

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

```
<!-- FILE : LR_II_model_1994.xml
```

```
CREATED : 19th September 2003
```

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LAST MODIFIED : 19th September 2003
```

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

```
MODEL STATUS : This model conforms to the CellML 1.1 Specification and the CellML Metadata 1.0
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```
DESCRIPTION : This file contains a CellML description of the mammalian  
ventricular action potential based on the Luo-Rudy II model, 1994. This model  
is a development of the LR-I model, and where appropriate, the import and reuse features of CellML
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CHANGES:
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```
<model
```

```
  name="LR_II_model_1994"  
  cmeta:id="LR_II_model_1994"  
  xmlns="http://www.cellml.org/cellml/1.1#"   
  xmlns:cellml="http://www.cellml.org/cellml/1.1#"   
  xmlns:cmeta="http://www.cellml.org/metadata/1.0#"   
  xmlns:xlink="http://www.w3.org/1999/xlink">
```

```
<rdf:RDF
```

```
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"   
  xmlns:cmeta="http://www.cellml.org/metadata/1.0#"   
  xmlns:bqs="http://www.cellml.org/bqs/1.1#"   
  xmlns:dc="http://purl.org/dc/elements/1.1/"   
  xmlns:dcterms="http://purl.org/dc/terms/"   
  xmlns:vCard="http://www.w3.org/2001/vcard-rdf/3.0#">
```

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<!--
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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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<!--
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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>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>

<!--
  The Creation Date metadata. This is the date on which the model
  was translated into CellML.
-->
<dcterms:created rdf:parseType="Resource">
  <dcterms:W3CDTF>2003-09-19</dcterms:W3CDTF>
</dcterms:created>

<!--
  The Modification History metadata. This lists the changes that have been
  made to the document, who made the changes, and when they were made.
-->

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

<!--
  The following metadata refers to the model itself, as indicated by the
  reference to the ID "LR_II_model_1994", which is declared on the
  <model> element.
-->
<rdf:Description rdf:about="#LR_II_model_1994">
  <!-- A human readable name for the model. -->
  <dc:title>
    The Luo-Rudy II Model of Mammalian Ventricular Cardiac Action
    Potentials, 1994
  </dc:title>

  <!-- A comment regarding the model. -->
  <cmeta:comment rdf:parseType="Resource">
    <rdf:value>
      This is the CellML description of Luo and Rudy's mathematical model of
      the mammalian cardiac ventricular action potential. It is a
      significant development on their original 1991 model, and where
      appropriate, the import and reuse features of CellML 1.1 have been
      used to import components and units from the LR I model intoth eLR II
      model.
    </rdf:value>
    <!-- The creator of the comment. -->
    <dc:creator rdf:parseType="Resource">
      <vCard:FN>Catherine Lloyd</vCard:FN>
    </dc:creator>
  </cmeta:comment>

  <!-- The model is relevant to all mammals. -->
  <cmeta:species>Mammalia</cmeta:species>

  <cmeta:bio_entity>Ventricular Myocyte</cmeta:bio_entity>

<!--
  The CellML Metadata Specification recommends that bibliographic metadata
  is used to provide information about the original model reference. The

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"identifier" attribute on the "BibliographicReference" class provides an elegant way to identify a cited reference using a database identifier date, etc can be looked up on the database.

such

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```
<bqs:reference rdf:parseType="Resource">
  <bqs:Pubmed_id>7514509</bqs:Pubmed_id>
  <bqs:JournalArticle rdf:parseType="Resource">
    <dc:creator>
      <rdf:Seq>
        <rdf:li rdf:parseType="Resource">
          <bqs:Person rdf:parseType="Resource">
            <vCard:N rdf:parseType="Resource">
              <vCard:Family>Luo</vCard:Family>
              <vCard:Given>Ching-hsing</vCard:Given>
            </vCard:N>
          </bqs:Person>
        </rdf:li>
        <rdf:li rdf:parseType="Resource">
          <bqs:Person rdf:parseType="Resource">
            <vCard:N rdf:parseType="Resource">
              <vCard:Family>Rudy</vCard:Family>
              <vCard:Given>Yoram</vCard:Given>
            </vCard:N>
          </bqs:Person>
        </rdf:li>
      </rdf:Seq>
    </dc:creator>
    <dc:title>
      A Dynamic Model of the Cardiac Ventricular Action Potential I.
    </dc:title>
    <dcterms:issued rdf:parseType="Resource">
      <dcterms:W3CDTF>1994-06</dcterms:W3CDTF>
    </dcterms:issued>
    <bqs:Journal rdf:parseType="Resource">
      <dc:title>Circulation Research</dc:title>
    </bqs:Journal>
    <bqs:volume>74</bqs:volume>
    <bqs:first_page>1071</bqs:first_page>
    <bqs:last_page>1096</bqs:last_page>
  </bqs:JournalArticle>
</bqs:reference>
</rdf:Description>
</rdf:RDF>

<import xlink:href="http://www.cellml.org/examples/models/luo_rudy_I_model_1991.xml">
  <units name="millisecond" units_ref="millisecond" />
  <units name="per_millisecond" units_ref="per_millisecond" />
  <units name="millivolt" units_ref="millivolt" />
  <units name="per_millivolt" units_ref="per_millivolt" />
  <units name="per_millivolt_millisecond" units_ref="per_millivolt_millisecond" />
  <units name="microF_per_cm2" units_ref="microF_per_cm2" />
  <units name="joule_per_kilomole_kelvin" units_ref="joule_per_kilomole_kelvin" />
  <units name="coulomb_per_mole" units_ref="coulomb_per_mole" />

  <component name="environment" component_ref="environment" />
  <component name="fast_sodium_current" component_ref="fast_sodium_current" />
  <component name="time_dependent_potassium_current" component_ref="time_dependent_potassium_current" />
  <component name="time_independent_potassium_current" component_ref="time_independent_potassium_current" />
  <component name="plateau_potassium_current" component_ref="plateau_potassium_current" />
```

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</import>

<!--
  Below, we define some additional units for association with variables and
  constants within the model.
-->

<units name="milliS_per_microF">
  <unit prefix="milli" units="siemens" />
  <unit prefix="milli" units="farad" exponent="-1" />
</units>

<units name="microF">
  <unit prefix="micro" units="farad" />
</units>

<units name="microA_per_microF">
  <unit prefix="micro" units="ampere" />
  <unit prefix="micro" units="farad" exponent="-1" />
</units>

<units name="millimolar_per_millisecond">
  <unit prefix="milli" units="mole" />
  <unit units="litre" exponent="-1" />
  <unit units="millisecond" exponent="-1" />
</units>

<units name="millimolar">
  <unit prefix="milli" units="mole" />
  <unit units="litre" exponent="-1" />
</units>

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

<units name="cm_per_second">
  <unit prefix="centi" units="metre" />
  <unit units="second" exponent="-1" />
</units>

<units name="mm2">
  <unit prefix="milli" units="metre" exponent="2" />
</units>

<units name="micro_litre">
  <unit prefix="micro" units="litre" />
</units>

<component name="membrane">
  <variable name="V" public_interface="out" initial_value="-84.624" units="millivolt" />
  <variable name="R" public_interface="out" initial_value="8314.0" units="joule_per_kilomo
  <variable name="T" public_interface="out" initial_value="310.0" units="kelvin" />
  <variable name="F" public_interface="out" initial_value="96500.0" units="coulomb_per_mole

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<variable name="Cm" initial_value="1.0" units="microF" />
<variable name="I_st" initial_value="-100.0" units="microA_per_microF" />

<variable name="time" public_interface="in" units="millisecond" />
<variable name="i_Na" public_interface="in" units="microA_per_microF" />
<variable name="i_Ca_L" public_interface="in" units="microA_per_microF" />
<variable name="i_K" public_interface="in" units="microA_per_microF" />
<variable name="i_NaCa" public_interface="in" units="microA_per_microF" />
<variable name="i_K1" public_interface="in" units="microA_per_microF" />
<variable name="i_Kp" public_interface="in" units="microA_per_microF" />
<variable name="i_p_Ca" public_interface="in" units="microA_per_microF" />
<variable name="i_Na_b" public_interface="in" units="microA_per_microF" />
<variable name="i_Ca_b" public_interface="in" units="microA_per_microF" />
<variable name="i_NaK" public_interface="in" units="microA_per_microF" />
<variable name="i_ns_Ca" public_interface="in" units="microA_per_microF" />

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

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  <apply id="membrane_voltage_diff_eq"><eq />
    <apply><diff />
      <bvar><ci> time </ci></bvar>
      <ci> V </ci>
    </apply>
    <apply><times />
      <apply><minus />
        <apply><divide />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <ci> Cm </ci>
        </apply>
      </apply>
      <apply><plus />
        <ci> i_Na </ci>
        <ci> i_Ca_L </ci>
        <ci> i_K </ci>
        <ci> i_K1 </ci>
        <ci> i_Kp </ci>
        <ci> i_NaCa </ci>
        <ci> i_p_Ca </ci>
        <ci> i_Na_b </ci>
        <ci> i_Ca_b </ci>
        <ci> i_NaK </ci>
        <ci> i_ns_Ca </ci>
        <ci> I_st </ci>
      </apply>
    </apply>
  </math>

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</component>

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<component name="L_type_Ca_channel">

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  <variable name="i_Ca_L" public_interface="out" units="microA_per_microF" />
  <variable name="i_CaCa" public_interface="out" units="microA_per_microF" />
  <variable name="i_CaK" public_interface="out" units="microA_per_microF" />
  <variable name="i_CaNa" public_interface="out" units="microA_per_microF" />
  <variable name="gamma_Nai" public_interface="out" initial_value="0.75" units="dimensionless" />
  <variable name="gamma_Nao" public_interface="out" initial_value="0.75" units="dimensionless" />
  <variable name="gamma_Ki" public_interface="out" initial_value="0.75" units="dimensionless" />
  <variable name="gamma_Ko" public_interface="out" initial_value="0.75" units="dimensionless" />

  <variable name="I_CaCa" units="microA_per_microF" />

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<variable name="I_CaK" units="microA_per_microF" />
<variable name="I_CaNa" units="microA_per_microF" />
<variable name="P_Ca" initial_value="0.00054" units="cm_per_second" />
<variable name="P_Na" initial_value="0.000000675" units="cm_per_second" />
<variable name="P_K" initial_value="0.000000193" units="cm_per_second" />
<variable name="gamma_Cai" initial_value="1.0" units="dimensionless" />
<variable name="gamma_Cao" initial_value="0.34" units="dimensionless" />

<variable name="time" public_interface="in" private_interface="out" units="millisecond" />
<variable name="V" public_interface="in" private_interface="out" units="millivolt" />
<variable name="Cai" public_interface="in" private_interface="out" units="micromolar" />
<variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
<variable name="T" public_interface="in" units="kelvin" />
<variable name="F" public_interface="in" units="coulomb_per_mole" />
<variable name="Cao" public_interface="in" units="millimolar" />
<variable name="Nao" public_interface="in" units="millimolar" />
<variable name="Ko" public_interface="in" units="millimolar" />
<variable name="Nai" public_interface="in" units="millimolar" />
<variable name="Ki" public_interface="in" units="millimolar" />

<variable name="d" private_interface="in" units="dimensionless" />
<variable name="f" private_interface="in" units="dimensionless" />
<variable name="f_Ca" private_interface="in" units="dimensionless" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="i_CaCa_calculation"><eq />
    <ci> i_CaCa </ci>
    <apply><times />
      <ci> d </ci>
      <ci> f </ci>
      <ci> f_Ca </ci>
      <ci> I_CaCa </ci>
    </apply>
  </apply>

  <apply id="i_CaNa_calculation"><eq />
    <ci> i_CaNa </ci>
    <apply><times />
      <ci> d </ci>
      <ci> f </ci>
      <ci> f_Ca </ci>
      <ci> I_CaNa </ci>
    </apply>
  </apply>

  <apply id="i_CaK_calculation"><eq />
    <ci> i_CaK </ci>
    <apply><times />
      <ci> d </ci>
      <ci> f </ci>
      <ci> f_Ca </ci>
      <ci> I_CaK </ci>
    </apply>
  </apply>

  <apply id="I_CaCa_calculation"><eq />
    <ci> I_CaCa </ci>
    <apply><times />
      <ci> P_Ca </ci>

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<apply><power />
  <cn cellml:units="dimensionless"> 2.0 </cn>
  <cn cellml:units="dimensionless"> 2.0 </cn>
</apply>
<apply><divide />
  <apply><times />
    <ci> V </ci>
    <apply><power />
      <ci> F </ci>
      <cn cellml:units="dimensionless"> 2.0 </cn>
    </apply>
  </apply>
  <apply><times />
    <ci> R </ci>
    <ci> T </ci>
  </apply>
</apply>
<apply><divide />
  <apply><minus />
    <apply><times />
      <ci> gamma_Cai </ci>
      <ci> Cai </ci>
      <apply><exp />
        <apply><divide />
          <apply><times />
            <cn cellml:units="dimensionless"> 2.0 </cn>
            <ci> V </ci>
            <ci> F </ci>
          </apply>
          <apply><times />
            <ci> R </ci>
            <ci> T </ci>
          </apply>
        </apply>
      </apply>
    </apply>
    <apply><times />
      <ci> gamma_Cao </ci>
      <ci> Cao </ci>
    </apply>
  </apply>
  <apply><minus />
    <apply><exp />
      <apply><divide />
        <apply><times />
          <cn cellml:units="dimensionless"> 2.0 </cn>
          <ci> V </ci>
          <ci> F </ci>
        </apply>
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
      </apply>
    </apply>
  </apply>
  <cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</apply>

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</apply>

<apply id="I_CaNa_calculation"><eq />
  <ci> I_CaNa </ci>
  <apply><times />
    <ci> P_Na </ci>
    <apply><power />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <cn cellml:units="dimensionless"> 2.0 </cn>
    </apply>
  </apply>
  <apply><divide />
    <apply><times />
      <ci> V </ci>
      <apply><power />
        <ci> F </ci>
        <cn cellml:units="dimensionless"> 2.0 </cn>
      </apply>
    </apply>
  </apply>
  <apply><times />
    <ci> R </ci>
    <ci> T </ci>
  </apply>
</apply>
<apply><divide />
  <apply><minus />
    <apply><times />
      <ci> gamma_Nai </ci>
      <ci> Nai </ci>
      <apply><exp />
        <apply><divide />
          <apply><times />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <ci> V </ci>
            <ci> F </ci>
          </apply>
          <apply><times />
            <ci> R </ci>
            <ci> T </ci>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><times />
    <ci> gamma_Nao </ci>
    <ci> Nao </ci>
  </apply>
</apply>
<apply><minus />
  <apply><exp />
    <apply><divide />
      <apply><times />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> V </ci>
        <ci> F </ci>
      </apply>
      <apply><times />
        <ci> R </ci>
        <ci> T </ci>
      </apply>
    </apply>
  </apply>
</apply>

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        </apply>
    </apply>
    <cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</apply>
</apply>
</apply>
</apply>
<apply id="I_CaK_calculation"><eq />
<ci> I_CaK </ci>
<apply><times />
    <ci> P_K </ci>
    <apply><power />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <cn cellml:units="dimensionless"> 2.0 </cn>
    </apply>
</apply><divide />
    <apply><times />
        <ci> V </ci>
        <apply><power />
            <ci> F </ci>
            <cn cellml:units="dimensionless"> 2.0 </cn>
        </apply>
    </apply>
</apply><times />
    <ci> R </ci>
    <ci> T </ci>
</apply>
</apply>
<apply><divide />
    <apply><minus />
        <apply><times />
            <ci> gamma_Ki </ci>
            <ci> Ki </ci>
            <apply><exp />
                <apply><divide />
                    <apply><times />
                        <cn cellml:units="dimensionless"> 1.0 </cn>
                        <ci> V </ci>
                        <ci> F </ci>
                    </apply>
                    <apply><times />
                        <ci> R </ci>
                        <ci> T </ci>
                    </apply>
                </apply>
            </apply>
        </apply>
    </apply>
    <apply><times />
        <ci> gamma_Ko </ci>
        <ci> Ko </ci>
    </apply>
</apply>
<apply><minus />
    <apply><exp />
        <apply><divide />
            <apply><times />
                <cn cellml:units="dimensionless"> 1.0 </cn>
                <ci> V </ci>
            </apply>
        </apply>
    </apply>
</apply>

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        <ci> F </ci>
      </apply>
    <apply><times />
      <ci> R </ci>
      <ci> T </ci>
    </apply>
  </apply>
</apply>
<cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</math>
</component>

<component name="L_type_Ca_channel_d_gate">
  <variable name="d" public_interface="out" units="dimensionless" />

  <variable name="alpha_d" units="per_millisecond" />
  <variable name="beta_d" units="per_millisecond" />
  <variable name="d_infinity" units="dimensionless" />
  <variable name="tau_d" units="millisecond" />

  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="time" public_interface="in" units="millisecond" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="alpha_d_calculation"><eq />
      <ci> alpha_d </ci>
      <apply><divide />
        <ci> d_infinity </ci>
        <ci> tau_d </ci>
      </apply>
    </apply>

    <apply id="d_infinity_calculation"><eq />
      <ci> d_infinity </ci>
      <apply><divide />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><plus />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <apply><exp />
            <apply><minus />
              <apply><divide />
                <apply><plus />
                  <ci> V </ci>
                  <cn cellml:units="millivolt"> 10.0 </cn>
                </apply>
              <cn cellml:units="millivolt"> 6.24 </cn>
            </apply>
          </apply>
        </apply>
      </apply>
    </math>
  </component>

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        </apply>
    </apply>
    <apply><times />
        <ci> beta_d </ci>
        <ci> d </ci>
    </apply>
</apply>
</math>
</component>

<component name="L_type_Ca_channel_f_gate">
    <variable name="f" public_interface="out" units="dimensionless" />

    <variable name="alpha_f" units="per_millisecond" />
    <variable name="beta_f" units="per_millisecond" />
    <variable name="f_infinity" units="dimensionless" />
    <variable name="tau_f" units="millisecond" />

    <variable name="V" public_interface="in" units="millivolt" />
    <variable name="time" public_interface="in" units="millisecond" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="alpha_f_calculation"><eq />
        <ci> alpha_f </ci>
        <apply><divide />
            <ci> f_infinity </ci>
            <ci> tau_f </ci>
        </apply>
    </apply>

    <apply id="f_infinity_calculation"><eq />
        <ci> f_infinity </ci>
        <apply><plus />
            <apply><divide />
                <cn cellml:units="dimensionless"> 1.0 </cn>
                <apply><plus />
                    <cn cellml:units="dimensionless"> 1.0 </cn>
                </apply><exp />
                    <apply><divide />
                        <apply><plus />
                            <ci> V </ci>
                            <cn cellml:units="millivolt"> 35.06 </cn>
                        </apply>
                        <cn cellml:units="millivolt"> 8.6 </cn>
                    </apply>
                </apply>
            </apply>
        </apply>
        <cn cellml:units="dimensionless"> 0.6 </cn>
        <apply><plus />
            <cn cellml:units="dimensionless"> 1.0 </cn>
        </apply><exp />
            <apply><divide />
                <apply><minus />
                    <cn cellml:units="millivolt"> 50.0 </cn>
                    <ci> V </ci>
                </apply>
            </apply>
    </apply>

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        <apply><times />
        <ci> beta_f </ci>
        <ci> f </ci>
    </apply>
</apply>
</math>
</component>

<component name="L_type_Ca_channel_f_Ca_gate">
    <variable name="f_Ca" public_interface="out" units="dimensionless" />

    <variable name="Km_Ca" initial_value="0.6" units="micromolar" />

    <variable name="V" public_interface="in" units="millivolt" />
    <variable name="time" public_interface="in" units="millisecond" />
    <variable name="Cai" public_interface="in" units="micromolar" />

    <math xmlns="http://www.w3.org/1998/Math/MathML">
        <apply id="f_Ca_calculation"><eq />
            <ci> f_Ca </ci>
            <apply><divide />
                <cn cellml:units="dimensionless"> 1.0 </cn>
                <apply><plus />
                    <cn cellml:units="dimensionless"> 1.0 </cn>
                    <apply><power />
                        <apply><divide />
                            <ci> Cai </ci>
                            <ci> Km_Ca </ci>
                        </apply>
                    <cn cellml:units="dimensionless"> 2.0 </cn>
                </apply>
            </apply>
        </math>
    </component>

<component name="sarcolemmal_calcium_pump">
    <variable name="i_p_Ca" public_interface="out" units="microA_per_microF" />

    <variable name="K_mpCa" initial_value="0.5" units="micromolar" />
    <variable name="I_pCa" initial_value="1.15" units="microA_per_microF" />

    <variable name="time" public_interface="in" units="millisecond" />
    <variable name="Cai" public_interface="in" units="micromolar" />

    <math xmlns="http://www.w3.org/1998/Math/MathML">
        <apply id="i_p_Ca_calculation"><eq />
            <ci> i_p_Ca </ci>
            <apply><times />
                <ci> I_pCa </ci>
                <apply><divide />
                    <ci> Cai </ci>
                    <apply><plus />
                        <ci> K_mpCa </ci>
                        <ci> Cai </ci>
                    </apply>
                </apply>
        </math>
    </component>

```

```

    </apply>
  </apply>
</math>
</component>

<component name="sodium_background_current">
  <variable name="i_Na_b" public_interface="out" units="microA_per_microF" />

  <variable name="g_Nab" initial_value="0.00141" units="milliS_per_microF" />
  <variable name="E_NaN" units="millivolt" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="E_Na" public_interface="in" units="millivolt" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="E_NaN_calculation"><eq />
      <ci> E_NaN </ci>
      <ci> E_Na </ci>
    </apply>

    <apply id="i_Na_b_calculation"><eq />
      <ci> i_Na_b </ci>
      <apply><times />
        <ci> g_Nab </ci>
      <apply><minus />
        <ci> V </ci>
        <ci> E_NaN </ci>
      </apply>
    </apply>
  </math>
</component>

<component name="calcium_background_current">
  <variable name="i_Ca_b" public_interface="out" units="microA_per_microF" />

  <variable name="g_Cab" initial_value="0.003016" units="milliS_per_microF" />
  <variable name="E_CaN" units="millivolt" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="Cai" public_interface="in" units="micromolar" />
  <variable name="Cao" public_interface="in" units="millimolar" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="E_CaN_calculation"><eq />
      <ci> E_CaN </ci>
      <apply><times />
        <apply><divide />
          <apply><times />
            <ci> R </ci>
            <ci> T </ci>
          </apply>
        <apply><times />
          <cn cellml:units="dimensionless"> 2.0 </cn>
        </apply>
      </apply>
    </math>

```

```

        <ci> F </ci>
      </apply>
    </apply>
  <apply><ln />
    <apply><divide />
      <ci> Cao </ci>
      <ci> Cai </ci>
    </apply>
  </apply>
</apply>
</math>
</component>

<component name="sodium_potassium_pump">
  <variable name="i_NaK" public_interface="out" units="microA_per_microF" />

  <variable name="I_NaK" initial_value="1.5" units="microA_per_microF" />
  <variable name="f_NaK" units="dimensionless" />
  <variable name="K_mNai" initial_value="10.0" units="millimolar" />
  <variable name="K_mKo" initial_value="1.5" units="millimolar" />
  <variable name="sigma" units="dimensionless" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="Nai" public_interface="in" units="millimolar" />
  <variable name="Nao" public_interface="in" units="millimolar" />
  <variable name="Ko" public_interface="in" units="millimolar" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="f_NaK_calculation"><eq />
      <ci> f_NaK </ci>
      <apply><divide />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><plus />
          <apply><plus />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <apply><times />
              <cn cellml:units="dimensionless"> 0.1245 </cn>
              <apply><exp />
                <apply><times />
                  <cn cellml:units="dimensionless"> -0.1 </cn>
                  <apply><divide />
                    <apply><times />
                      <ci> V </ci>

```



```

    <apply><plus />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><power />
        <apply><divide />
          <ci> K_mNai </ci>
          <ci> Nai </ci>
        </apply>
      <cn cellml:units="dimensionless"> 1.5 </cn>
    </apply>
  </apply>
</apply>
<apply><divide />
  <ci> Ko </ci>
  <apply><plus />
    <ci> Ko </ci>
    <ci> K_mKo </ci>
  </apply>
</apply>
</math>
</component>

<component name="non_specific_calcium_activated_current">
  <variable name="i_ns_Ca" public_interface="out" units="microA_per_microF" />
  <variable name="i_ns_Na" public_interface="out" units="microA_per_microF" />
  <variable name="i_ns_K" public_interface="out" units="microA_per_microF" />

  <variable name="P_ns_Ca" initial_value="1.75E-7" units="cm_per_second" />

  <variable name="gamma_Nai" public_interface="in" units="dimensionless" />
  <variable name="gamma_Nao" public_interface="in" units="dimensionless" />
  <variable name="gamma_Ki" public_interface="in" units="dimensionless" />
  <variable name="gamma_Ko" public_interface="in" units="dimensionless" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="Cao" public_interface="in" units="millimolar" />
  <variable name="Nao" public_interface="in" units="millimolar" />
  <variable name="Ko" public_interface="in" units="millimolar" />
  <variable name="Nai" public_interface="in" units="millimolar" />
  <variable name="Ki" public_interface="in" units="millimolar" />
  <variable name="I_ns_Na" units="microA_per_microF" />
  <variable name="I_ns_K" units="microA_per_microF" />
  <variable name="K_m_ns_Ca" initial_value="1.2" units="micromolar" />
  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="Cai" public_interface="in" units="micromolar" />
  <variable name="V" public_interface="in" units="millivolt" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="i_ns_Na_calculation"><eq />
      <ci> i_ns_Na </ci>
      <apply><times />
        <ci> I_ns_Na </ci>
      </apply><divide />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><plus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
      </apply><power />

```



```

</apply>
<apply><divide />
  <apply><minus />
    <apply><times />
      <ci> gamma_Nai </ci>
      <ci> Nai </ci>
      <apply><exp />
        <apply><divide />
          <apply><times />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <ci> V </ci>
            <ci> F </ci>
          </apply>
          <apply><times />
            <ci> R </ci>
            <ci> T </ci>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><times />
    <ci> gamma_Nao </ci>
    <ci> Nao </ci>
  </apply>
</apply>
<apply><minus />
  <apply><exp />
    <apply><divide />
      <apply><times />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> V </ci>
        <ci> F </ci>
      </apply>
      <apply><times />
        <ci> R </ci>
        <ci> T </ci>
      </apply>
    </apply>
  </apply>
  <cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</apply>
</apply>

<apply id="I_ns_K_calculation"><eq />
  <ci> I_ns_K </ci>
  <apply><times />
    <ci> P_ns_Ca </ci>
    <apply><power />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <cn cellml:units="dimensionless"> 2.0 </cn>
    </apply>
  </apply>
  <apply><divide />
    <apply><times />
      <ci> V </ci>
      <apply><power />
        <ci> F </ci>
        <cn cellml:units="dimensionless"> 2.0 </cn>
      </apply>
    </apply>
  </apply>
</eq>

```

```

        </apply>
    </apply>
    <apply><times />
        <ci> R </ci>
        <ci> T </ci>
    </apply>
</apply>
<apply><divide />
    <apply><minus />
        <apply><times />
            <ci> gamma_Ki </ci>
            <ci> Ki </ci>
        <apply><exp />
            <apply><divide />
                <apply><times />
                    <cn cellml:units="dimensionless"> 1.0 </cn>
                    <ci> V </ci>
                    <ci> F </ci>
                </apply>
                <apply><times />
                    <ci> R </ci>
                    <ci> T </ci>
                </apply>
            </apply>
        </apply>
    </apply>
    <apply><times />
        <ci> gamma_Ko </ci>
        <ci> Ko </ci>
    </apply>
</apply>
<apply><minus />
    <apply><exp />
        <apply><divide />
            <apply><times />
                <cn cellml:units="dimensionless"> 1.0 </cn>
                <ci> V </ci>
                <ci> F </ci>
            </apply>
            <apply><times />
                <ci> R </ci>
                <ci> T </ci>
            </apply>
        </apply>
    </apply>
    <cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</apply>
</math>
</component>

<component name="Na_Ca_exchanger">
    <variable name="i_NaCa" public_interface="out" units="microA_per_microF" />

    <variable name="K_NaCa" initial_value="2000.0" units="microA_per_microF" />
    <variable name="K_mNa" initial_value="87.5" units="millimolar" />
    <variable name="K_mCa" initial_value="1.38" units="millimolar" />

```

```

<variable name="K_sat" initial_value="0.1" units="dimensionless" />
<variable name="eta" initial_value="0.35" units="dimensionless" />

<variable name="time" public_interface="in" units="millisecond" />
<variable name="V" public_interface="in" units="millivolt" />
<variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
<variable name="T" public_interface="in" units="kelvin" />
<variable name="F" public_interface="in" units="coulomb_per_mole" />
<variable name="Nai" public_interface="in" units="millimolar" />
<variable name="Nao" public_interface="in" units="millimolar" />
<variable name="Cai" public_interface="in" units="micromolar" />
<variable name="Cao" public_interface="in" units="millimolar" />

```

```

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="Na_Ca_exchanger"><eq />
    <ci> i_NaCa </ci>
    <apply><times />
      <ci> K_NaCa </ci>
      <apply><divide />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><plus />
          <apply><power />
            <ci> K_mNa </ci>
            <cn cellml:units="dimensionless"> 3.0 </cn>
          </apply>
          <apply><power />
            <ci> Nao </ci>
            <cn cellml:units="dimensionless"> 3.0 </cn>
          </apply>
        </apply>
      </apply>
    <apply><divide />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><plus />
        <ci> K_mCa </ci>
        <ci> Cao </ci>
      </apply>
    </apply>
    <apply><divide />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><plus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><times />
          <ci> K_sat </ci>
          <apply><exp />
            <apply><times />
              <apply><minus />
                <ci> eta </ci>
                <cn cellml:units="dimensionless"> 1.0 </cn>
              </apply>
            <ci> V </ci>
          </apply>
          <apply><divide />
            <ci> F </ci>
            <apply><times />
              <ci> R </ci>
              <ci> T </ci>
            </apply>
          </apply>
        </apply>
      </apply>
    </apply>
  </math>

```

```

        </apply>
      </apply>
    </apply>
  </apply>
  <apply><minus />
    <apply><times />
      <apply><exp />
        <apply><times />
          <ci> eta </ci>
          <ci> V </ci>
          <apply><divide />
            <ci> F </ci>
            <apply><times />
              <ci> R </ci>
              <ci> T </ci>
            </apply>
          </apply>
        </apply>
      </apply>
    </apply>
  <apply><power />
    <ci> Nai </ci>
    <cn cellml:units="dimensionless"> 3.0 </cn>
  </apply>
  <ci> Cao </ci>
</apply>
<apply><times />
  <apply><exp />
    <apply><times />
      <apply><minus />
        <ci> eta </ci>
        <cn cellml:units="dimensionless"> 1.0 </cn>
      </apply>
      <ci> V </ci>
      <apply><divide />
        <ci> F </ci>
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><power />
    <ci> Nao </ci>
    <cn cellml:units="dimensionless"> 3.0 </cn>
  </apply>
  <ci> Cai </ci>
</apply>
</apply>
</math>
</component>

<component name="calcium_buffers_in_the_myoplasm">
  <variable name="K_mTn" initial_value="0.5" units="micromolar" />
  <variable name="K_mCMDN" initial_value="2.38" units="micromolar" />
  <variable name="Tn_max" initial_value="70.0" units="micromolar" />
  <variable name="CMDN_max" initial_value="50.0" units="micromolar" />

```

```

<variable name="Tn_buff" units="micromolar" />
<variable name="CMDN_buff" units="micromolar" />

<variable name="time" public_interface="in" units="millisecond" />
<variable name="Cai" public_interface="in" units="micromolar" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="Tn_buff_calculation"><eq />
    <ci> Tn_buff </ci>
    <apply><times />
      <ci> Tn_max </ci>
      <apply><divide />
        <ci> Cai </ci>
        <apply><plus />
          <ci> Cai </ci>
          <ci> K_mTn </ci>
        </apply>
      </apply>
    </apply>
  </math>

  <apply id="CMDN_buff_calculation"><eq />
    <ci> CMDN_buff </ci>
    <apply><times />
      <ci> CMDN_max </ci>
      <apply><divide />
        <ci> Cai </ci>
        <apply><plus />
          <ci> Cai </ci>
          <ci> K_mCMDN </ci>
        </apply>
      </apply>
    </apply>
  </math>
</component>

<component name="calcium_fluxes_in_the_SR">
  <variable name="i_rel" public_interface="out" units="millimolar_per_millisecond" />
  <variable name="i_up" public_interface="out" units="millimolar_per_millisecond" />
  <variable name="i_leak" public_interface="out" units="millimolar_per_millisecond" />
  <variable name="i_tr" public_interface="out" units="millimolar_per_millisecond" />

  <variable name="G_rel" units="per_millisecond" />
  <variable name="G_rel_max" units="per_millisecond" />
  <variable name="tau_on" initial_value="2.0" units="millisecond" />
  <variable name="tau_off" initial_value="2.0" units="millisecond" />
  <variable name="tau_tr" initial_value="180.0" units="millisecond" />
  <variable name="t" initial_value="0.0" units="millisecond" />
  <variable name="K_mrel" initial_value="0.8" units="micromolar" />
  <variable name="delta_Ca_i2" units="micromolar" />
  <variable name="delta_Ca_ith" initial_value="0.18" units="micromolar" />
  <variable name="CSQN_buff" units="millimolar" />
  <variable name="CSQN_max" initial_value="10.0" units="millimolar" />
  <variable name="CSQN_th" initial_value="0.7" units="millimolar" />
  <variable name="K_mCSQN" initial_value="0.8" units="millimolar" />
  <variable name="K_mup" initial_value="0.92" units="micromolar" />
  <variable name="K_leak" units="per_millisecond" />

```

```

<variable name="I_up" initial_value="0.005" units="millimolar_per_millisecond" />
<variable name="Ca_NSR_max" initial_value="0.15" units="millimolar" />
<variable name="calcium_overload" units="dimensionless" />

<variable name="time" public_interface="in" units="millisecond" />
<variable name="Cai" public_interface="in" units="micromolar" />
<variable name="Ca_JSR" public_interface="in" units="millimolar" />
<variable name="Ca_NSR" public_interface="in" units="millimolar" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="i_rel_calculation"><eq />
    <ci> i_rel </ci>
    <apply><times />
      <ci> G_rel </ci>
      <apply><minus />
        <ci> Ca_JSR </ci>
        <ci> Cai </ci>
      </apply>
    </apply>
  </apply>

  <apply id="G_rel_calculation"><eq />
    <ci> G_rel </ci>
    <piecewise>
      <piece>
        <apply><times />
          <ci> G_rel_max </ci>
          <apply><divide />
            <apply><minus />
              <ci> delta_Ca_i2 </ci>
              <ci> delta_Ca_ith </ci>
            </apply>
            <apply><minus />
              <apply><plus />
                <ci> K_mrel </ci>
                <ci> delta_Ca_i2 </ci>
              </apply>
              <ci> delta_Ca_ith </ci>
            </apply>
          </apply>
        </piece>
        <apply><minus />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <apply><exp />
            <apply><minus />
              <apply><divide />
                <ci> t </ci>
                <ci> tau_on </ci>
              </apply>
            </apply>
          </apply>
        </piece>
      </piecewise>
    </apply>
  </apply>

```

```

</apply>
<apply><eq />
  <ci> calcium_overload </ci>
  <cn cellml:units="dimensionless"> 0.0 </cn>
</apply>
</piece>
<otherwise>
  <apply><times />
    <ci> G_rel_max </ci>
    <apply><minus />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><exp />
        <apply><minus />
          <apply><divide />
            <ci> t </ci>
            <ci> tau_on </ci>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><exp />
    <apply><minus />
      <apply><divide />
        <ci> t </ci>
        <ci> tau_off </ci>
      </apply>
    </apply>
  </apply>
</otherwise>
</piecewise>
</apply>

<apply id="G_rel_max_calculation"><eq />
  <ci> G_rel_max </ci>
  <piecewise>
    <piece>
      <piecewise>
        <piece>
          <cn cellml:units="per_millisecond"> 0.0 </cn>
          <apply><lt />
            <ci> delta_Ca_i2 </ci>
            <ci> delta_Ca_ith </ci>
          </apply>
        </piece>
        <otherwise>
          <cn cellml:units="per_millisecond"> 60.0 </cn>
        </otherwise>
      </piecewise>
    </piece>
  </piecewise>
  <apply><eq />
    <ci> calcium_overload </ci>
    <cn cellml:units="dimensionless"> 0.0 </cn>
  </apply>
</piece>
<otherwise>
  <piecewise>
    <piece>
      <cn cellml:units="per_millisecond"> 0.0 </cn>
      <apply><lt />
    </piece>
  </piecewise>

```

```

        <ci> CSQN_buff </ci>
        <ci> CSQN_th </ci>
    </apply>
</piece>
<otherwise>
    <cn cellml:units="per_millisecond"> 4.0 </cn>
</otherwise>
</piecewise>
</otherwise>
</piecewise>
</apply>

```

```

<apply id="CSQN_buff_calculation"><eq />
    <ci> CSQN_buff </ci>
    <apply><times />
        <ci> CSQN_max </ci>
        <apply><divide />
            <ci> Ca_JSR </ci>
            <apply><plus />
                <ci> Ca_JSR </ci>
                <ci> K_mCSQN </ci>
            </apply>
        </apply>
    </apply>
</apply>

```

```

<apply id="i_up_calculation"><eq />
    <ci> i_up </ci>
    <apply><times />
        <ci> I_up </ci>
        <apply><divide />
            <ci> Cai </ci>
            <apply><plus />
                <ci> Cai </ci>
                <ci> K_mup </ci>
            </apply>
        </apply>
    </apply>
</apply>

```

```

<apply id="i_leak_calcualtion"><eq />
    <ci> i_leak </ci>
    <apply><times />
        <ci> K_leak </ci>
        <ci> Ca_NSR </ci>
    </apply>
</apply>

```

```

<apply id="K_leak_calculation"><eq />
    <ci> K_leak </ci>
    <apply><divide />
        <ci> I_up </ci>
        <ci> Ca_NSR_max </ci>
    </apply>
</apply>

```

```

<apply id="i_tr_calculation"><eq />
    <ci> i_tr </ci>
    <apply><divide />

```

```

    <apply><minus />
      <ci> Ca_NSR </ci>
      <ci> Ca_JSR </ci>
    </apply>
    <ci> tau_tr </ci>
  </apply>
</math>
</component>

<component name="ionic_concentrations">
  <variable name="Nai" public_interface="out" initial_value="10.0" units="millimolar" />
  <variable name="Nao" public_interface="out" initial_value="140.0" units="millimolar" />
  <variable name="Cai" public_interface="out" initial_value="0.12" units="micromolar" />
  <variable name="Cao" public_interface="out" initial_value="1.8" units="millimolar" />
  <variable name="Ki" public_interface="out" initial_value="145.0" units="millimolar" />
  <variable name="Ko" public_interface="out" initial_value="5.4" units="millimolar" />
  <variable name="Ca_JSR" public_interface="out" units="millimolar" />
  <variable name="Ca_NSR" public_interface="out" initial_value="15.0" units="millimolar" />
  <variable name="Ca_foot" units="micromolar" />

  <variable name="A_cap" initial_value="0.000153" units="mm2" />
  <variable name="R_A_V" units="dimensionless" />
  <variable name="V_myo" units="micro_litre" />
  <variable name="V_cleft" units="micro_litre" />
  <variable name="V_JSR" units="micro_litre" />
  <variable name="V_NSR" units="micro_litre" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="i_Na" public_interface="in" units="microA_per_microF" /> <variabl
  <variable name="i_Na_b" public_interface="in" units="microA_per_microF" />
  <variable name="i_ns_Na" public_interface="in" units="microA_per_microF" /> <variabl
  <variable name="i_NaK" public_interface="in" units="microA_per_microF" />
  <variable name="i_CaCa" public_interface="in" units="microA_per_microF" />
  <variable name="i_CaK" public_interface="in" units="microA_per_microF" />
  <variable name="i_p_Ca" public_interface="in" units="microA_per_microF" />
  <variable name="i_Ca_b" public_interface="in" units="microA_per_microF" />
  <variable name="i_K" public_interface="in" units="microA_per_microF" />
  <variable name="i_K1" public_interface="in" units="microA_per_microF" />
  <variable name="i_Kp" public_interface="in" units="microA_per_microF" /> <variabl
  <variable name="i_tr" public_interface="in" units="millimolar_per_millisecond" />
  <variable name="i_rel" public_interface="in" units="millimolar_per_millisecond" />
  <variable name="i_leak" public_interface="in" units="millimolar_per_millisecond" />
  <variable name="i_up" public_interface="in" units="millimolar_per_millisecond" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="sodium_diff_eq"><eq />
    <apply><diff />
      <bvar><ci> time </ci></bvar>
      <ci> Nai </ci>
    </apply>
    <apply><times />
      <apply><minus />
        <apply><plus />
          <ci> i_Na </ci>
          <ci> i_CaNa </ci>
          <ci> i_Na_b </ci>
          <ci> i_ns_Na </ci>

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    <apply><times />
      <ci> i_NaCa </ci>
      <cn cellml:units="dimensionless"> 3.0 </cn>
    </apply>
    <apply><times />
      <ci> i_NaK </ci>
      <cn cellml:units="dimensionless"> 3.0 </cn>
    </apply>
  </apply>
</apply>
<apply><divide />
  <ci> A_cap </ci>
  <apply><times />
    <ci> V_myo </ci>
    <ci> F </ci>
  </apply>
</apply>
</apply>
</apply>
</apply>
<apply id="calcium_internal_diff_eq"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> Cai </ci>
  </apply>
  <apply><plus />
    <apply><times />
      <apply><minus />
        <apply><plus />
          <ci> i_CaCa </ci>
          <ci> i_p_Ca </ci>
          <ci> i_Ca_b </ci>
        </apply>
        <ci> i_NaCa </ci>
      </apply>
      <apply><divide />
        <ci> A_cap </ci>
        <apply><times />
          <cn cellml:units="dimensionless"> 2.0 </cn>
          <ci> V_myo </ci>
          <ci> F </ci>
        </apply>
      </apply>
    </apply>
    <apply><times />
      <ci> i_rel </ci>
      <apply><divide />
        <ci> V_JSR </ci>
        <ci> V_myo </ci>
      </apply>
    </apply>
    <apply><times />
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        <ci> i_leak </ci>
        <ci> i_up </ci>
      </apply>
      <apply><divide />
        <ci> V_NSR </ci>
        <ci> V_myo </ci>
      </apply>
    </apply>
  </apply>

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    </apply>
  </apply>
</apply>
</apply>

<apply id="potassium_internal_diff_eq"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> Ki </ci>
  </apply>
  <apply><times />
    <apply><minus />
      <apply><plus />
        <ci> i_CaK </ci>
        <ci> i_K </ci>
        <ci> i_K1 </ci>
        <ci> i_Kp </ci>
        <ci> i_ns_K </ci>
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        <apply><times />
          <ci> i_NaK </ci>
          <cn cellml:units="dimensionless"> 2.0 </cn>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><divide />
    <ci> A_cap </ci>
    <apply><times />
      <ci> V_myo </ci>
      <ci> F </ci>
    </apply>
  </apply>
</apply>
</apply>

<apply id="potassium_external_diff_eq"><eq />
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    <bvar><ci> time </ci></bvar>
    <ci> Ko </ci>
  </apply>
  <apply><times />
    <apply><plus />
      <ci> i_CaK </ci>
      <ci> i_K </ci>
      <ci> i_K1 </ci>
      <ci> i_Kp </ci>
      <ci> i_ns_K </ci>
    <apply><minus />
      <apply><times />
        <ci> i_NaK </ci>
        <cn cellml:units="dimensionless"> 2.0 </cn>
      </apply>
    </apply>
  </apply>
  <apply><divide />
    <ci> A_cap </ci>
    <apply><times />
      <ci> V_cleft </ci>
    </apply>
  </apply>
</apply>

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        <ci> F </ci>
    </apply>
</apply>
</apply>
</apply>
</apply>

<apply id="calcium_JSR_diff_eq"><eq />
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  </apply>
  <apply><minus />
    <apply><minus />
      <ci> i_rel </ci>
      <apply><times />
        <ci> i_tr </ci>
        <apply><divide />
          <ci> V_NSR </ci>
          <ci> V_JSR </ci>
        </apply>
      </apply>
    </apply>
  </apply>
</apply>

<apply id="calcium_NSR_diff_eq"><eq />
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    <ci> Ca_NSR </ci>
  </apply>
  <apply><minus />
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      <apply><plus />
        <ci> i_leak </ci>
        <ci> i_tr </ci>
      </apply>
      <ci> i_up </ci>
    </apply>
  </apply>
</apply>

<apply id="calcium_foot_diff_eq"><eq />
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    <ci> Ca_foot </ci>
  </apply>
  <apply><times />
    <apply><minus />
      <ci> i_CaCa </ci>
    </apply>
    <apply><divide />
      <ci> A_cap </ci>
      <apply><times />
        <cn cellml:units="dimensionless"> 2.0 </cn>
        <ci> V_myo </ci>
        <ci> F </ci>
      </apply>
    </apply>
  </apply>
  <ci> R_A_V </ci>
</apply>

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    </apply>
  </apply>
</math>
</component>
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  <component_ref component="membrane">
    <component_ref component="fast_sodium_current" />
    <component_ref component="L_type_Ca_channel">
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    </component_ref>
    <component_ref component="time_dependent_potassium_current" />
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    <component_ref component="plateau_potassium_current" />
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    <component_ref component="sodium_potassium_pump" />
    <component_ref component="non_specific_calcium_activated_current" />
    <component_ref component="ionic_concentrations" />
    <component_ref component="calcium_buffers_in_the_myoplasm" />
    <component_ref component="calcium_fluxes_in_the_SR" />
  </component_ref>
</group>
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<group>
  <relationship_ref relationship="encapsulation" />
  <component_ref component="L_type_Ca_channel">
    <component_ref component="L_type_Ca_channel_d_gate" />
    <component_ref component="L_type_Ca_channel_f_gate" />
    <component_ref component="L_type_Ca_channel_f_Ca_gate" />
  </component_ref>
</group>
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<connection>
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  <map_variables variable_1="time" variable_2="time" />
</connection>
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<connection>
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  <map_variables variable_1="time" variable_2="time" />
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<connection>
  <map_components component_1="Na_Ca_exchanger" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />
</connection>
```

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<connection>
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</connection>
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<connection>
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</connection>

<connection>
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  <map_variables variable_1="time" variable_2="time" />
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<connection>
  <map_components component_1="sodium_potassium_pump" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

<connection>
  <map_components component_1="non_specific_calcium_activated_current" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />
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<connection>
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<connection>
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</connection>

<connection>
  <map_components component_1="calcium_fluxes_in_the_SR" component_2="environment" />
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<connection>
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  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_Na" variable_2="i_Na" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
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  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_Ca_L" variable_2="i_Ca_L" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
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</connection>

<connection>
  <map_components component_1="membrane" component_2="time_dependent_potassium_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_K" variable_2="i_K" />
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    <map_variables variable_1="T" variable_2="T" />
    <map_variables variable_1="F" variable_2="F" />
</connection>

<connection>
    <map_components component_1="membrane" component_2="Na_Ca_exchanger" />
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    <map_variables variable_1="i_NaCa" variable_2="i_NaCa" />
    <map_variables variable_1="R" variable_2="R" />
    <map_variables variable_1="T" variable_2="T" />
    <map_variables variable_1="F" variable_2="F" />
</connection>

<connection>
    <map_components component_1="membrane" component_2="time_independent_potassium_current" />
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    <map_variables variable_1="i_K1" variable_2="i_K1" />
    <map_variables variable_1="R" variable_2="R" />
    <map_variables variable_1="T" variable_2="T" />
    <map_variables variable_1="F" variable_2="F" />
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<connection>
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    <map_variables variable_1="i_Kp" variable_2="i_Kp" />
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<connection>
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</connection>

<connection>
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<connection>
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    <map_variables variable_1="R" variable_2="R" />
    <map_variables variable_1="T" variable_2="T" />
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    <map_variables variable_1="R" variable_2="R" />
    <map_variables variable_1="T" variable_2="T" />
    <map_variables variable_1="F" variable_2="F" />
</connection>

<connection>
    <map_components component_1="membrane" component_2="non_specific_calcium_activated_curren

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    <map_variables variable_1="V" variable_2="V" />
    <map_variables variable_1="R" variable_2="R" />
    <map_variables variable_1="T" variable_2="T" />
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    <map_variables variable_1="i_ns_Ca" variable_2="i_ns_Ca" />
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</connection>

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    <map_variables variable_1="Nai" variable_2="Nai" />
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    <map_variables variable_1="E_Na" variable_2="E_Na" />
</connection>

<connection>
    <map_components component_1="L_type_Ca_channel" component_2="ionic_concentrations" />
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    <map_variables variable_1="Cao" variable_2="Cao" />
    <map_variables variable_1="Nao" variable_2="Nao" />
    <map_variables variable_1="Nai" variable_2="Nai" />
    <map_variables variable_1="Ko" variable_2="Ko" />
    <map_variables variable_1="Ki" variable_2="Ki" />
    <map_variables variable_1="i_CaCa" variable_2="i_CaCa" />
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<connection>
    <map_components component_1="time_dependent_potassium_current" component_2="ionic_concentrations" />
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    <map_variables variable_1="Ko" variable_2="Ko" />
    <map_variables variable_1="Nao" variable_2="Nao" />
    <map_variables variable_1="Nai" variable_2="Nai" />
    <map_variables variable_1="i_K" variable_2="i_K" />
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<connection>
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    <map_variables variable_1="Nai" variable_2="Nai" />
    <map_variables variable_1="Cao" variable_2="Cao" />
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    <map_variables variable_1="i_NaCa" variable_2="i_NaCa" />
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    <map_variables variable_1="Ki" variable_2="Ki" />
    <map_variables variable_1="Ko" variable_2="Ko" />

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    <map_variables variable_1="i_K1" variable_2="i_K1" />
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<connection>
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<connection>
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<connection>
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</connection>

<connection>
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    <map_variables variable_1="Nao" variable_2="Nao" />
    <map_variables variable_1="Ko" variable_2="Ko" />
    <map_variables variable_1="i_NaK" variable_2="i_NaK" />
</connection>

<connection>
    <map_components component_1="non_specific_calcium_activated_current" component_2="ionic_concentrations" />
    <map_variables variable_1="Cai" variable_2="Cai" />
    <map_variables variable_1="Cao" variable_2="Cao" />
    <map_variables variable_1="Nao" variable_2="Nao" />
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    <map_variables variable_1="Ko" variable_2="Ko" />
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<connection>
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</connection>

<connection>
    <map_components component_1="calcium_fluxes_in_the_SR" component_2="ionic_concentrations" />
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    <map_variables variable_1="i_tr" variable_2="i_tr" />
    <map_variables variable_1="i_leak" variable_2="i_leak" />
    <map_variables variable_1="i_up" variable_2="i_up" />
    <map_variables variable_1="Cai" variable_2="Cai" />
    <map_variables variable_1="Ca_JSR" variable_2="Ca_JSR" />

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    <map_variables variable_1="Ca_NSR" variable_2="Ca_NSR" />
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  <map_variables variable_1="gamma_Nao" variable_2="gamma_Nao" />
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  <map_variables variable_1="gamma_Ko" variable_2="gamma_Ko" />
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  <map_components component_1="L_type_Ca_channel" component_2="L_type_Ca_channel_d_gate" />
  <map_variables variable_1="d" variable_2="d" />
  <map_variables variable_1="time" variable_2="time" />
  <map_variables variable_1="V" variable_2="V" />
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<connection>
  <map_components component_1="L_type_Ca_channel" component_2="L_type_Ca_channel_f_gate" />
  <map_variables variable_1="f" variable_2="f" />
  <map_variables variable_1="time" variable_2="time" />
  <map_variables variable_1="V" variable_2="V" />
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<connection>
  <map_components component_1="L_type_Ca_channel" component_2="L_type_Ca_channel_f_Ca_gate
  <map_variables variable_1="f_Ca" variable_2="f_Ca" />
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  <map_variables variable_1="Cai" variable_2="Cai" />
  <map_variables variable_1="V" variable_2="V" />
</connection>

</model>

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