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<?xml version="1.0"?>
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<!--
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```
FILE : basic_ep_model.xml
```

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CREATED : 27 November 2000
```

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

```
AUTHOR : Warren Hedley (w.hedley@auckland.ac.nz)  
         Department of Engineering Science  
         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 an extremely simple  
              electro-physiological/membrane cellular model. The model and associated  
              markup have been created solely for demonstration purposes.
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```
The root element for our CellML model description is <model>. This contains  
a "name" attribute which would be used if the model were to be combined with  
another model at a later date, or if the model is to be referenced in some  
way by another model.
```

```
Two namespaces are declared on the root element. The first sets the default  
namespace for the <model> element and all elements contained within the  
<model> element to the CellML namespace. The second namespace is again the  
CellML namespace, but this time declared with an explicit "cellml" prefix.  
This declaration has document-wide scope, so the "cellml" prefix may be used  
anywhere to move an element or attribute into the CellML namespace.
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```
<model name="basic_ep_model" xmlns="http://www.cellml.org/cellml/1.0#" xmlns:cellml="http://www.cellml.org/cellml/1.0#" />
```

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns:bqgs="http://www.cellml.org/bqgs/1.0#" />
```

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```
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.
```

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

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```
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>Hedley</vCard:Family>
```

```
<vCard:Given>Warren</vCard:Given>
```

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

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

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

```
<vCard:Orgunit>The Engineering Science Department</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>2000-11-20</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>
    Added 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 "basic_ep_model", which is declared on the <model>
-->
<rdf:Description rdf:about="#basic_ep_model">
  <!-- A human readable name for the model. -->
  <dc:title>A Simple Electrophysiological Model</dc:title>

  <!-- A comment regarding the model. -->
  <cmeta:comment rdf:parseType="Resource">
    <rdf:value>
      Below is a CellML description of a simple electrophysiological model.
      The purpose of this description is to illustrate how CellML can be
      used to model ionic currents and changes in ionic concentrations
    </rdf:value>
    <!-- The creator of the comment. -->
    <dc:creator>
      <vCard:FN>Catherine Lloyd</vCard:FN>
    </dc:creator>
  </cmeta:comment>
</rdf:Description>
</rdf:RDF>

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<!--
  The following <units> elements are used to declare a set of unit names
  that can be referenced by units attributes on <variable> and <cn> elements
  elsewhere in the model. See the example documentation of the simple
  electro-physiological model for more details.
-->
<units name="concentration_units">
  <unit prefix="milli" units="mole" />
  <unit units="litre" exponent="-1" />
</units>

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

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

<!--
  The environment component is used to declare variables that are used
  by all or most of the other components. Variables must be declared inside
  of a component element.
-->
<component name="environment">
  <variable name="time" public_interface="out" units="second" />
</component>

<!--
  The first component to be defined in this simple model is the intra-
  cellular compartment. This defines the intra-cellular concentrations of
  sodium and calcium ions, and defines their behaviour in terms of the fluxes
  across the membrane.
-->
<component name="intra_cellular_space">
  <!-- the following variables are used in other components -->
  <variable name="Na" public_interface="out" units="concentration_units" />
  <variable name="Ca" public_interface="out" units="concentration_units" />

  <!-- the following variables are imported from other components -->
  <variable name="time" public_interface="in" units="second" />
  <variable name="I_Na" public_interface="in" units="flux_units" />
  <variable name="I_Ca" public_interface="in" units="flux_units" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply><eq />
      <apply><diff />
        <bvar><ci> time </ci></bvar>
        <ci> Na </ci>
      </apply>
      <ci> I_Na </ci>
    </apply>

    <apply><eq />

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    <apply><diff />
      <bvar><ci> time </ci></bvar>
      <ci> Ca </ci>
    </apply>
    <ci> I_Ca </ci>
  </apply>
</math>
</component>

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The second component corresponds to the extra-cellular space. The variables and equations are the same as for the intra-cellular compartment.

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```

<component name="extra_cellular_space">

```

```

  <!-- the following variables are used in other components -->

```

```

  <variable name="Na" public_interface="out" units="concentration_units" />

```

```

  <variable name="Ca" public_interface="out" units="concentration_units" />

```

```

  <!-- the following variables are imported from other components -->

```

```

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

```

```

  <variable name="I_Na" public_interface="in" units="flux_units" />

```

```

  <variable name="I_Ca" public_interface="in" units="flux_units" />

```

```

  <math xmlns="http://www.w3.org/1998/Math/MathML">

```

```

    <apply><eq />

```

```

      <apply><diff />

```

```

        <bvar><ci> time </ci></bvar>

```

```

        <ci> Na </ci>

```

```

      </apply>

```

```

      <apply><times />

```

```

        <cn cellml:units="dimensionless"> -1.0 </cn>

```

```

        <ci> I_Na </ci>

```

```

      </apply>

```

```

    </apply>

```

```

  <apply><eq />

```

```

    <apply><diff />

```

```

      <bvar><ci> time </ci></bvar>

```

```

      <ci> Ca </ci>

```

```

    </apply>

```

```

    <apply><times />

```

```

      <cn cellml:units="dimensionless"> -1.0 </cn>

```

```

      <ci> I_Ca </ci>

```

```

    </apply>

```

```

  </apply>

```

```

</math>

```

```

</component>

```

```

<!--

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The membrane component defines the fluxes across the membrane in terms of the intra- and extra-cellular ion concentrations and some rate constants.

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```

<component name="cell_membrane">

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```

  <!-- the following variables are used in other components -->

```

```

  <variable name="I_Na" public_interface="out" units="flux_units" />

```

```

  <variable name="I_Ca" public_interface="out" units="flux_units" />

```

```

<!-- the following variables are imported from other components -->
<variable name="Na_i" public_interface="in" units="concentration_units" />
<variable name="Na_e" public_interface="in" units="concentration_units" />
<variable name="Ca_i" public_interface="in" units="concentration_units" />
<variable name="Ca_e" public_interface="in" units="concentration_units" />

<!-- the following variables are only used internally -->
<variable name="v_Na" initial_value="1.0e-8" units="rate_constant" />
<variable name="v_Ca" initial_value="1.5e-8" units="rate_constant" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply><eq />
    <ci> I_Na </ci>
    <apply><times />
      <ci> v_Na </ci>
      <apply><minus />
        <ci> Na_i </ci>
        <ci> Na_e </ci>
      </apply>
    </apply>
  </math>

  <apply><eq />
    <ci> I_Ca </ci>
    <apply><times />
      <ci> v_Ca </ci>
      <apply><minus />
        <ci> Ca_i </ci>
        <ci> Ca_e </ci>
      </apply>
    </apply>
  </math>
</component>

<!--
  Both the intra- and extra-cellular components are simply connected to the
  membrane, and the ion concentrations and fluxes are passed back and forth
  as appropriate.
-->
<connection>
  <map_components component_1="intra_cellular_space" component_2="cell_membrane" />
  <map_variables variable_1="Na" variable_2="Na_i" />
  <map_variables variable_1="Ca" variable_2="Ca_i" />
  <map_variables variable_1="I_Na" variable_2="I_Na" />
  <map_variables variable_1="I_Ca" variable_2="I_Ca" />
</connection>

<connection>
  <map_components component_1="extra_cellular_space" component_2="cell_membrane" />
  <map_variables variable_1="Na" variable_2="Na_e" />
  <map_variables variable_1="Ca" variable_2="Ca_e" />
  <map_variables variable_1="I_Na" variable_2="I_Na" />
  <map_variables variable_1="I_Ca" variable_2="I_Ca" />
</connection>

```

```
<!--  
  The following connections explicitly pass the variable "time" between the  
  "global_variables" component and the intra- and extra-cellular components,  
  where it is used.  
-->  
<connection>  
  <map_components component_1="environment" component_2="intra_cellular_space" />  
  <map_variables variable_1="time" variable_2="time" />  
</connection>  
  
<connection>  
  <map_components component_1="environment" component_2="extra_cellular_space" />  
  <map_variables variable_1="time" variable_2="time" />  
</connection>  
  
</model>
```