

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

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

```
CREATED : 4th June 2002
```

```
LAST MODIFIED : 20nd April 2005
```

```
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  
transamination.
```

```
CHANGES:
```

```
22/07/2002 - CML - Added more metadata.
```

```
20/04/2005 - PJV - Updated syntax to conform with cellml1.1 specs
```

```
-->
```

```
<model name="transamination_model" pathway_editor:rendering_config_file="transamination_CellML
```

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

```
<!--
```

```
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.
```

```
-->
```

```
<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>
```

```
</vCard:ORG>
```

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

```
<!--
```

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

```
-->
```

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

```
<dcterms:W3CDTF>2002-06-04</dcterms:W3CDTF>
```

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

```

<!--
  The Last Modified Date metadata. This is the date on which
  the model was last changed.
-->
<cmeta:modification rdf:parseType="Resource">
  <rdf:value>
    Updated syntax to conform with cellml1.1 specs
  </rdf:value>
  <cmeta:modifier rdf:parseType="Resource">
    <vCard:N rdf:parseType="Resource">
      <vCard:Family>Villiger</vCard:Family>
      <vCard:Given>Peter</vCard:Given>
      <vCard:Other>J</vCard:Other>
    </vCard:N>
  </cmeta:modifier>
  <dcterms:modified rdf:parseType="Resource">
    <dcterms:W3CDTF>2005-04-20</dcterms:W3CDTF>
  </dcterms:modified>
</cmeta:modification>
<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 "transamination_model", which is declared on the
  <model> element.
-->
<rdf:Description rdf:about="#transamination_model">
  <!-- A human readable name for the model. -->
  <dc:title>A Generic Model Of Transamination</dc:title>

  <!-- A comment regarding the model. -->
  <cmeta:comment rdf:parseType="Resource">
    <rdf:value>
      Below is a CellML description of a general model of transamination.
      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">
    <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>

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

<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>

<units name="fourth_order_rate_constant">
    <unit units="micromolar" exponent="-3" />
    <unit units="second" exponent="-1" />
</units>

<!--
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 transamination.
-->

<component name="Oxaloacetate" cmeta:id="Oxaloacetate">
    <variable name="Oxaloacetate" public_interface="out" initial_value="1.0" units="micromolar" />
    <variable name="delta_Oxaloacetate_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>Oxaloacetate</ci>
            </apply>
            <ci>delta_Oxaloacetate_rxn0</ci>
        </apply>
    </math>
</component>

<component name="Aspartate" cmeta:id="Aspartate">
    <variable name="Aspartate" public_interface="out" initial_value="1.0" units="micromolar" />
    <variable name="delta_Aspartate_rxn0" public_interface="in" units="flux" />
    <variable name="delta_Aspartate_rxn5" public_interface="in" units="flux" />
    <variable name="time" public_interface="in" units="second" />

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```

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply>
    <eq />
    <apply>
      <diff />
      <bvar>
        <ci>time</ci>
      </bvar>
      <ci>Aspartate</ci>
    </apply>
    <apply>
      <plus />
      <ci>delta_Aspartate_rxn0</ci>
      <ci>delta_Aspartate_rxn5</ci>
    </apply>
  </apply>
</math>
</component>

<component name="alpha_amino_acid" cmeta:id="alpha_amino_acid">
  <variable name="alpha_amino_acid" public_interface="out" initial_value="1.0" units="micromol">
  <variable name="delta_alpha_amino_acid_rxn0" public_interface="in" units="flux" />
  <variable name="delta_alpha_amino_acid_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>alpha_amino_acid</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_alpha_amino_acid_rxn0</ci>
        <ci>delta_alpha_amino_acid_rxn1</ci>
      </apply>
    </apply>
  </math>
</component>

<component name="Oxo_2_acid" cmeta:id="Oxo_2_acid">
  <variable name="Oxo_2_acid" public_interface="out" initial_value="1.0" units="micromol">
  <variable name="delta_Oxo_2_acid_rxn0" public_interface="in" units="flux" />
  <variable name="delta_Oxo_2_acid_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>Oxo_2_acid</ci>
      </apply>
      <apply>
    </math>
  </component>

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        <plus />
        <ci>delta_Oxo_2_acid_rxn0</ci>
        <ci>delta_Oxo_2_acid_rxn1</ci>
    </apply>
</apply>
</math>
</component>

<component name="Oxoglutarate_2" cmeta:id="Oxoglutarate_2">
    <variable name="Oxoglutarate_2" public_interface="out" initial_value="1.0" units="micro
    <variable name="delta_Oxoglutarate_2_rxn2" public_interface="in" units="flux" />
    <variable name="delta_Oxoglutarate_2_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>Oxoglutarate_2</ci>
            </apply>
            <apply>
                <plus />
                <ci>delta_Oxoglutarate_2_rxn2</ci>
                <ci>delta_Oxoglutarate_2_rxn1</ci>
            </apply>
        </apply>
    </math>
</component>

<component name="Glutamate" cmeta:id="Glutamate">
    <variable name="Glutamate" public_interface="out" initial_value="1.0" units="micromolar
    <variable name="delta_Glutamate_rxn1" public_interface="in" units="flux" />
    <variable name="delta_Glutamate_rxn4" public_interface="in" units="flux" />
    <variable name="delta_Glutamate_rxn2" public_interface="in" units="flux" />
    <variable name="delta_Glutamate_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>Glutamate</ci>
            </apply>
            <apply>
                <plus />
                <ci>delta_Glutamate_rxn1</ci>
                <ci>delta_Glutamate_rxn4</ci>
                <ci>delta_Glutamate_rxn2</ci>
                <ci>delta_Glutamate_rxn3</ci>
            </apply>
        </apply>
    </math>
</component>

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```

<component name="NADH" cmeta:id="NADH">
  <variable name="NADH" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_NADH_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>NADH</ci>
      </apply>
      <ci>delta_NADH_rxn2</ci>
    </apply>
  </math>
</component>

```

```

<component name="NH4" cmeta:id="NH4">
  <variable name="NH4" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_NH4_rxn2" public_interface="in" units="flux" />
  <variable name="delta_NH4_rxn4" public_interface="in" units="flux" />
  <variable name="delta_NH4_rxn3" public_interface="in" units="flux" />
  <variable name="delta_NH4_rxn8" 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>NH4</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_NH4_rxn2</ci>
        <ci>delta_NH4_rxn4</ci>
        <ci>delta_NH4_rxn3</ci>
        <ci>delta_NH4_rxn8</ci>
      </apply>
    </apply>
  </math>
</component>

```

```

<component name="H" cmeta:id="H">
  <variable name="H" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_H_rxn2" public_interface="in" units="flux" />
  <variable name="delta_H_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>H</ci>
    </apply>
  <apply>
    <plus />
    <ci>delta_H_rxn2</ci>
    <ci>delta_H_rxn3</ci>
  </apply>
</apply>
</math>
</component>

<component name="NAD" cmeta:id="NAD">
  <variable name="NAD" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_NAD_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>NAD</ci>
      </apply>
      <ci>delta_NAD_rxn2</ci>
    </apply>
  </math>
</component>

<component name="H2O" cmeta:id="H2O">
  <variable name="H2O" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_H2O_rxn2" public_interface="in" units="flux" />
  <variable name="delta_H2O_rxn4" public_interface="in" units="flux" />
  <variable name="delta_H2O_rxn6" 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>H2O</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_H2O_rxn2</ci>
        <ci>delta_H2O_rxn4</ci>
        <ci>delta_H2O_rxn6</ci>
      </apply>
    </apply>
  </math>
</component>

<component name="Glutamine" cmeta:id="Glutamine">

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```

<variable name="Glutamine" public_interface="out" initial_value="1.0" units="micromolar" />
<variable name="delta_Glutamine_rxn3" public_interface="in" units="flux" />
<variable name="delta_Glutamine_rxn4" 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>Glutamine</ci>
    </apply>
    <apply>
      <plus />
      <ci>delta_Glutamine_rxn3</ci>
      <ci>delta_Glutamine_rxn4</ci>
    </apply>
  </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_rxn3" public_interface="in" units="flux" />
  <variable name="delta_ATP_rxn5" public_interface="in" units="flux" />
  <variable name="delta_ATP_rxn8" 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>
      <apply>
        <plus />
        <ci>delta_ATP_rxn3</ci>
        <ci>delta_ATP_rxn5</ci>
        <ci>delta_ATP_rxn8</ci>
      </apply>
    </apply>
  </math>
</component>

```

```

<component name="ADP" cmeta:id="ADP">
  <variable name="ADP" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_ADP_rxn3" public_interface="in" units="flux" />
  <variable name="delta_ADP_rxn8" 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 />

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```

        <bvar>
            <ci>time</ci>
        </bvar>
        <ci>ADP</ci>
    </apply>
    <apply>
        <plus />
        <ci>delta_ADP_rxn3</ci>
        <ci>delta_ADP_rxn8</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_rxn3" public_interface="in" units="flux" />
    <variable name="delta_Pi_rxn5" public_interface="in" units="flux" />
    <variable name="delta_Pi_rxn7" public_interface="in" units="flux" />
    <variable name="delta_Pi_rxn8" 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>
            <apply>
                <plus />
                <ci>delta_Pi_rxn3</ci>
                <ci>delta_Pi_rxn5</ci>
                <ci>delta_Pi_rxn7</ci>
                <ci>delta_Pi_rxn8</ci>
            </apply>
        </math>
    </component>

<component name="Fumarate" cmeta:id="Fumarate">
    <variable name="Fumarate" public_interface="out" initial_value="1.0" units="micromolar" />
    <variable name="delta_Fumarate_rxn5b" 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>Fumarate</ci>
            </apply>
            <ci>delta_Fumarate_rxn5b</ci>
        </math>
    </component>

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</component>

<component name="AMP" cmeta:id="AMP">

<variable name="AMP" public_interface="out" initial_value="1.0" units="micromolar" />

<variable name="delta_AMP_rxn5" 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>AMP</ci>

</apply>

<ci>delta_AMP_rxn5</ci>

</apply>

</math>

</component>

<component name="Arginine" cmeta:id="Arginine">

<variable name="Arginine" public_interface="out" initial_value="1.0" units="micromolar" />

<variable name="delta_Arginine_rxn5b" public_interface="in" units="flux" />

<variable name="delta_Arginine_rxn6" 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>Arginine</ci>

</apply>

<apply>

<plus />

<ci>delta_Arginine_rxn5b</ci>

<ci>delta_Arginine_rxn6</ci>

</apply>

</apply>

</math>

</component>

<component name="Argininosuccinate" cmeta:id="Argininosuccinate">

<variable name="Argininosuccinate" public_interface="out" initial_value="1.0" units="m" />

<variable name="delta_Argininosuccinate_rxn5" public_interface="in" units="flux" />

<variable name="delta_Argininosuccinate_rxn5b" 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>Argininosuccinate</ci>

```

    </apply>
    <apply>
      <plus />
      <ci>delta_Argininosuccinate_rxn5</ci>
      <ci>delta_Argininosuccinate_rxn5b</ci>
    </apply>
  </apply>
</math>
</component>

<component name="Citrulline" cmeta:id="Citrulline">
  <variable name="Citrulline" public_interface="out" initial_value="1.0" units="micromola
  <variable name="delta_Citrulline_rxn7" public_interface="in" units="flux" />
  <variable name="delta_Citrulline_rxn5" 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>Citrulline</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_Citrulline_rxn7</ci>
        <ci>delta_Citrulline_rxn5</ci>
      </apply>
    </apply>
  </math>
</component>

<component name="Ornithine" cmeta:id="Ornithine">
  <variable name="Ornithine" public_interface="out" initial_value="1.0" units="micromola
  <variable name="delta_Ornithine_rxn6" public_interface="in" units="flux" />
  <variable name="delta_Ornithine_rxn7" 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>Ornithine</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_Ornithine_rxn6</ci>
        <ci>delta_Ornithine_rxn7</ci>
      </apply>
    </apply>
  </math>
</component>

<component name="Urea" cmeta:id="Urea">

```

```

<variable name="Urea" public_interface="out" initial_value="1.0" units="micromolar" />
<variable name="delta_Urea_rxn6" 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>Urea</ci>
    </apply>
    <ci>delta_Urea_rxn6</ci>
  </apply>
</math>
</component>

<component name="Carbamoyl_Pi" cmeta:id="Carbamoyl_Pi">
  <variable name="Carbamoyl_Pi" public_interface="out" initial_value="1.0" units="micromolar" />
  <variable name="delta_Carbamoyl_Pi_rxn8" public_interface="in" units="flux" />
  <variable name="delta_Carbamoyl_Pi_rxn7" 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>Carbamoyl_Pi</ci>
      </apply>
      <apply>
        <plus />
        <ci>delta_Carbamoyl_Pi_rxn8</ci>
        <ci>delta_Carbamoyl_Pi_rxn7</ci>
      </apply>
    </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_rxn8" 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_rxn8</ci>
    </apply>
  </math>

```

```
</component>
```

```
<!--
```

```
The following components describe all the enzymes involved in  
transamination.
```

```
-->
```

```
<component name="Arginase" cmeta:id="Arginase">
```

```
  <variable name="Arginase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Aminotransferase" cmeta:id="Aminotransferase">
```

```
  <variable name="Aminotransferase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Glutamate_dehydrogenase" cmeta:id="Glutamate_dehydrogenase">
```

```
  <variable name="Glutamate_dehydrogenase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Glutamine_synthetase" cmeta:id="Glutamine_synthetase">
```

```
  <variable name="Glutamine_synthetase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Carbamoyl_phosphate_synthetase" cmeta:id="Carbamoyl_phosphate_synthetase">
```

```
  <variable name="Carbamoyl_phosphate_synthetase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Glutaminase" cmeta:id="Glutaminase">
```

```
  <variable name="Glutaminase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Argininosuccinate_synthetase" cmeta:id="Argininosuccinate_synthetase">
```

```
  <variable name="Argininosuccinate_synthetase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Argininosuccinase" cmeta:id="Argininosuccinase">
```

```
  <variable name="Argininosuccinase" public_interface="out" initial_value="1.0" units="micromolar">
```

```
  <variable name="time" public_interface="in" units="second" />
```

```
</component>
```

```
<component name="Ornithine_transcarbamylase" cmeta:id="Ornithine_transcarbamylase">
```

```
  <variable name="Ornithine_transcarbamylase" 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 transamination.
```

```
-->
```

```
<component name="reaction0">
```

```
  <variable name="alpha_amino_acid" public_interface="in" units="micromolar" />
```

```
  <variable name="Oxaloacetate" public_interface="in" units="micromolar" />
```

```

<variable name="Oxo_2_acid" public_interface="in" units="micromolar" />
<variable name="Aspartate" public_interface="in" units="micromolar" />
<variable name="Aminotransferase" public_interface="in" units="micromolar" />
<variable name="delta_alpha_amino_acid_rxn0" public_interface="out" units="flux" />
<variable name="delta_Oxaloacetate_rxn0" public_interface="out" units="flux" />
<variable name="delta_Oxo_2_acid_rxn0" public_interface="out" units="flux" />
<variable name="delta_Aspartate_rxn0" public_interface="out" units="flux" />
<variable name="vmax0" initial_value="1.0" units="second_order_rate_constant" />
<variable name="km0" initial_value="1.0" units="micromolar" />
<variable name="rate" units="flux" />
<reaction reversible="no">
  <variable_ref variable="alpha_amino_acid">
    <role role="reactant" delta_variable="delta_alpha_amino_acid_rxn0" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Oxaloacetate">
    <role role="reactant" delta_variable="delta_Oxaloacetate_rxn0" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Oxo_2_acid">
    <role role="product" delta_variable="delta_Oxo_2_acid_rxn0" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Aspartate">
    <role role="product" delta_variable="delta_Aspartate_rxn0" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Aminotransferase">
    <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>alpha_amino_acid</ci>
              <ci>Oxaloacetate</ci>
            </apply>
          <apply><plus />
            <ci>km0</ci>
            <ci>alpha_amino_acid</ci>
            <ci>Oxaloacetate</ci>
          </apply>
        </apply>
      </math>
    </role>
  </variable_ref>
</reaction>
</component>

<component name="reaction1">
  <variable name="alpha_amino_acid" public_interface="in" units="micromolar" />
  <variable name="Oxoglutarate_2" public_interface="in" units="micromolar" />
  <variable name="Glutamate" public_interface="in" units="micromolar" />
  <variable name="Oxo_2_acid" public_interface="in" units="micromolar" />
  <variable name="Aminotransferase" public_interface="in" units="micromolar" />
  <variable name="delta_alpha_amino_acid_rxn1" public_interface="out" units="flux" />
  <variable name="delta_Oxoglutarate_2_rxn1" public_interface="out" units="flux" />

```

```

<variable name="delta_Glutamate_rxn1" public_interface="out" units="flux" />
<variable name="delta_Oxo_2_acid_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="rate" units="flux" />
<reaction reversible="no">
  <variable_ref variable="alpha_amino_acid">
    <role role="reactant" delta_variable="delta_alpha_amino_acid_rxn1" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Oxoglutarate_2">
    <role role="reactant" delta_variable="delta_Oxoglutarate_2_rxn1" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Glutamate">
    <role role="product" delta_variable="delta_Glutamate_rxn1" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Oxo_2_acid">
    <role role="product" delta_variable="delta_Oxo_2_acid_rxn1" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Aminotransferase">
    <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>alpha_amino_acid</ci>
              <ci>Oxoglutarate_2</ci>
              <ci>vmax1</ci>
            </apply>
            <apply>
              <plus />
              <ci>kml</ci>
              <ci>alpha_amino_acid</ci>
              <ci>Oxoglutarate_2</ci>
            </apply>
          </apply>
        </math>
      </role>
    </variable_ref>
  </reaction>
</component>

<component name="reaction2">
  <variable name="H2O" public_interface="in" units="micromolar" />
  <variable name="NAD" public_interface="in" units="micromolar" />
  <variable name="Glutamate" public_interface="in" units="micromolar" />
  <variable name="Oxoglutarate_2" public_interface="in" units="micromolar" />
  <variable name="H" public_interface="in" units="micromolar" />
  <variable name="NH4" public_interface="in" units="micromolar" />
  <variable name="NADH" public_interface="in" units="micromolar" />
  <variable name="Glutamate_dehydrogenase" public_interface="in" units="micromolar" />
  <variable name="delta_H2O_rxn2" public_interface="out" units="flux" />

```

```

<variable name="delta_NAD_rxn2" public_interface="out" units="flux" />
<variable name="delta_Glutamate_rxn2" public_interface="out" units="flux" />
<variable name="delta_Oxoglutarate_2_rxn2" public_interface="out" units="flux" />
<variable name="delta_H_rxn2" public_interface="out" units="flux" />
<variable name="delta_NH4_rxn2" public_interface="out" units="flux" />
<variable name="delta_NADH_rxn2" public_interface="out" units="flux" />
<variable name="km2" initial_value="1.0" units="micromolar" />
<variable name="vmax2" initial_value="1.0" units="third_order_rate_constant" />
<variable name="rate" units="flux" />
<reaction reversible="no">
  <variable_ref variable="H2O">
    <role role="reactant" delta_variable="delta_H2O_rxn2" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="NAD">
    <role role="reactant" delta_variable="delta_NAD_rxn2" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Glutamate">
    <role role="reactant" delta_variable="delta_Glutamate_rxn2" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Oxoglutarate_2">
    <role role="product" delta_variable="delta_Oxoglutarate_2_rxn2" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="H">
    <role role="product" delta_variable="delta_H_rxn2" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="NH4">
    <role role="product" delta_variable="delta_NH4_rxn2" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="NADH">
    <role role="product" delta_variable="delta_NADH_rxn2" stoichiometry="1" />
  </variable_ref>
  <variable_ref variable="Glutamate_dehydrogenase">
    <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>H2O</ci>
              <ci>NAD</ci>
              <ci>Glutamate</ci>
              <ci>vmax2</ci>
            </apply>
          </apply>
          <apply>
            <plus />
            <ci>km2</ci>
            <ci>H2O</ci>
            <ci>NAD</ci>
            <ci>Glutamate</ci>
          </apply>
        </math>
      </role>
    </variable_ref>
  </reaction>

```

```

    </role>
  </variable_ref>
</reaction>
</component>

<component name="reaction3">
  <variable name="Glutamate" public_interface="in" units="micromolar" />
  <variable name="ATP" public_interface="in" units="micromolar" />
  <variable name="NH4" public_interface="in" units="micromolar" />
  <variable name="H" public_interface="in" units="micromolar" />
  <variable name="Pi" public_interface="in" units="micromolar" />
  <variable name="ADP" public_interface="in" units="micromolar" />
  <variable name="Glutamine" public_interface="in" units="micromolar" />
  <variable name="Glutamine_synthetase" public_interface="in" units="micromolar" />
  <variable name="delta_Glutamate_rxn3" public_interface="out" units="flux" />
  <variable name="delta_ATP_rxn3" public_interface="out" units="flux" />
  <variable name="delta_NH4_rxn3" public_interface="out" units="flux" />
  <variable name="delta_H_rxn3" public_interface="out" units="flux" />
  <variable name="delta_Pi_rxn3" public_interface="out" units="flux" />
  <variable name="delta_ADP_rxn3" public_interface="out" units="flux" />
  <variable name="delta_Glutamine_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="rate" units="flux" />
  <reaction reversible="no">
    <variable_ref variable="Glutamate">
      <role role="reactant" delta_variable="delta_Glutamate_rxn3" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="ATP">
      <role role="reactant" delta_variable="delta_ATP_rxn3" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="NH4">
      <role role="reactant" delta_variable="delta_NH4_rxn3" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="H">
      <role role="product" delta_variable="delta_H_rxn3" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Pi">
      <role role="product" delta_variable="delta_Pi_rxn3" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="ADP">
      <role role="product" delta_variable="delta_ADP_rxn3" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Glutamine">
      <role role="product" delta_variable="delta_Glutamine_rxn3" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Glutamine_synthetase">
      <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>Glutamine</ci>
        <ci>vmax4</ci>
    </apply>
    <apply>
        <plus />
        <ci>km4</ci>
        <ci>H2O</ci>
        <ci>Glutamine</ci>
    </apply>
</apply>
</math>
</role>
</variable_ref>
</reaction>
</component>

<component name="reaction5">
    <variable name="Aspartate" public_interface="in" units="micromolar" />
    <variable name="ATP" public_interface="in" units="micromolar" />
    <variable name="Citrulline" public_interface="in" units="micromolar" />
    <variable name="AMP" public_interface="in" units="micromolar" />
    <variable name="Pi" public_interface="in" units="micromolar" />
    <variable name="Argininosuccinate" public_interface="in" units="micromolar" />
    <variable name="Argininosuccinate_synthetase" public_interface="in" units="micromolar" />
    <variable name="delta_Aspartate_rxn5" public_interface="out" units="flux" />
    <variable name="delta_ATP_rxn5" public_interface="out" units="flux" />
    <variable name="delta_Citrulline_rxn5" public_interface="out" units="flux" />
    <variable name="delta_AMP_rxn5" public_interface="out" units="flux" />
    <variable name="delta_Pi_rxn5" public_interface="out" units="flux" />
    <variable name="delta_Argininosuccinate_rxn5" public_interface="out" units="flux" />
    <variable name="rate" units="flux" />
    <variable name="km5" initial_value="1.0" units="micromolar" />
    <variable name="vmax5" initial_value="1.0" units="third_order_rate_constant" />
    <reaction reversible="no">
        <variable_ref variable="Aspartate">
            <role role="reactant" delta_variable="delta_Aspartate_rxn5" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="ATP">
            <role role="reactant" delta_variable="delta_ATP_rxn5" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="Citrulline">
            <role role="reactant" delta_variable="delta_Citrulline_rxn5" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="AMP">
            <role role="product" delta_variable="delta_AMP_rxn5" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="Pi">
            <role role="product" delta_variable="delta_Pi_rxn5" stoichiometry="2" />
        </variable_ref>
        <variable_ref variable="Argininosuccinate">
            <role role="product" delta_variable="delta_Argininosuccinate_rxn5" stoichiometry="1" />
        </variable_ref>
        <variable_ref variable="Argininosuccinate_synthetase">
            <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>
          <times />
          <ci>Aspartate</ci>
          <ci>ATP</ci>
          <ci>Citrulline</ci>
          <ci>vmax5</ci>
        </apply>
        <apply>
          <plus />
          <ci>km5</ci>
          <ci>Aspartate</ci>
          <ci>ATP</ci>
          <ci>Citrulline</ci>
        </apply>
      </apply>
    </math>
  </role>
</variable_ref>
</reaction>
</component>

<component name="reaction5b">
  <variable name="Argininosuccinate" public_interface="in" units="micromolar" />
  <variable name="Arginine" public_interface="in" units="micromolar" />
  <variable name="Fumarate" public_interface="in" units="micromolar" />
  <variable name="Argininosuccinase" public_interface="in" units="micromolar" />
  <variable name="delta_Argininosuccinate_rxn5b" public_interface="out" units="flux" />
  <variable name="delta_Arginine_rxn5b" public_interface="out" units="flux" />
  <variable name="delta_Fumarate_rxn5b" public_interface="out" units="flux" />
  <variable name="rate" units="flux" />
  <variable name="km5b" initial_value="1.0" units="micromolar" />
  <variable name="vmax5b" initial_value="1.0" units="first_order_rate_constant" />
  <reaction reversible="no">
    <variable_ref variable="Argininosuccinate">
      <role role="reactant" delta_variable="delta_Argininosuccinate_rxn5b" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Arginine">
      <role role="product" delta_variable="delta_Arginine_rxn5b" stoichiometry="2" />
    </variable_ref>
    <variable_ref variable="Fumarate">
      <role role="product" delta_variable="delta_Fumarate_rxn5b" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Argininosuccinase">
      <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>
          <times />
          <ci>Argininosuccinate</ci>
          <ci>vmax5b</ci>
        </apply>
        <apply>
          <plus />
          <ci>km5b</ci>
          <ci>Argininosuccinate</ci>
        </apply>
      </apply>
    </math>
  </role>
</variable_ref>
</reaction>
</component>

<component name="reaction6">
  <variable name="H2O" public_interface="in" units="micromolar" />
  <variable name="Arginine" public_interface="in" units="micromolar" />
  <variable name="Ornithine" public_interface="in" units="micromolar" />
  <variable name="Urea" public_interface="in" units="micromolar" />
  <variable name="Arginase" public_interface="in" units="micromolar" />
  <variable name="delta_H2O_rxn6" public_interface="out" units="flux" />
  <variable name="delta_Arginine_rxn6" public_interface="out" units="flux" />
  <variable name="delta_Ornithine_rxn6" public_interface="out" units="flux" />
  <variable name="delta_Urea_rxn6" public_interface="out" units="flux" />
  <variable name="km6" initial_value="1.0" units="micromolar" />
  <variable name="vmax6" initial_value="1.0" units="second_order_rate_constant" />
  <variable name="rate" units="flux" />
  <reaction reversible="no">
    <variable_ref variable="H2O">
      <role role="reactant" delta_variable="delta_H2O_rxn6" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Arginine">
      <role role="reactant" delta_variable="delta_Arginine_rxn6" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Ornithine">
      <role role="product" delta_variable="delta_Ornithine_rxn6" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Urea">
      <role role="product" delta_variable="delta_Urea_rxn6" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Arginase">
      <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>
                <times />
                <ci>H2O</ci>
                <ci>Arginine</ci>

```

```

        <ci>vmax6</ci>
      </apply>
    </apply>
    <plus />
    <ci>km6</ci>
    <ci>H2O</ci>
    <ci>Arginine</ci>
  </apply>
</apply>
</math>
</role>
</variable_ref>
</reaction>
</component>

<component name="reaction7">
  <variable name="Carbamoyl_Pi" public_interface="in" units="micromolar" />
  <variable name="Ornithine" public_interface="in" units="micromolar" />
  <variable name="Citrulline" public_interface="in" units="micromolar" />
  <variable name="Pi" public_interface="in" units="micromolar" />
  <variable name="Ornithine_transcarbamylase" public_interface="in" units="micromolar" />
  <variable name="delta_Carbamoyl_Pi_rxn7" public_interface="out" units="flux" />
  <variable name="delta_Pi_rxn7" public_interface="out" units="flux" />
  <variable name="delta_Ornithine_rxn7" public_interface="out" units="flux" />
  <variable name="delta_Citrulline_rxn7" public_interface="out" units="flux" />
  <variable name="km7" initial_value="1.0" units="micromolar" />
  <variable name="vmax7" initial_value="1.0" units="second_order_rate_constant" />
  <variable name="rate" units="flux" />
  <reaction reversible="no">
    <variable_ref variable="Carbamoyl_Pi">
      <role role="reactant" delta_variable="delta_Carbamoyl_Pi_rxn7" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Ornithine">
      <role role="reactant" delta_variable="delta_Ornithine_rxn7" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Citrulline">
      <role role="product" delta_variable="delta_Citrulline_rxn7" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Pi">
      <role role="product" delta_variable="delta_Pi_rxn7" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Ornithine_transcarbamylase">
      <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>
                <times />
                <ci>Carbamoyl_Pi</ci>
                <ci>Ornithine</ci>
                <ci>vmax7</ci>
              </apply>
            </apply>
          </math>
        </role>
      </variable_ref>
    </reaction>
  </component>

```

```

        <apply>
          <plus />
          <ci>km7</ci>
          <ci>Carbamoyl_Pi</ci>
          <ci>Ornithine</ci>
        </apply>
      </apply>
    </math>
  </role>
</variable_ref>
</reaction>
</component>

<component name="reaction8">
  <variable name="NH4" public_interface="in" units="micromolar" />
  <variable name="ATP" public_interface="in" units="micromolar" />
  <variable name="CO2" public_interface="in" units="micromolar" />
  <variable name="ADP" public_interface="in" units="micromolar" />
  <variable name="Pi" public_interface="in" units="micromolar" />
  <variable name="Carbamoyl_Pi" public_interface="in" units="micromolar" />
  <variable name="Carbamoyl_phosphate_synthetase" public_interface="in" units="micromolar" />
  <variable name="delta_NH4_rxn8" public_interface="out" units="flux" />
  <variable name="delta_ATP_rxn8" public_interface="out" units="flux" />
  <variable name="delta_CO2_rxn8" public_interface="out" units="flux" />
  <variable name="delta_ADP_rxn8" public_interface="out" units="flux" />
  <variable name="delta_Pi_rxn8" public_interface="out" units="flux" />
  <variable name="delta_Carbamoyl_Pi_rxn8" public_interface="out" units="flux" />
  <variable name="km8" initial_value="1.0" units="micromolar" />
  <variable name="vmax8" initial_value="1.0" units="fourth_order_rate_constant" />
  <variable name="rate" units="flux" />
  <reaction reversible="no">
    <variable_ref variable="NH4">
      <role role="reactant" delta_variable="delta_NH4_rxn8" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="ATP">
      <role role="reactant" delta_variable="delta_ATP_rxn8" stoichiometry="2" />
    </variable_ref>
    <variable_ref variable="CO2">
      <role role="reactant" delta_variable="delta_CO2_rxn8" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="ADP">
      <role role="product" delta_variable="delta_ADP_rxn8" stoichiometry="2" />
    </variable_ref>
    <variable_ref variable="Pi">
      <role role="product" delta_variable="delta_Pi_rxn8" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Carbamoyl_Pi">
      <role role="product" delta_variable="delta_Carbamoyl_Pi_rxn8" stoichiometry="1" />
    </variable_ref>
    <variable_ref variable="Carbamoyl_phosphate_synthetase">
      <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>
        </math>
      </role>
    </variable_ref>
  </reaction>

```

```

    <apply>
      <divide />
      <apply>
        <times />
        <ci>NH4</ci>
        <apply>
          <power />
          <ci>ATP</ci>
          <cn cellml:units="dimensionless">2.0</cn>
        </apply>
        <ci>CO2</ci>
        <ci>vmax8</ci>
      </apply>
      <apply>
        <plus />
        <ci>km8</ci>
        <ci>NH4</ci>
        <apply>
          <power />
          <ci>ATP</ci>
          <cn cellml:units="dimensionless">2.0</cn>
        </apply>
        <ci>CO2</ci>
      </apply>
    </apply>
  </math>
</role>
</variable_ref>
</reaction>
</component>

<connection>
  <map_components component_1="Oxaloacetate" component_2="reaction0" />
  <map_variables variable_1="Oxaloacetate" variable_2="Oxaloacetate" />
  <map_variables variable_1="delta_Oxaloacetate_rxn0" variable_2="delta_Oxaloacetate_rxn0" />
</connection>

<connection>
  <map_components component_1="Aspartate" component_2="reaction0" />
  <map_variables variable_1="Aspartate" variable_2="Aspartate" />
  <map_variables variable_1="delta_Aspartate_rxn0" variable_2="delta_Aspartate_rxn0" />
</connection>

<connection>
  <map_components component_1="Aspartate" component_2="reaction5" />
  <map_variables variable_1="Aspartate" variable_2="Aspartate" />
  <map_variables variable_1="delta_Aspartate_rxn5" variable_2="delta_Aspartate_rxn5" />
</connection>

<connection>
  <map_components component_1="Argininosuccinate" component_2="reaction5" />
  <map_variables variable_1="Argininosuccinate" variable_2="Argininosuccinate" />
  <map_variables variable_1="delta_Argininosuccinate_rxn5" variable_2="delta_Argininosuccinate_rxn5" />
</connection>

<connection>
  <map_components component_1="Argininosuccinate" component_2="reaction5b" />
  <map_variables variable_1="Argininosuccinate" variable_2="Argininosuccinate" />

```

```
<map_variables variable_1="delta_Argininosuccinate_rxn5b" variable_2="delta_Argininosuccinate_rxn5b" />
</connection>

<connection>
  <map_components component_1="alpha_amino_acid" component_2="reaction0" />
  <map_variables variable_1="alpha_amino_acid" variable_2="alpha_amino_acid" />
  <map_variables variable_1="delta_alpha_amino_acid_rxn0" variable_2="delta_alpha_amino_acid_rxn0" />
</connection>

<connection>
  <map_components component_1="alpha_amino_acid" component_2="reaction1" />
  <map_variables variable_1="alpha_amino_acid" variable_2="alpha_amino_acid" />
  <map_variables variable_1="delta_alpha_amino_acid_rxn1" variable_2="delta_alpha_amino_acid_rxn1" />
</connection>

<connection>
  <map_components component_1="Oxo_2_acid" component_2="reaction0" />
  <map_variables variable_1="Oxo_2_acid" variable_2="Oxo_2_acid" />
  <map_variables variable_1="delta_Oxo_2_acid_rxn0" variable_2="delta_Oxo_2_acid_rxn0" />
</connection>

<connection>
  <map_components component_1="Oxo_2_acid" component_2="reaction1" />
  <map_variables variable_1="Oxo_2_acid" variable_2="Oxo_2_acid" />
  <map_variables variable_1="delta_Oxo_2_acid_rxn1" variable_2="delta_Oxo_2_acid_rxn1" />
</connection>

<connection>
  <map_components component_1="Oxoglutarate_2" component_2="reaction2" />
  <map_variables variable_1="Oxoglutarate_2" variable_2="Oxoglutarate_2" />
  <map_variables variable_1="delta_Oxoglutarate_2_rxn2" variable_2="delta_Oxoglutarate_2_rxn2" />
</connection>

<connection>
  <map_components component_1="Oxoglutarate_2" component_2="reaction1" />
  <map_variables variable_1="Oxoglutarate_2" variable_2="Oxoglutarate_2" />
  <map_variables variable_1="delta_Oxoglutarate_2_rxn1" variable_2="delta_Oxoglutarate_2_rxn1" />
</connection>

<connection>
  <map_components component_1="Glutamate" component_2="reaction1" />
  <map_variables variable_1="Glutamate" variable_2="Glutamate" />
  <map_variables variable_1="delta_Glutamate_rxn1" variable_2="delta_Glutamate_rxn1" />
</connection>

<connection>
  <map_components component_1="Glutamate" component_2="reaction4" />
  <map_variables variable_1="Glutamate" variable_2="Glutamate" />
  <map_variables variable_1="delta_Glutamate_rxn4" variable_2="delta_Glutamate_rxn4" />
</connection>

<connection>
  <map_components component_1="Glutamate" component_2="reaction2" />
  <map_variables variable_1="Glutamate" variable_2="Glutamate" />
  <map_variables variable_1="delta_Glutamate_rxn2" variable_2="delta_Glutamate_rxn2" />
</connection>

<connection>
  <map_components component_1="Glutamate" component_2="reaction3" />
```

```
<map_variables variable_1="Glutamate" variable_2="Glutamate" />
<map_variables variable_1="delta_Glutamate_rxn3" variable_2="delta_Glutamate_rxn3" />
</connection>

<connection>
  <map_components component_1="NADH" component_2="reaction2" />
  <map_variables variable_1="NADH" variable_2="NADH" />
  <map_variables variable_1="delta_NADH_rxn2" variable_2="delta_NADH_rxn2" />
</connection>

<connection>
  <map_components component_1="NH4" component_2="reaction2" />
  <map_variables variable_1="NH4" variable_2="NH4" />
  <map_variables variable_1="delta_NH4_rxn2" variable_2="delta_NH4_rxn2" />
</connection>

<connection>
  <map_components component_1="NH4" component_2="reaction4" />
  <map_variables variable_1="NH4" variable_2="NH4" />
  <map_variables variable_1="delta_NH4_rxn4" variable_2="delta_NH4_rxn4" />
</connection>

<connection>
  <map_components component_1="NH4" component_2="reaction3" />
  <map_variables variable_1="NH4" variable_2="NH4" />
  <map_variables variable_1="delta_NH4_rxn3" variable_2="delta_NH4_rxn3" />
</connection>

<connection>
  <map_components component_1="NH4" component_2="reaction8" />
  <map_variables variable_1="NH4" variable_2="NH4" />
  <map_variables variable_1="delta_NH4_rxn8" variable_2="delta_NH4_rxn8" />
</connection>

<connection>
  <map_components component_1="H" component_2="reaction2" />
  <map_variables variable_1="H" variable_2="H" />
  <map_variables variable_1="delta_H_rxn2" variable_2="delta_H_rxn2" />
</connection>

<connection>
  <map_components component_1="H" component_2="reaction3" />
  <map_variables variable_1="H" variable_2="H" />
  <map_variables variable_1="delta_H_rxn3" variable_2="delta_H_rxn3" />
</connection>

<connection>
  <map_components component_1="NAD" component_2="reaction2" />
  <map_variables variable_1="NAD" variable_2="NAD" />
  <map_variables variable_1="delta_NAD_rxn2" variable_2="delta_NAD_rxn2" />
</connection>

<connection>
  <map_components component_1="H2O" component_2="reaction2" />
  <map_variables variable_1="H2O" variable_2="H2O" />
  <map_variables variable_1="delta_H2O_rxn2" variable_2="delta_H2O_rxn2" />
</connection>

<connection>
```

```
<map_components component_1="H2O" component_2="reaction4" />
<map_variables variable_1="H2O" variable_2="H2O" />
<map_variables variable_1="delta_H2O_rxn4" variable_2="delta_H2O_rxn4" />
</connection>

<connection>
  <map_components component_1="H2O" component_2="reaction6" />
  <map_variables variable_1="H2O" variable_2="H2O" />
  <map_variables variable_1="delta_H2O_rxn6" variable_2="delta_H2O_rxn6" />
</connection>

<connection>
  <map_components component_1="Glutamine" component_2="reaction3" />
  <map_variables variable_1="Glutamine" variable_2="Glutamine" />
  <map_variables variable_1="delta_Glutamine_rxn3" variable_2="delta_Glutamine_rxn3" />
</connection>

<connection>
  <map_components component_1="Glutamine" component_2="reaction4" />
  <map_variables variable_1="Glutamine" variable_2="Glutamine" />
  <map_variables variable_1="delta_Glutamine_rxn4" variable_2="delta_Glutamine_rxn4" />
</connection>

<connection>
  <map_components component_1="ATP" component_2="reaction3" />
  <map_variables variable_1="ATP" variable_2="ATP" />
  <map_variables variable_1="delta_ATP_rxn3" variable_2="delta_ATP_rxn3" />
</connection>

<connection>
  <map_components component_1="ATP" component_2="reaction5" />
  <map_variables variable_1="ATP" variable_2="ATP" />
  <map_variables variable_1="delta_ATP_rxn5" variable_2="delta_ATP_rxn5" />
</connection>

<connection>
  <map_components component_1="ATP" component_2="reaction8" />
  <map_variables variable_1="ATP" variable_2="ATP" />
  <map_variables variable_1="delta_ATP_rxn8" variable_2="delta_ATP_rxn8" />
</connection>

<connection>
  <map_components component_1="ADP" component_2="reaction3" />
  <map_variables variable_1="ADP" variable_2="ADP" />
  <map_variables variable_1="delta_ADP_rxn3" variable_2="delta_ADP_rxn3" />
</connection>

<connection>
  <map_components component_1="ADP" component_2="reaction8" />
  <map_variables variable_1="ADP" variable_2="ADP" />
  <map_variables variable_1="delta_ADP_rxn8" variable_2="delta_ADP_rxn8" />
</connection>

<connection>
  <map_components component_1="Pi" component_2="reaction3" />
  <map_variables variable_1="Pi" variable_2="Pi" />
  <map_variables variable_1="delta_Pi_rxn3" variable_2="delta_Pi_rxn3" />
</connection>
```

```
<connection>
  <map_components component_1="Pi" component_2="reaction5" />
  <map_variables variable_1="Pi" variable_2="Pi" />
  <map_variables variable_1="delta_Pi_rxn5" variable_2="delta_Pi_rxn5" />
</connection>

<connection>
  <map_components component_1="Pi" component_2="reaction7" />
  <map_variables variable_1="Pi" variable_2="Pi" />
  <map_variables variable_1="delta_Pi_rxn7" variable_2="delta_Pi_rxn7" />
</connection>

<connection>
  <map_components component_1="Pi" component_2="reaction8" />
  <map_variables variable_1="Pi" variable_2="Pi" />
  <map_variables variable_1="delta_Pi_rxn8" variable_2="delta_Pi_rxn8" />
</connection>

<connection>
  <map_components component_1="Fumarate" component_2="reaction5b" />
  <map_variables variable_1="Fumarate" variable_2="Fumarate" />
  <map_variables variable_1="delta_Fumarate_rxn5b" variable_2="delta_Fumarate_rxn5b" />
</connection>

<connection>
  <map_components component_1="AMP" component_2="reaction5" />
  <map_variables variable_1="AMP" variable_2="AMP" />
  <map_variables variable_1="delta_AMP_rxn5" variable_2="delta_AMP_rxn5" />
</connection>

<connection>
  <map_components component_1="Arginine" component_2="reaction5b" />
  <map_variables variable_1="Arginine" variable_2="Arginine" />
  <map_variables variable_1="delta_Arginine_rxn5b" variable_2="delta_Arginine_rxn5b" />
</connection>

<connection>
  <map_components component_1="Arginine" component_2="reaction6" />
  <map_variables variable_1="Arginine" variable_2="Arginine" />
  <map_variables variable_1="delta_Arginine_rxn6" variable_2="delta_Arginine_rxn6" />
</connection>

<connection>
  <map_components component_1="Citrulline" component_2="reaction7" />
  <map_variables variable_1="Citrulline" variable_2="Citrulline" />
  <map_variables variable_1="delta_Citrulline_rxn7" variable_2="delta_Citrulline_rxn7" />
</connection>

<connection>
  <map_components component_1="Citrulline" component_2="reaction5" />
  <map_variables variable_1="Citrulline" variable_2="Citrulline" />
  <map_variables variable_1="delta_Citrulline_rxn5" variable_2="delta_Citrulline_rxn5" />
</connection>

<connection>
  <map_components component_1="Ornithine" component_2="reaction6" />
  <map_variables variable_1="Ornithine" variable_2="Ornithine" />
  <map_variables variable_1="delta_Ornithine_rxn6" variable_2="delta_Ornithine_rxn6" />
</connection>
```

```

<connection>
  <map_components component_1="Ornithine" component_2="reaction7" />
  <map_variables variable_1="Ornithine" variable_2="Ornithine" />
  <map_variables variable_1="delta_Ornithine_rxn7" variable_2="delta_Ornithine_rxn7" />
</connection>

<connection>
  <map_components component_1="Urea" component_2="reaction6" />
  <map_variables variable_1="Urea" variable_2="Urea" />
  <map_variables variable_1="delta_Urea_rxn6" variable_2="delta_Urea_rxn6" />
</connection>

<connection>
  <map_components component_1="Carbamoyl_Pi" component_2="reaction8" />
  <map_variables variable_1="Carbamoyl_Pi" variable_2="Carbamoyl_Pi" />
  <map_variables variable_1="delta_Carbamoyl_Pi_rxn8" variable_2="delta_Carbamoyl_Pi_rxn8" />
</connection>

<connection>
  <map_components component_1="Carbamoyl_Pi" component_2="reaction7" />
  <map_variables variable_1="Carbamoyl_Pi" variable_2="Carbamoyl_Pi" />
  <map_variables variable_1="delta_Carbamoyl_Pi_rxn7" variable_2="delta_Carbamoyl_Pi_rxn7" />
</connection>

<connection>
  <map_components component_1="CO2" component_2="reaction8" />
  <map_variables variable_1="CO2" variable_2="CO2" />
  <map_variables variable_1="delta_CO2_rxn8" variable_2="delta_CO2_rxn8" />
</connection>

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

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

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

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

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

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

```

```
</connection>

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

<connection>
  <map_components component_1="Oxo_2_acid" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="Oxoglutarate_2" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

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

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

<connection>
  <map_components component_1="NH4" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

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

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

<connection>
  <map_components component_1="H2O" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

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

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

<connection>
  <map_components component_1="Arginine" component_2="global_variables" />
  <map_variables variable_1="time" variable_2="time" />
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<connection>
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<connection>
  <map_components component_1="Aminotransferase" component_2="global_variables" />
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    <map_components component_1="Glutaminase" component_2="reaction4" />
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<connection>
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    <map_components component_1="Arginase" component_2="reaction6" />
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<connection>
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