Updated Luo-Rudy Mammalian Ventricular Model II

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CellML 1.1

The historical series of ventricular myocyte models described below is naturally illustrated by use of the *import* and *reuse* features of CellML 1.1. Components and units are imported from the original model and they are used as a foundation upon which the more developed models are built. New components are added and then connected up to the relevant imported components.

Model Structure

A subsequent pair of papers by Ching-hsing Luo and Yoram Rudy (1994a; 1994b) further developed the Luo-Rudy I model [../../repository/LR_I_model_1991_doc.html] by addressing some of the issues which were not investigated in their original model. In particular, the LR-II model incorporates a more thorough description of the processes which regulate intracellular calcium ion concentration and the movement of calcium ions through the cell and to and from the sarcoplasmic reticulum (see Figure 1 below).

The complete original paper reference is cited below:

A Dynamic Model of the Cardiac Ventricular Action Potential - Simulations of Ionic Currents and Concentration Changes [http://circres.ahajournals.org/cgi/content/abstract/74/6/1071], Ching-hsing Luo and Yoram Rudy, 1994, *Circulation Research* [http://circres.ahajournals.org/], 74, 1071-1097.

Since the model was published in 1994, it has been updated several times, incorporating new experimental data taken from papers written by other authors. These modifications have been considered in the model presented here. To illustrate how the Luo-Rudy II dynamic model has been developed, see the sequence of diagrams (Figure 1, Figure 2, Figure 3 and Figure 4) below. The 1997 Shaw and Rudy model diagram is identical to the 1999 Viswanathan model diagram since the only difference between the two models is that the Viswanathan model introduces a second activation gate (X_{s2}) into the formulation of I_{Ks}. The development of the Luo-Rudy II model has been documented by Case Western Reserve University (To view this website, follow this link: http://www.cwru.edu/med/CBRTC/LRdOnline/development.htm [http://www.cwru.edu/med/CBRTC/LRdOnline/development.htm])

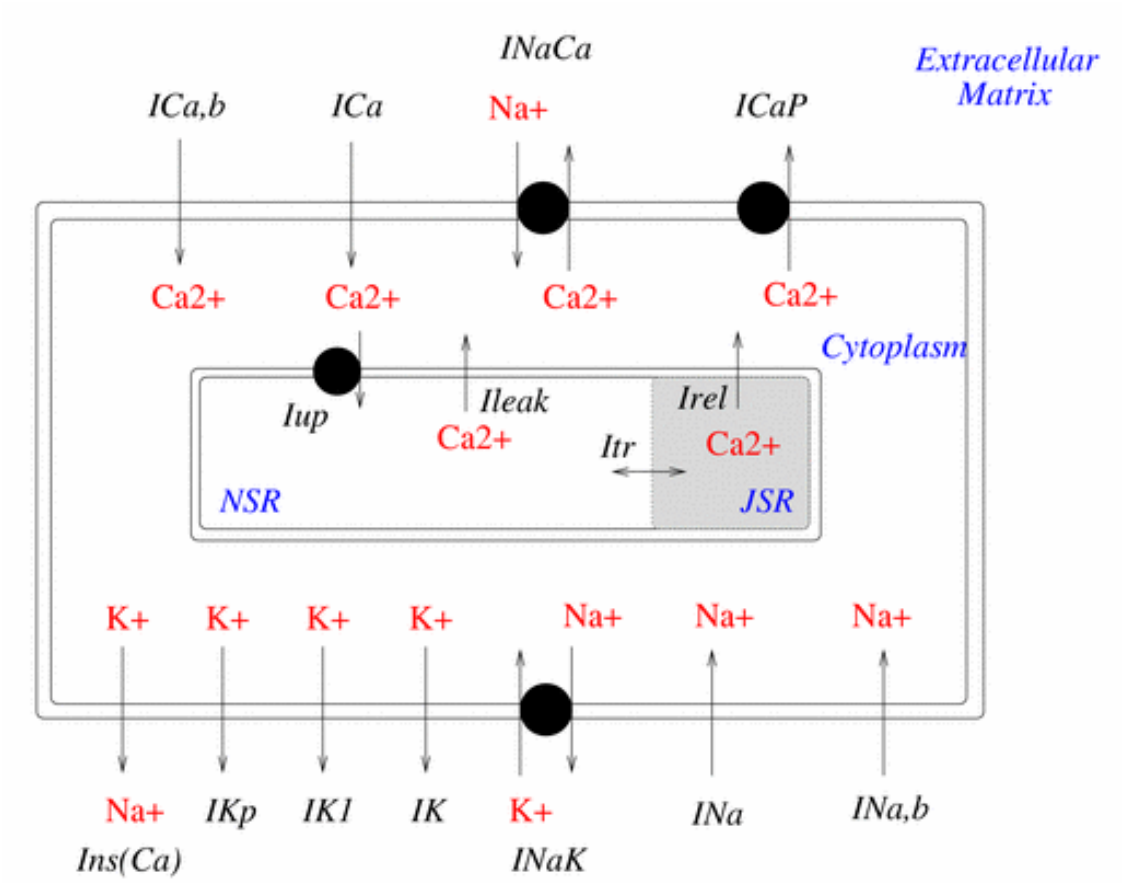

Figure 1. A schematic diagram describing the current flows across the cell membrane that are captured in the original, 1994 Luo-Rudy II, dynamic model.

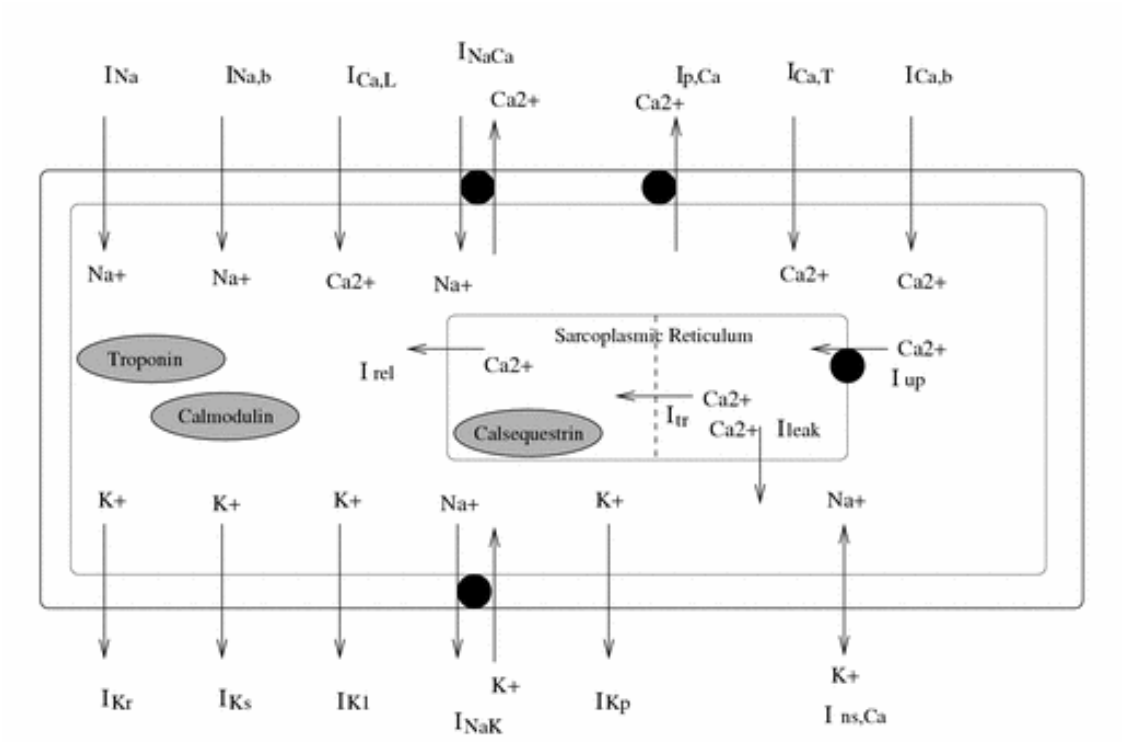

Figure 2. A schematic diagram showing the updated Luo-Rudy II, dynamic model. In their 1995 ventricular model Zeng *et al* have included the slow and fast components of the delayed rectifier K^+ current, I_{Kr} and I_{Ks}. A T-type Calcium channel ($I_{Ca(T)}$) is also added.

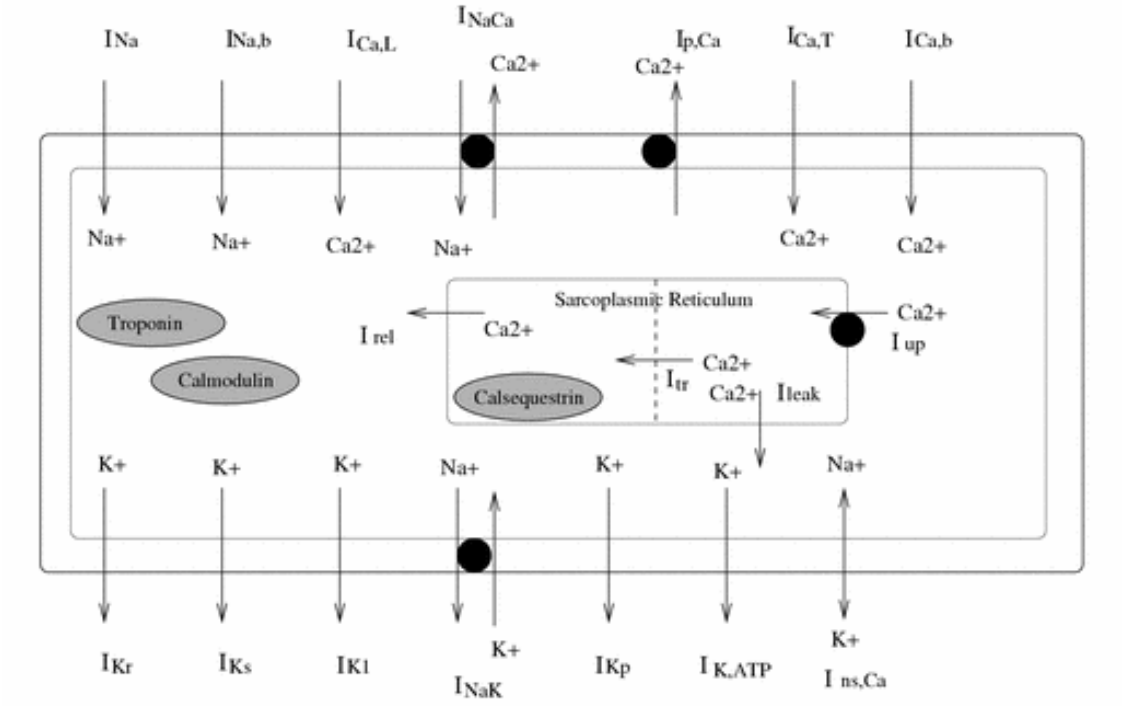

Figure 3. In their 1997 model Shaw and Rudy have built upon the 1995 Zeng *et al* version of the 1994 Luo-Rudy Dynamic Ventricular Model. In addition to the slow and fast components of the delayed rectifier K^+ current, (I_{Kr} and I_{Ks}) and the T-type Calcium channel ($I_{Ca(T)}$), Shaw and Rudy have included an

ATP-dependent potassium current ($I_{K(ATP)}$) in their model. In turn, Viswanathan *et al* develop this model to include two activation gates (X_{s1} and X_{s2}) into the formulation of I_{Ks}.

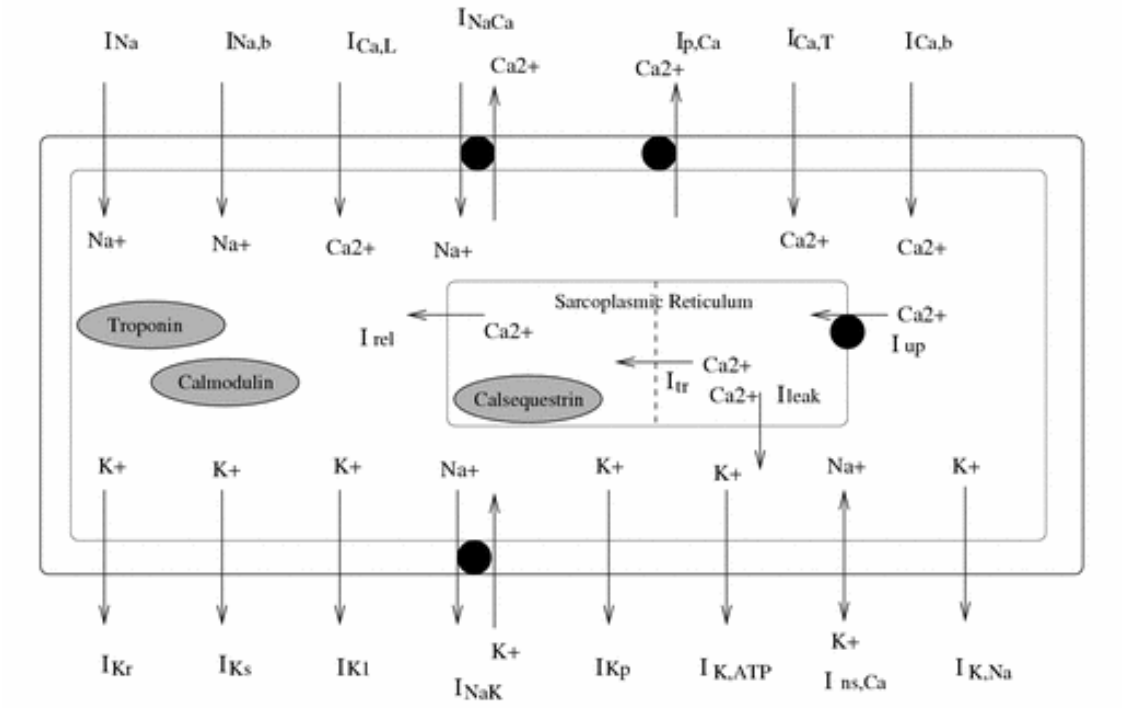

Figure 4. In this most recent version of the 1994 Luo-Rudy Dynamic Ventricular Model, Faber and Rudy have built upon the 1999 Viswanathan model and they have added a sodium-dependent potassium current ($I_{K(Na)}$).

All the original paper references are cited below:

Two Components of the Delayed Rectifier K^+ Current in Ventricular Myocytes of the Guinea Pig Type [http://circres.ahajournals.org/cgi/content/abstract/77/1/140], Jinglin Zeng, Kenneth R. Laurita, David S. Rosenbaum and Yoram Rudy, 1995, *Circulation Research* [http://circres.ahajournals.org/], 77, 140-152. (The full text [http://circres.ahajournals.org/cgi/content/full/77/1/140] version of the article is available for Journal Members on the Circulation Research website.)

Electrophysiological effects of acute myocardial ischemia: a theoretical study of altered cell excitability and action potential duration [http://www.elsevier.com/gej-ng/10/13/52/39/26/36/abstract.html], Robin M. Shaw and Yoram Rudy, 1997, *Cardiovascular Research* [http://www.sciencedirect.com/science?_ob=JournalURL&_cdi=4880&_auth=y&_acct=C000011498&_version=1&_urlVersion=0&_userid=140507&md5=845774525765eaf31dec5d2fc2a614f6], 35, 256-272.

Effects of I_{Kr} and I_{Ks} Heterogeneity on Action Potential Duration and Its Rate Dependence: A Simulation Study [http://circ.ahajournals.org/cgi/content/abstract/99/18/2466], Prakash C. Viswanathan, BE; Robin M. Shaw, PhD; and Yoram Rudy, PhD, 1999, *Circulation* [http://circ.ahajournals.org/], 99, 2466-2474. (Full text [http://www.circ.ahajournals.org/cgi/content/full/99/18/2466] and PDF [http://www.circ.ahajournals.org/cgi/reprint/99/18/2466.pdf] versions of the article are available for Journal Members on the Circulation website.)

Action Potential and Contractility in $[Na^+]_i$ Overloaded Cardiac Myocytes [http://www.biophysj.org/cgi/content/abstract/78/5/2392], Gregory M. Faber and Yoram Rudy, 2000, *Biophysical Journal* [http://www.biophysj.org/], 78, 2392-2404. (Full text [http://www.biophysj.org/cgi/content/full/78/5/2392] and PDF

[http://www.biophysj.org/cgi/reprint/78/5/2392.pdf] versions of the article are available for Journal Members on the Biophysical Journal website.)

Download This Model

- LR_II_model_1994.xml [../../models/LR_II_model_1994.xml] — the raw XML.
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- LR_II_model_1994.pdf [../../models/LR_II_model_1994.pdf] — a PDF version suitable for printing.
- cellml_LR_II_model_1994.tar.gz [../../downloads/cellml_LR_II_model_1994.tar.gz] — a gzipped tarball with the XML and this documentation.

- zeng_model_1_1_1995.xml [../../models/import/zeng_model_1995_reuse.xml] — the raw XML.
- zeng_model_1_1_1995.html [../../models/import/zeng_model_1995_reuse.html] — an HTML version for browsing online.
- zeng_model_1_1_1995.pdf [../../models/import/zeng_model_1995_reuse.pdf] — a PDF version suitable for printing.
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- shaw_model_1_1_1997.xml [../../models/import/shaw_model_1997_reuse.xml] — the raw XML.
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- cellml_viswanathan_model_1_1_1999.tar.gz [../../maths_pdf/import/viswanathan_model_1999_reuse_maths.pdf] — a gzipped tarball with the XML and this documentation.

- faber_model_1_1_2000.xml [../../models/import/faber_model_2000_reuse.xml] — the raw XML.

- faber_model_1_1_2000.html [../../models/import/faber_model_2000_reuse.html] — an HTML version for browsing online.
- faber_model_1_1_2000.pdf [../../models/import/faber_model_2000_reuse.pdf] — a PDF version suitable for printing.
- cellml_faber_1_1_model_2000.tar.gz [../../downloads/cellml_faber_import_ex_2000.tar.gz] — a gzipped tarball with the XML and this documentation.