Methyl acceptor}
\]

*see examples

Methylated acceptor

Methyl acceptor
A. Biosynthesis of methionine
(see also the Amino Acid Metabolism handout)

\[
\begin{align*}
\text{homocysteine} & \xrightarrow{\text{N}^5\text{-methyl THF}} \text{vitamin B}_12 \xrightarrow{} \text{methionine} \\
\text{methionine} & \xrightarrow{\text{NAD}^+ + \text{H}^+} \text{NADH} + \text{H}^+ \\
\text{methionine} & \xrightarrow{\text{N}^5\text{-methyl tetrahydrofolate}} \text{tetrahydrofolate} \\
\text{tetrahydrofolate} & \xrightarrow{\text{Carbon donor} (\text{e.g. serine or glycine})} \text{N}^5, \text{N}^{10}\text{methylene tetrahydrofolate} \\
\text{N}^5, \text{N}^{10}\text{methylene tetrahydrofolate} & \xrightarrow{\text{NAD}^+ \text{or NADH}} \text{tetrahydrofolate} \\
\text{tetrahydrofolate} & \xrightarrow{\text{NADH} + \text{H}^+} \text{methionine} \\
\text{methionine} & \xrightarrow{\text{N}^5\text{-methionine}} \text{S-adenosyl methionine} \\
\text{S-adenosyl methionine} & \xrightarrow{\text{ATP}} \text{methionine} \\
\text{methionine} & \xrightarrow{\text{PP + Pi}} \text{S-adenosyl methionine} \\
\text{S-adenosyl methionine} & \xrightarrow{\text{adenine}} \text{S-adenosyl methionine}
\end{align*}
\]

B. Re-utilization of folates:

C. Synthesis of S-Adenosyl Methionine

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

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.