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<?xml version="1.0"?>
```

```
<!-- FILE : oxidation_of_odd_chain_fatty_acids_model.xml
```

```
CREATED : 17th June 2002
```

```
LAST MODIFIED : 22nd July 2002
```

```
AUTHOR : Catherine Lloyd  
The Bioengineering Institute  
The University of Auckland
```

```
MODEL STATUS : This model conforms to the CellML 1.0 Specification released on  
10th August 2001, and the 16/01/2002 CellML Metadata 1.0  
Specification.
```

```
DESCRIPTION : This file contains a CellML description of a generic model of  
odd-chain fatty acid oxidation.
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CHANGES:
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```
22/07/2002 - CML - Added more metadata.
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-->
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```
<model name="oxidation_of_odd_chain_fatty_acids_model" pathway_editor:rendering_config_file=
```

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns:bgs="http://www.cel
```

```
<!--
```

```
The following RDF block contains metadata that applies to this document  
as a whole, as indicated by the empty about attribute on the  
<rdf:Description> element.
```

```
-->
```

```
<rdf:Description rdf:about="">
```

```
<!--
```

```
The Model Builder Metadata. The Dublin Core "creator" element is used  
to indicate the person who translated the model into CellML.
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```
-->
```

```
<dc:creator rdf:parseType="Resource">
```

```
<vCard:N rdf:parseType="Resource">
```

```
<vCard:Family>Lloyd</vCard:Family>
```

```
<vCard:Given>Catherine</vCard:Given>
```

```
<vCard:Other>May</vCard:Other>
```

```
</vCard:N>
```

```
<vCard:EMAIL rdf:parseType="Resource">
```

```
<rdf:value>c.lloyd@auckland.ac.nz</rdf:value>
```

```
<rdf:type rdf:resource="http://imc.org/vCard/3.0#internet" />
```

```
</vCard:EMAIL>
```

```
<vCard:ORG rdf:parseType="Resource">
```

```
<vCard:Orgname>The University of Auckland</vCard:Orgname>
```

```
<vCard:Orgunit>The Bioengineering Institute</vCard:Orgunit>
```

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</vCard:ORG>
```

```
</dc:creator>
```

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<!--
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```
The Creation Date metadata. This is the date on which the model  
was translated into CellML.
```

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```
<dcterms:created rdf:parseType="Resource">
```

```
<dcterms:W3CDTF>2002-06-17</dcterms:W3CDTF>
```

```
</dcterms:created>
```

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<!--
  The Last Modified Date metadata. This is the date on which
  the model was last changed.
-->
<cmeta:modification rdf:parseType="Resource">
  <rdf:value>
    Added more metadata.
  </rdf:value>
  <cmeta:modifier rdf:parseType="Resource">
    <vCard:N rdf:parseType="Resource">
      <vCard:Family>Lloyd</vCard:Family>
      <vCard:Given>Catherine</vCard:Given>
      <vCard:Other>May</vCard:Other>
    </vCard:N>
  </cmeta:modifier>
  <dcterms:modified rdf:parseType="Resource">
    <dcterms:W3CDTF>2002-07-22</dcterms:W3CDTF>
  </dcterms:modified>
</cmeta:modification>

<!-- The Publisher metadata. -->
<dc:publisher>
  The University of Auckland, Bioengineering Institute
</dc:publisher>
</rdf:Description>

<!--
  The following metadata refers to the model itself, as indicated by the
  reference to the ID "oxidation_of_odd_chain_fatty_acids_model", which is
  declared on the <model> element.
-->
<rdf:Description rdf:about="#oxidation_of_odd_chain_fatty_acids_model">
  <!-- A human readable name for the model. -->
  <dc:title>A Generic Model Of Odd-Chain Fatty Acid Oxidation</dc:title>

  <!-- A comment regarding the model. -->
  <cmeta:comment rdf:parseType="Resource">
    <rdf:value>
      Below is a CellML description of a general model of odd-chain fatty
      acid oxidation. It is not based on a specific published mathematical
      model, but instead it is based on a textbook defined pathway. The
      general sequential structure and all the reactant, product and enzyme
      components are included. Michaelis-Menten enzyme kinetics are
      assumed.

      The purpose of this description is to illustrate how CellML can be
      used to model a general metabolic pathway.
    </rdf:value>
    <!-- The creator of the comment. -->
    <dc:creator>
      <vCard:FN>Catherine Lloyd</vCard:FN>
    </dc:creator>
  </cmeta:comment>

  <cmeta:species>Homo sapiens</cmeta:species>

  <!-- Keyword(s) -->
  <bqs:reference rdf:parseType="Resource">
    <dc:subject rdf:parseType="Resource">

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    <bqs:subject_type>keyword</bqs:subject_type>
    <rdf:value>metabolism</rdf:value>
  </dc:subject>
</bqs:reference>

<bqs:Book rdf:parseType="Resource">
  <dc:creator rdf:parseType="Resource">
    <bqs:Person rdf:parseType="Resource">
      <vCard:N rdf:parseType="Resource">
        <vCard:Family>Bronk</vCard:Family>
        <vCard:Given>J</vCard:Given>
        <vCard:Other>Ramsey</vCard:Other>
      </vCard:N>
    </bqs:Person>
  </dc:creator>
  <dc:title>Human Metabolism</dc:title>
  <dcterms:issued rdf:parseType="Resource">
    <dcterms:W3CDTF>1999</dcterms:W3CDTF>
  </dcterms:issued>
  <dc:publisher rdf:parseType="Resource">
    <bqs:Organisation>Addison Wesley Longman Limited</bqs:Organisation>
    <bqs:Property rdf:parseType="Resource">
      <bqs:property_type>location</bqs:property_type>
      <rdf:value>England</rdf:value>
    </bqs:Property>
  </dc:publisher>
</bqs:Book>
</rdf:Description>
</rdf:RDF>

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  We start the model definition with a definition of some named
  sets of units for use throughout the model.

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```

<units name="micromolar">
  <unit prefix="micro" units="mole" />
  <unit units="litre" exponent="-1" />
</units>

<units name="flux">
  <unit units="micromolar" />
  <unit units="second" exponent="-1" />
</units>

<units name="first_order_rate_constant">
  <unit units="second" exponent="-1" />
</units>

<units name="second_order_rate_constant">
  <unit units="micromolar" exponent="-1" />
  <unit units="second" exponent="-1" />
</units>

<units name="third_order_rate_constant">
  <unit units="micromolar" exponent="-2" />
  <unit units="second" exponent="-1" />
</units>

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<!--
  The following component is defined for modelling convenience.  It contains
  all the universal variables, in this case, only time.
-->
<component name="global_variables">
  <variable name="time" public_interface="out" units="second" />
</component>

<!--
  The following components describe all the metabolites - both reactants and
  products - involved in odd-chain fatty acid oxidation.
-->

<component name="Propionyl_CoA" cmeta:id="Propionyl_CoA">
  <variable name="Propionyl_CoA" public_interface="out" initial_value="1.0" units="micromol" />
  <variable name="delta_Propionyl_CoA_rxn0" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>Propionyl_CoA</ci>
      </apply>
      <ci>delta_Propionyl_CoA_rxn0</ci>
    </apply>
  </math>
</component>

<component name="Methylmalonyl_CoA" cmeta:id="Methylmalonyl_CoA">
  <variable name="Methylmalonyl_CoA" public_interface="out" initial_value="1.0" units="micromol" />
  <variable name="delta_Methylmalonyl_CoA_rxn0" public_interface="in" units="flux" />
  <variable name="delta_Methylmalonyl_CoA_rxn1" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>Methylmalonyl_CoA</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_Methylmalonyl_CoA_rxn0</ci>
        <ci>delta_Methylmalonyl_CoA_rxn1</ci>
      </apply>
    </apply>
  </math>
</component>

<component name="Methylmalonyl_B12" cmeta:id="Methylmalonyl_B12">
  <variable name="Methylmalonyl_B12" public_interface="out" initial_value="1.0" units="micromol" />
  <variable name="delta_Methylmalonyl_B12_rxn1" public_interface="in" units="flux" />

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<variable name="delta_Methylmalonyl_B12_rxn2" public_interface="in" units="flux" />
<variable name="time" public_interface="in" units="second" />
<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply>
    <eq />
    <apply>
      <diff />
      <bvar>
        <ci>time</ci>
      </bvar>
      <ci>Methylmalonyl_B12</ci>
    </apply>
    <apply>
      <plus />
      <ci>delta_Methylmalonyl_B12_rxn1</ci>
      <ci>delta_Methylmalonyl_B12_rxn2</ci>
    </apply>
  </apply>
</math>
</component>

<component name="Succinyl_CoA" cmeta:id="Succinyl_CoA">
  <variable name="Succinyl_CoA" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_Succinyl_CoA_rxn3" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>Succinyl_CoA</ci>
      </apply>
      <ci>delta_Succinyl_CoA_rxn3</ci>
    </apply>
  </math>
</component>

<component name="ATP" cmeta:id="ATP">
  <variable name="ATP" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_ATP_rxn0" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>ATP</ci>
      </apply>
      <ci>delta_ATP_rxn0</ci>
    </apply>
  </math>
</component>

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<component name="ADP" cmeta:id="ADP">
  <variable name="ADP" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_ADPrxn0" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>ADP</ci>
      </apply>
      <ci>delta_ADPrxn0</ci>
    </apply>
  </math>
</component>

<component name="Pi" cmeta:id="Pi">
  <variable name="Pi" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_Pi_rxn0" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>Pi</ci>
      </apply>
      <ci>delta_Pi_rxn0</ci>
    </apply>
  </math>
</component>

<component name="CO2" cmeta:id="CO2">
  <variable name="CO2" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_CO2_rxn0" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>CO2</ci>
      </apply>
      <ci>delta_CO2_rxn0</ci>
    </apply>
  </math>
</component>

<component name="Deoxyadenosyl_5_B12" cmeta:id="Deoxyadenosyl_5_B12">
  <variable name="Deoxyadenosyl_5_B12" public_interface="out" initial_value="1.0" units="

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<variable name="delta_Deoxyadenosyl_5_B12_rxn3" public_interface="in" units="flux" />
<variable name="delta_Deoxyadenosyl_5_B12_rxn1" public_interface="in" units="flux" />
<variable name="time" public_interface="in" units="second" />
<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply>
    <eq />
    <apply>
      <diff />
      <bvar>
        <ci>time</ci>
      </bvar>
      <ci>Deoxyadenosyl_5_B12</ci>
    </apply>
    <apply>
      <plus />
      <ci>delta_Deoxyadenosyl_5_B12_rxn3</ci>
      <ci>delta_Deoxyadenosyl_5_B12_rxn1</ci>
    </apply>
  </apply>
</math>
</component>

<component name="Succinyl_B12" cmeta:id="Succinyl_B12">
  <variable name="Succinyl_B12" public_interface="out" initial_value="1.0" units="micromol" />
  <variable name="delta_Succinyl_B12_rxn2" public_interface="in" units="flux" />
  <variable name="delta_Succinyl_B12_rxn3" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>
        <ci>Succinyl_B12</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_Succinyl_B12_rxn2</ci>
        <ci>delta_Succinyl_B12_rxn3</ci>
      </apply>
    </apply>
  </math>
</component>

<component name="Deoxyadenosine_5" cmeta:id="Deoxyadenosine_5">
  <variable name="Deoxyadenosine_5" public_interface="out" initial_value="1.0" units="micromol" />
  <variable name="delta_Deoxyadenosine_5_rxn1" public_interface="in" units="flux" />
  <variable name="delta_Deoxyadenosine_5_rxn3" public_interface="in" units="flux" />
  <variable name="time" public_interface="in" units="second" />
  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply>
      <eq />
      <apply>
        <diff />
        <bvar>
          <ci>time</ci>
        </bvar>

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        <ci>Deoxyadenosine_5</ci>
    </apply>
    <apply>
        <plus />
        <ci>delta_Deoxyadenosine_5_rxn1</ci>
        <ci>delta_Deoxyadenosine_5_rxn3</ci>
    </apply>
</apply>
</math>
</component>

<!--
The following components describe all the enzymes and protein complexes
involved in odd-chain fatty acid oxidation.
-->

<component name="Methylmalonyl_CoA_mutase" cmeta:id="Methylmalonyl_CoA_mutase">
    <variable name="Methylmalonyl_CoA_mutase" public_interface="out" initial_value="1.0" units="micromolar" />
    <variable name="time" public_interface="in" units="second" />
</component>

<component name="Propionyl_CoA_carboxylase" cmeta:id="Propionyl_CoA_carboxylase">
    <variable name="Propionyl_CoA_carboxylase" public_interface="out" initial_value="1.0" units="micromolar" />
    <variable name="time" public_interface="in" units="second" />
</component>

<!--
The following components represent the reaction steps of odd-chain fatty
acid oxidation.
-->

<component name="reaction0">
    <variable name="Propionyl_CoA" public_interface="in" units="micromolar" />
    <variable name="ATP" public_interface="in" units="micromolar" />
    <variable name="CO2" public_interface="in" units="micromolar" />
    <variable name="Pi" public_interface="in" units="micromolar" />
    <variable name="ADP" public_interface="in" units="micromolar" />
    <variable name="Methylmalonyl_CoA" public_interface="in" units="micromolar" />
    <variable name="Propionyl_CoA_carboxylase" public_interface="in" units="micromolar" />
    <variable name="delta_Propionyl_CoA_rxn0" public_interface="out" units="flux" />
    <variable name="delta_ATP_rxn0" public_interface="out" units="flux" />
    <variable name="delta_CO2_rxn0" public_interface="out" units="flux" />
    <variable name="delta_Pi_rxn0" public_interface="out" units="flux" />
    <variable name="delta_ADP_rxn0" public_interface="out" units="flux" />
    <variable name="delta_Methylmalonyl_CoA_rxn0" public_interface="out" units="flux" />
    <variable name="vmax0" initial_value="1.0" units="third_order_rate_constant" />
    <variable name="km0" initial_value="1.0" units="micromolar" />
    <variable name="rate" units="flux" />
    <reaction reversible="no">
        <variable_ref variable="Propionyl_CoA">
            <role role="reactant" delta_variable="delta_Propionyl_CoA_rxn0" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="ATP">
            <role role="reactant" delta_variable="delta_ATP_rxn0" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="CO2">
            <role role="reactant" delta_variable="delta_CO2_rxn0" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="Pi">

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    <role role="product" delta_variable="delta_Pi_rxn0" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="ADP">
    <role role="product" delta_variable="delta_ADP_rxn0" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Methylmalonyl_CoA">
    <role role="product" delta_variable="delta_Methylmalonyl_CoA_rxn0" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Propionyl_CoA_carboxylase">
    <role role="catalyst" />
  </variable_ref>
  <variable_ref variable="rate">
    <role role="rate">
      <math xmlns="http://www.w3.org/1998/Math/MathML">
        <apply>
          <eq />
          <ci>rate</ci>
          <apply><divide />
            <apply><times />
              <ci>vmax0</ci>
              <ci>Propionyl_CoA</ci>
              <ci>ATP</ci>
              <ci>CO2</ci>
            </apply>
          <apply><plus />
            <ci>km0</ci>
            <ci>Propionyl_CoA</ci>
            <ci>ATP</ci>
            <ci>CO2</ci>
          </apply>
        </apply>
      </math>
    </role>
  </variable_ref>
</reaction>
</component>

<component name="reaction1">
  <variable name="Methylmalonyl_CoA" public_interface="in" units="micromolar" />
  <variable name="Deoxyadenosyl_5_B12" public_interface="in" units="micromolar" />
  <variable name="Methylmalonyl_B12" public_interface="in" units="micromolar" />
  <variable name="Methylmalonyl_CoA_mutase" public_interface="in" units="micromolar" />
  <variable name="Deoxyadenosine_5" public_interface="in" units="micromolar" />
  <variable name="delta_Methylmalonyl_CoA_rxn1" public_interface="out" units="flux" />
  <variable name="delta_Deoxyadenosyl_5_B12_rxn1" public_interface="out" units="flux" />
  <variable name="delta_Methylmalonyl_B12_rxn1" public_interface="out" units="flux" />
  <variable name="delta_Deoxyadenosine_5_rxn1" public_interface="out" units="flux" />
  <variable name="kml" initial_value="1.0" units="micromolar" />
  <variable name="vmax1" initial_value="1.0" units="second_order_rate_constant" />
  <variable name="kml_" initial_value="1.0" units="micromolar" />
  <variable name="vmax1_" initial_value="1.0" units="second_order_rate_constant" />
  <variable name="rate" units="flux" />
  <reaction reversible="yes">
    <variable_ref variable="Methylmalonyl_CoA">
      <role role="reactant" direction="forward" delta_variable="delta_Methylmalonyl_CoA_rxn1" />
    </variable_ref>
    <variable_ref variable="Deoxyadenosyl_5_B12">
      <role role="reactant" direction="forward" delta_variable="delta_Deoxyadenosyl_5_B12_rxn1" />
    </variable_ref>
    <variable_ref variable="Methylmalonyl_B12">
      <role role="product" direction="forward" delta_variable="delta_Methylmalonyl_B12_rxn1" />
    </variable_ref>
    <variable_ref variable="Deoxyadenosine_5">
      <role role="product" direction="forward" delta_variable="delta_Deoxyadenosine_5_rxn1" />
    </variable_ref>
  </reaction>
</component>

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</variable_ref>
<variable_ref variable="Methylmalonyl_B12">
  <role role="product" direction="forward" delta_variable="delta_Methylmalonyl_B12">
</variable_ref>
<variable_ref variable="Deoxyadenosine_5">
  <role role="product" direction="forward" delta_variable="delta_Deoxyadenosine_5">
</variable_ref>
<variable_ref variable="Methylmalonyl_CoA_mutase">
  <role role="catalyst" direction="forward" />
</variable_ref>
<variable_ref variable="rate">
  <role role="rate">
    <math xmlns="http://www.w3.org/1998/Math/MathML">
      <apply>
        <eq />
        <ci>rate</ci>
        <apply>
          <divide />
          <apply>
            <minus />
            <apply>
              <times />
              <ci>vmax1</ci>
              <apply>
                <divide />
                <apply>
                  <times />
                  <ci>Methylmalonyl_CoA</ci>
                  <ci>Deoxyadenosyl_5_B12</ci>
                </apply>
                <ci>kml</ci>
              </apply>
            </apply>
          </apply>
          <times />
          <ci>vmax1</ci>
          <apply>
            <divide />
            <apply>
              <times />
              <ci>Methylmalonyl_B12</ci>
              <ci>Deoxyadenosine_5</ci>
            </apply>
            <ci>kml</ci>
          </apply>
        </apply>
      </math>
      <cn cellml:units="dimensionless">1.0</cn>
      <apply>
        <divide />
        <apply>
          <times />
          <ci>Methylmalonyl_CoA</ci>
          <ci>Deoxyadenosyl_5_B12</ci>
        </apply>
        <ci>kml</ci>
      </apply>
    </math>
  </role>

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        <apply>
          <divide />
          <apply>
            <times />
            <ci>Methylmalonyl_B12</ci>
            <ci>Deoxyadenosine_5</ci>
          </apply>
          <ci>km1</ci>
        </apply>
      </apply>
    </apply>
  </math>
</variable_ref>
</reaction>
</component>

<component name="reaction2">
  <variable name="Methylmalonyl_B12" public_interface="in" units="micromolar" />
  <variable name="Succinyl_B12" public_interface="in" units="micromolar" />
  <variable name="Methylmalonyl_CoA_mutase" public_interface="in" units="micromolar" />
  <variable name="delta_Methylmalonyl_B12_rxn2" public_interface="out" units="flux" />
  <variable name="delta_Succinyl_B12_rxn2" public_interface="out" units="flux" />
  <variable name="km2" initial_value="1.0" units="micromolar" />
  <variable name="vmax2" initial_value="1.0" units="first_order_rate_constant" />
  <variable name="km2_" initial_value="1.0" units="micromolar" />
  <variable name="vmax2_" initial_value="1.0" units="first_order_rate_constant" />
  <variable name="rate" units="flux" />
  <reaction reversible="yes">
    <variable_ref variable="Methylmalonyl_B12">
      <role role="reactant" direction="forward" delta_variable="delta_Methylmalonyl_B12_rxn2" />
    </variable_ref>
    <variable_ref variable="Succinyl_B12">
      <role role="product" direction="forward" delta_variable="delta_Succinyl_B12_rxn2" />
    </variable_ref>
    <variable_ref variable="Methylmalonyl_CoA_mutase">
      <role role="catalyst" direction="forward" />
    </variable_ref>
    <variable_ref variable="rate">
      <role role="rate">
        <math xmlns="http://www.w3.org/1998/Math/MathML">
          <apply>
            <eq />
            <ci>rate</ci>
            <apply>
              <divide />
              <apply>
                <minus />
                <apply>
                  <times />
                  <ci>vmax2</ci>
                </apply>
                <divide />
                <ci>Methylmalonyl_B12</ci>
                <ci>km2</ci>
              </apply>
            </apply>
          </math>
        </variable_ref>
      </role>
    </variable_ref>
  </reaction>
</component>

```

```

        <times />
        <ci>vmax2_</ci>
        <apply>
            <divide />
            <ci>Succinyl_B12</ci>
            <ci>km2_</ci>
        </apply>
    </apply>
</apply>
<apply>
    <plus />
    <cn cellml:units="dimensionless">1.0</cn>
    <apply>
        <divide />
        <ci>Methylmalonyl_B12</ci>
        <ci>km2</ci>
    </apply>
    <apply>
        <divide />
        <ci>Succinyl_B12</ci>
        <ci>km2_</ci>
    </apply>
</apply>
</apply>
</math>
</role>
</variable_ref>
</reaction>
</component>

```

```

<component name="reaction3">
    <variable name="Deoxyadenosine_5" public_interface="in" units="micromolar" />
    <variable name="Succinyl_B12" public_interface="in" units="micromolar" />
    <variable name="Succinyl_CoA" public_interface="in" units="micromolar" />
    <variable name="Deoxyadenosyl_5_B12" public_interface="in" units="micromolar" />
    <variable name="Methylmalonyl_CoA_mutase" public_interface="in" units="micromolar" />
    <variable name="delta_Deoxyadenosine_5_rxn3" public_interface="out" units="flux" />
    <variable name="delta_Succinyl_B12_rxn3" public_interface="out" units="flux" />
    <variable name="delta_Succinyl_CoA_rxn3" public_interface="out" units="flux" />
    <variable name="delta_Deoxyadenosyl_5_B12_rxn3" public_interface="out" units="flux" />
    <variable name="km3" initial_value="1.0" units="micromolar" />
    <variable name="vmax3" initial_value="1.0" units="third_order_rate_constant" />
    <variable name="km3_" initial_value="1.0" units="micromolar" />
    <variable name="vmax3_" initial_value="1.0" units="second_order_rate_constant" />
    <variable name="rate" units="flux" />
    <reaction reversible="yes">
        <variable_ref variable="Deoxyadenosine_5">
            <role role="reactant" direction="forward" delta_variable="delta_Deoxyadenosine_5" />
        </variable_ref>
        <variable_ref variable="Succinyl_B12">
            <role role="reactant" direction="forward" delta_variable="delta_Succinyl_B12_rxn3" />
        </variable_ref>
        <variable_ref variable="Succinyl_CoA">
            <role role="product" direction="forward" delta_variable="delta_Succinyl_CoA_rxn3" />
        </variable_ref>
        <variable_ref variable="Deoxyadenosyl_5_B12">
            <role role="product" direction="forward" delta_variable="delta_Deoxyadenosyl_5_B12_rxn3" />
        </variable_ref>
    </reaction>

```

```

<variable_ref variable="Methylmalonyl_CoA_mutase">
  <role role="catalyst" direction="forward" />
</variable_ref>
<variable_ref variable="rate">
  <role role="rate">
    <math xmlns="http://www.w3.org/1998/Math/MathML">
      <apply>
        <eq />
        <ci>rate</ci>
        <apply>
          <divide />
          <apply>
            <minus />
            <apply>
              <times />
              <ci>vmax3</ci>
              <apply>
                <divide />
                <apply>
                  <times />
                  <ci>Deoxyadenosine_5</ci>
                  <ci>Succinyl_B12</ci>
                </apply>
                <ci>km3</ci>
              </apply>
            </apply>
          </apply>
          <times />
          <ci>vmax3_</ci>
          <apply>
            <divide />
            <apply>
              <times />
              <ci>Succinyl_CoA</ci>
              <ci>Deoxyadenosyl_5_B12</ci>
            </apply>
            <ci>km3_</ci>
          </apply>
        </apply>
      </apply>
      <plus />
      <cn cellml:units="dimensionless">1.0</cn>
      <apply>
        <divide />
        <apply>
          <times />
          <ci>Deoxyadenosine_5</ci>
          <ci>Succinyl_B12</ci>
        </apply>
        <ci>km3</ci>
      </apply>
      <apply>
        <divide />
        <apply>
          <times />
          <ci>Succinyl_CoA</ci>
          <ci>Deoxyadenosyl_5_B12</ci>
        </apply>
      </apply>
    </math>
  </role>
</variable_ref>

```

```

        <ci>km3.</ci>
      </apply>
    </apply>
  </apply>
</math>
</role>
</variable_ref>
</reaction>
</component>

<connection>
  <map_components component_1="Propionyl_CoA" component_2="reaction0" />
  <map_variables variable_1="Propionyl_CoA" variable_2="Propionyl_CoA" />
  <map_variables variable_1="delta_Propionyl_CoA_rxn0" variable_2="delta_Propionyl_CoA_r
</connection>

<connection>
  <map_components component_1="Methylmalonyl_CoA" component_2="reaction0" />
  <map_variables variable_1="Methylmalonyl_CoA" variable_2="Methylmalonyl_CoA" />
  <map_variables variable_1="delta_Methylmalonyl_CoA_rxn0" variable_2="delta_Methylmalony
</connection>

<connection>
  <map_components component_1="Methylmalonyl_CoA" component_2="reaction1" />
  <map_variables variable_1="Methylmalonyl_CoA" variable_2="Methylmalonyl_CoA" />
  <map_variables variable_1="delta_Methylmalonyl_CoA_rxn1" variable_2="delta_Methylmalony
</connection>

<connection>
  <map_components component_1="Methylmalonyl_B12" component_2="reaction1" />
  <map_variables variable_1="Methylmalonyl_B12" variable_2="Methylmalonyl_B12" />
  <map_variables variable_1="delta_Methylmalonyl_B12_rxn1" variable_2="delta_Methylmalony
</connection>

<connection>
  <map_components component_1="Methylmalonyl_B12" component_2="reaction2" />
  <map_variables variable_1="Methylmalonyl_B12" variable_2="Methylmalonyl_B12" />
  <map_variables variable_1="delta_Methylmalonyl_B12_rxn2" variable_2="delta_Methylmalony
</connection>

<connection>
  <map_components component_1="Succinyl_CoA" component_2="reaction3" />
  <map_variables variable_1="Succinyl_CoA" variable_2="Succinyl_CoA" />
  <map_variables variable_1="delta_Succinyl_CoA_rxn3" variable_2="delta_Succinyl_CoA_rxn
</connection>

<connection>
  <map_components component_1="ATP" component_2="reaction0" />
  <map_variables variable_1="ATP" variable_2="ATP" />
  <map_variables variable_1="delta_ATP_rxn0" variable_2="delta_ATP_rxn0" />
</connection>

<connection>
  <map_components component_1="ADP" component_2="reaction0" />
  <map_variables variable_1="ADP" variable_2="ADP" />
  <map_variables variable_1="delta_ADP_rxn0" variable_2="delta_ADP_rxn0" />
</connection>

```

```
<connection>
  <map_components component_1="Pi" component_2="reaction0" />
  <map_variables variable_1="Pi" variable_2="Pi" />
  <map_variables variable_1="delta_Pi_rxn0" variable_2="delta_Pi_rxn0" />
</connection>

<connection>
  <map_components component_1="CO2" component_2="reaction0" />
  <map_variables variable_1="CO2" variable_2="CO2" />
  <map_variables variable_1="delta_CO2_rxn0" variable_2="delta_CO2_rxn0" />
</connection>

<connection>
  <map_components component_1="Deoxyadenosyl_5_B12" component_2="reaction3" />
  <map_variables variable_1="Deoxyadenosyl_5_B12" variable_2="Deoxyadenosyl_5_B12" />
  <map_variables variable_1="delta_Deoxyadenosyl_5_B12_rxn3" variable_2="delta_Deoxyadenosyl_5_B12_rxn3" />
</connection>

<connection>
  <map_components component_1="Deoxyadenosyl_5_B12" component_2="reaction1" />
  <map_variables variable_1="Deoxyadenosyl_5_B12" variable_2="Deoxyadenosyl_5_B12" />
  <map_variables variable_1="delta_Deoxyadenosyl_5_B12_rxn1" variable_2="delta_Deoxyadenosyl_5_B12_rxn1" />
</connection>

<connection>
  <map_components component_1="Succinyl_B12" component_2="reaction2" />
  <map_variables variable_1="Succinyl_B12" variable_2="Succinyl_B12" />
  <map_variables variable_1="delta_Succinyl_B12_rxn2" variable_2="delta_Succinyl_B12_rxn2" />
</connection>

<connection>
  <map_components component_1="Succinyl_B12" component_2="reaction3" />
  <map_variables variable_1="Succinyl_B12" variable_2="Succinyl_B12" />
  <map_variables variable_1="delta_Succinyl_B12_rxn3" variable_2="delta_Succinyl_B12_rxn3" />
</connection>

<connection>
  <map_components component_1="Deoxyadenosine_5" component_2="reaction1" />
  <map_variables variable_1="Deoxyadenosine_5" variable_2="Deoxyadenosine_5" />
  <map_variables variable_1="delta_Deoxyadenosine_5_rxn1" variable_2="delta_Deoxyadenosine_5_rxn1" />
</connection>

<connection>
  <map_components component_1="Deoxyadenosine_5" component_2="reaction3" />
  <map_variables variable_1="Deoxyadenosine_5" variable_2="Deoxyadenosine_5" />
  <map_variables variable_1="delta_Deoxyadenosine_5_rxn3" variable_2="delta_Deoxyadenosine_5_rxn3" />
</connection>

<connection>
  <map_components component_1="Propionyl_CoA" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Methylmalonyl_CoA" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
```

```
<map_components component_1="Methylmalonyl_B12" component_2="global_variables" />
<map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Succinyl_CoA" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="ATP" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="ADP" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Pi" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="CO2" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Deoxyadenosyl_5_B12" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Succinyl_B12" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Deoxyadenosine_5" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Methylmalonyl_CoA_mutase" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Propionyl_CoA_carboxylase" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Propionyl_CoA_carboxylase" component_2="reaction0" />
  <map_variables variable_1="Propionyl_CoA_carboxylase" variable_2="Propionyl_CoA_carboxylase" />
</connection>
```

```
<connection>
  <map_components component_1="Methylmalonyl_CoA_mutase" component_2="reaction1" />
  <map_variables variable_1="Methylmalonyl_CoA_mutase" variable_2="Methylmalonyl_CoA_mutase" />
</connection>

<connection>
  <map_components component_1="Methylmalonyl_CoA_mutase" component_2="reaction2" />
  <map_variables variable_1="Methylmalonyl_CoA_mutase" variable_2="Methylmalonyl_CoA_mutase" />
</connection>

<connection>
  <map_components component_1="Methylmalonyl_CoA_mutase" component_2="reaction3" />
  <map_variables variable_1="Methylmalonyl_CoA_mutase" variable_2="Methylmalonyl_CoA_mutase" />
</connection>

</model>
```