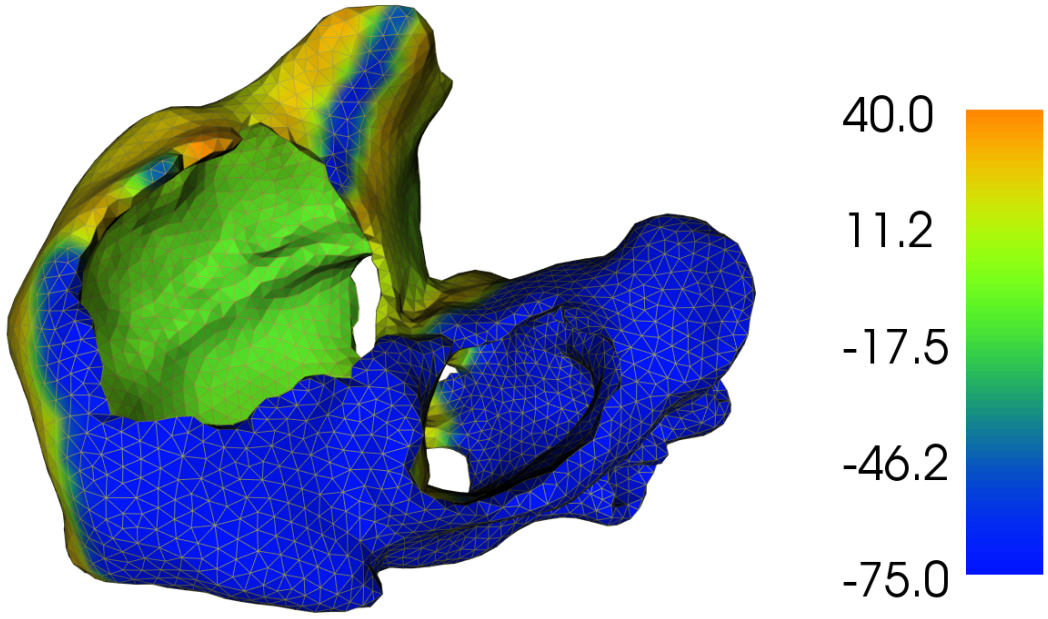
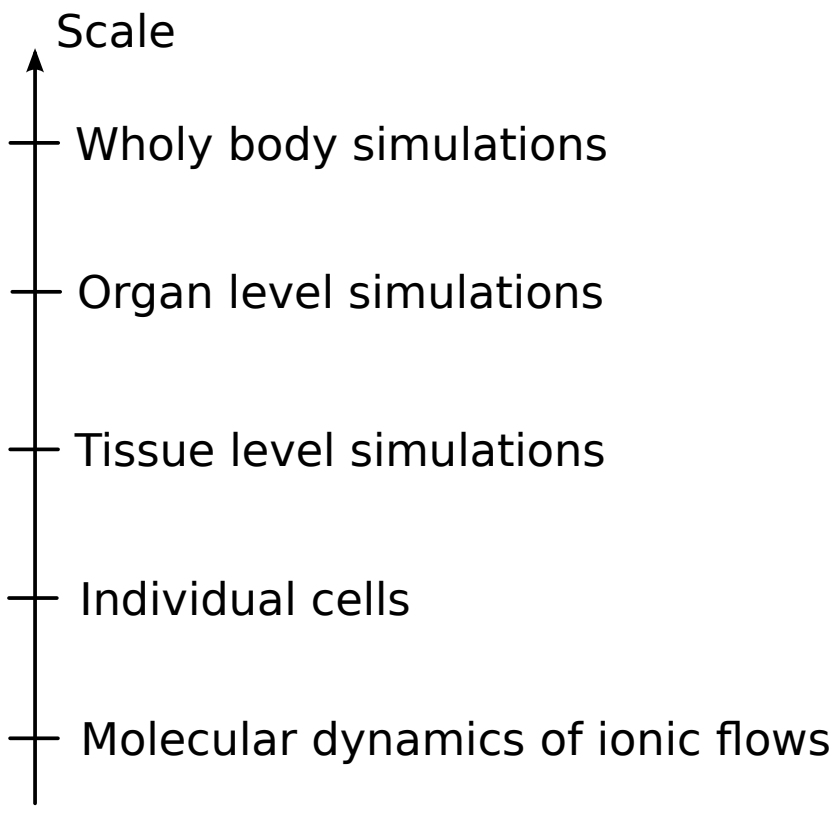
Computational cardiac electrophyisology



Jonas van den Brink

Computational cardiology is a problem in multiscale modeling



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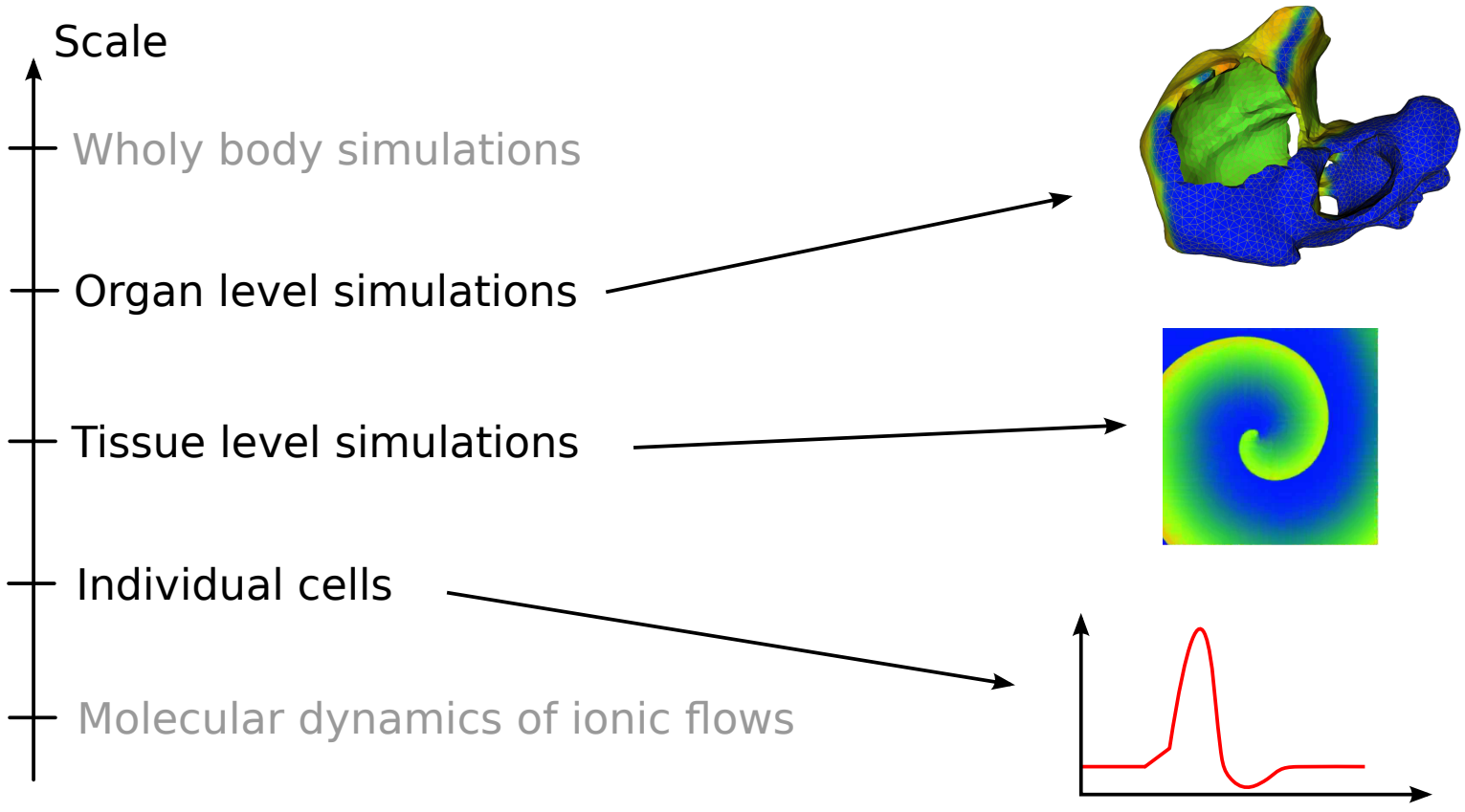
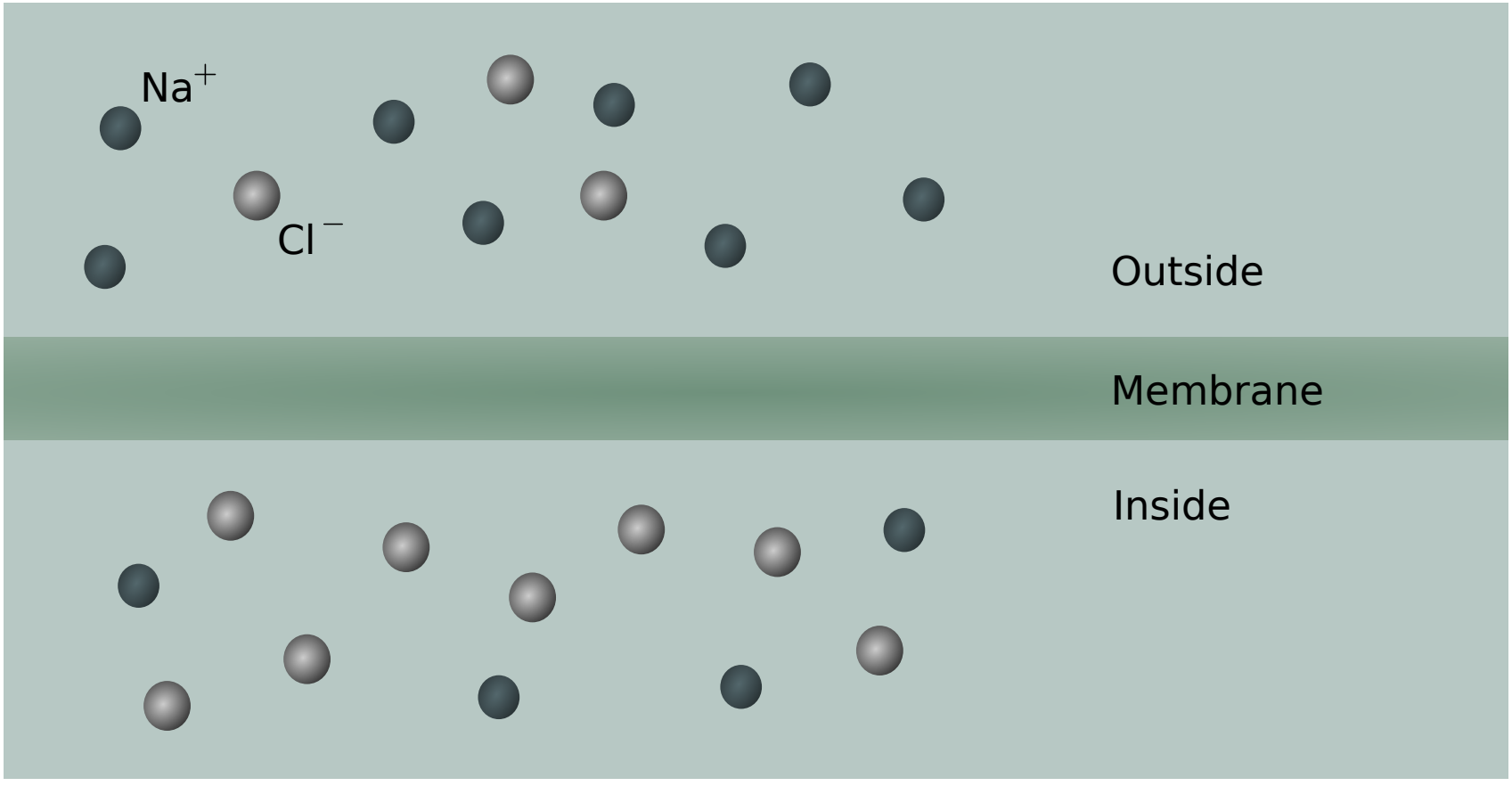


Differences in ionic concentration lead to an electric charge difference



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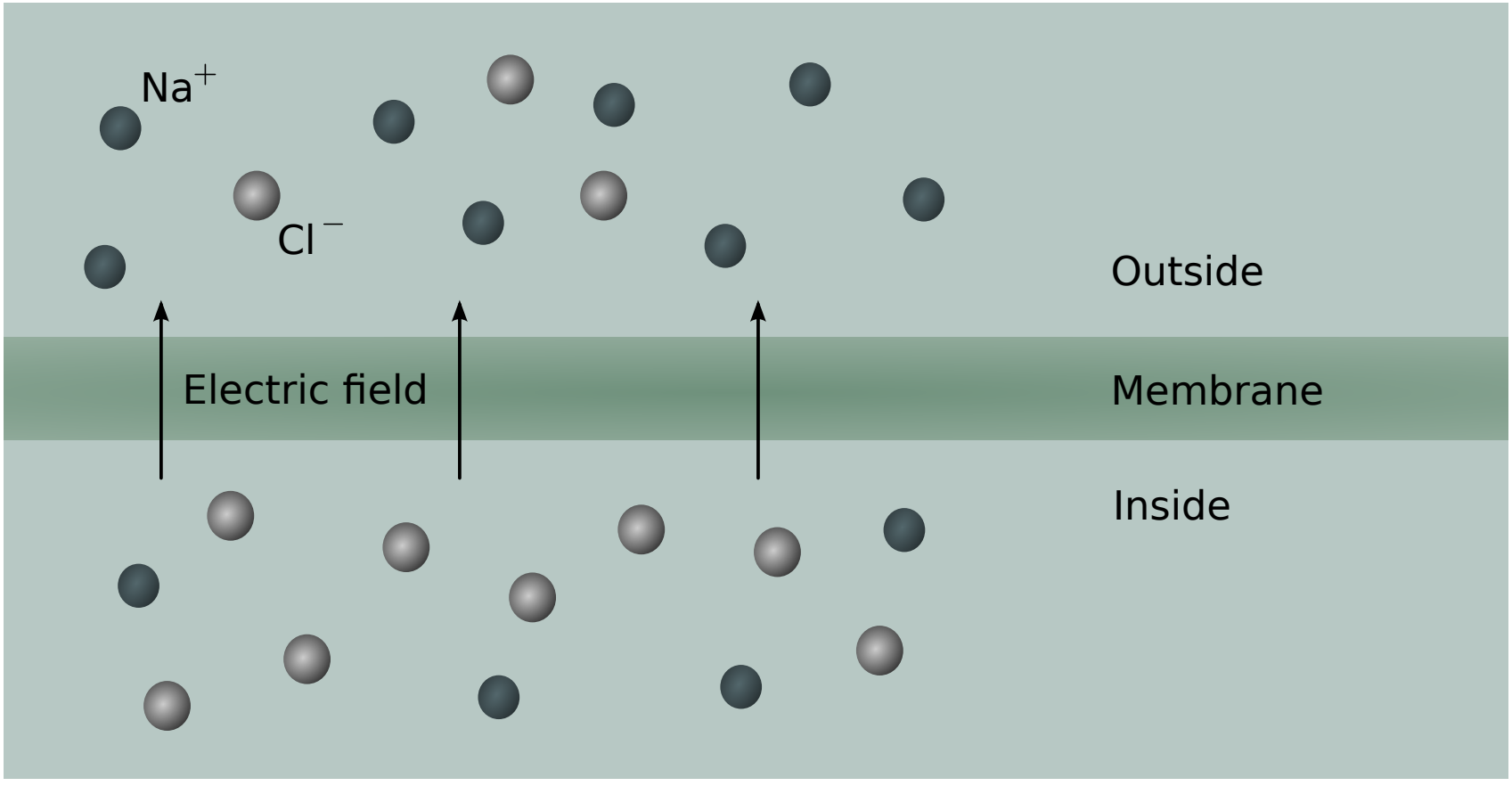
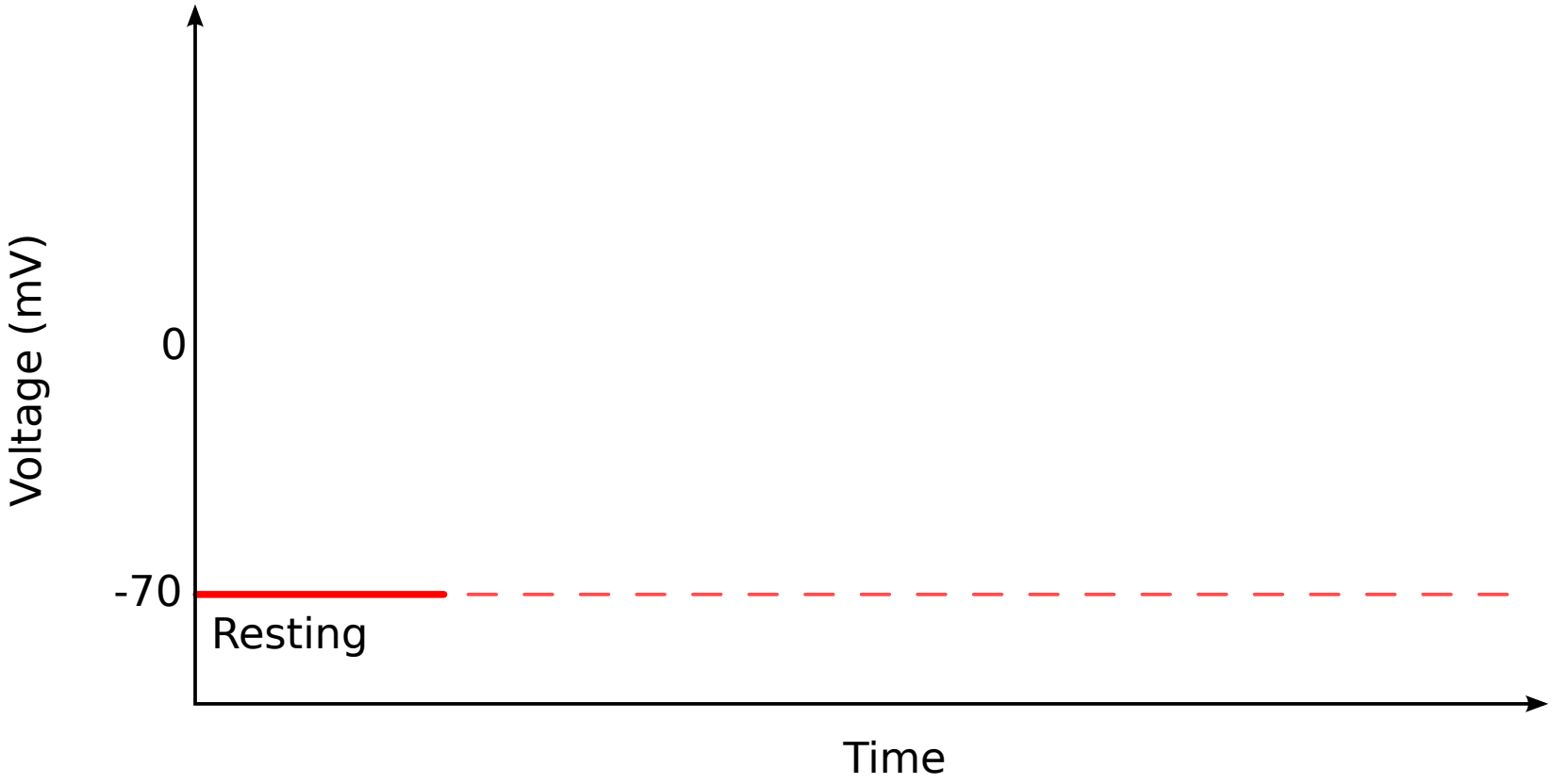


Heart cells are excitable



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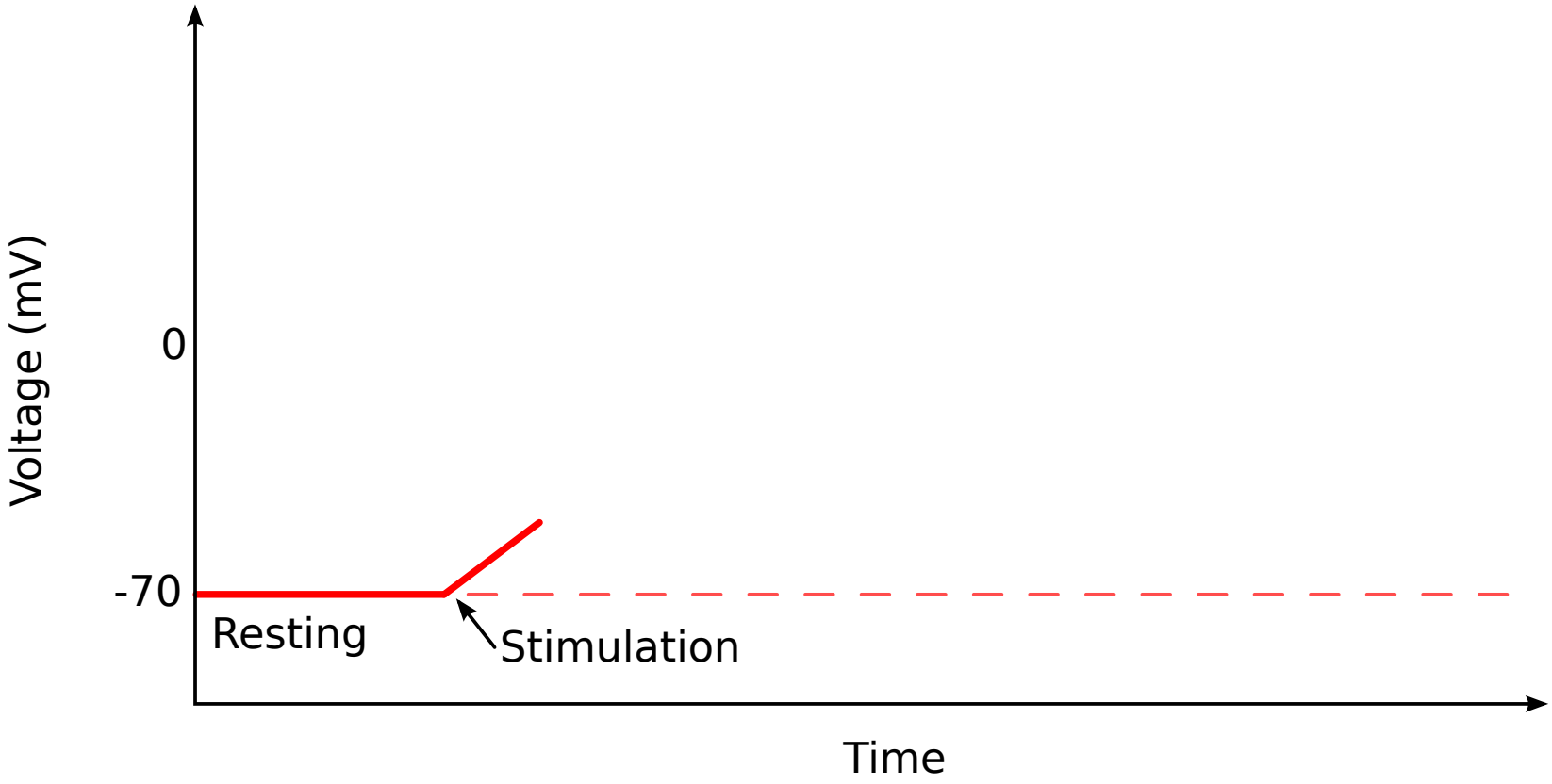

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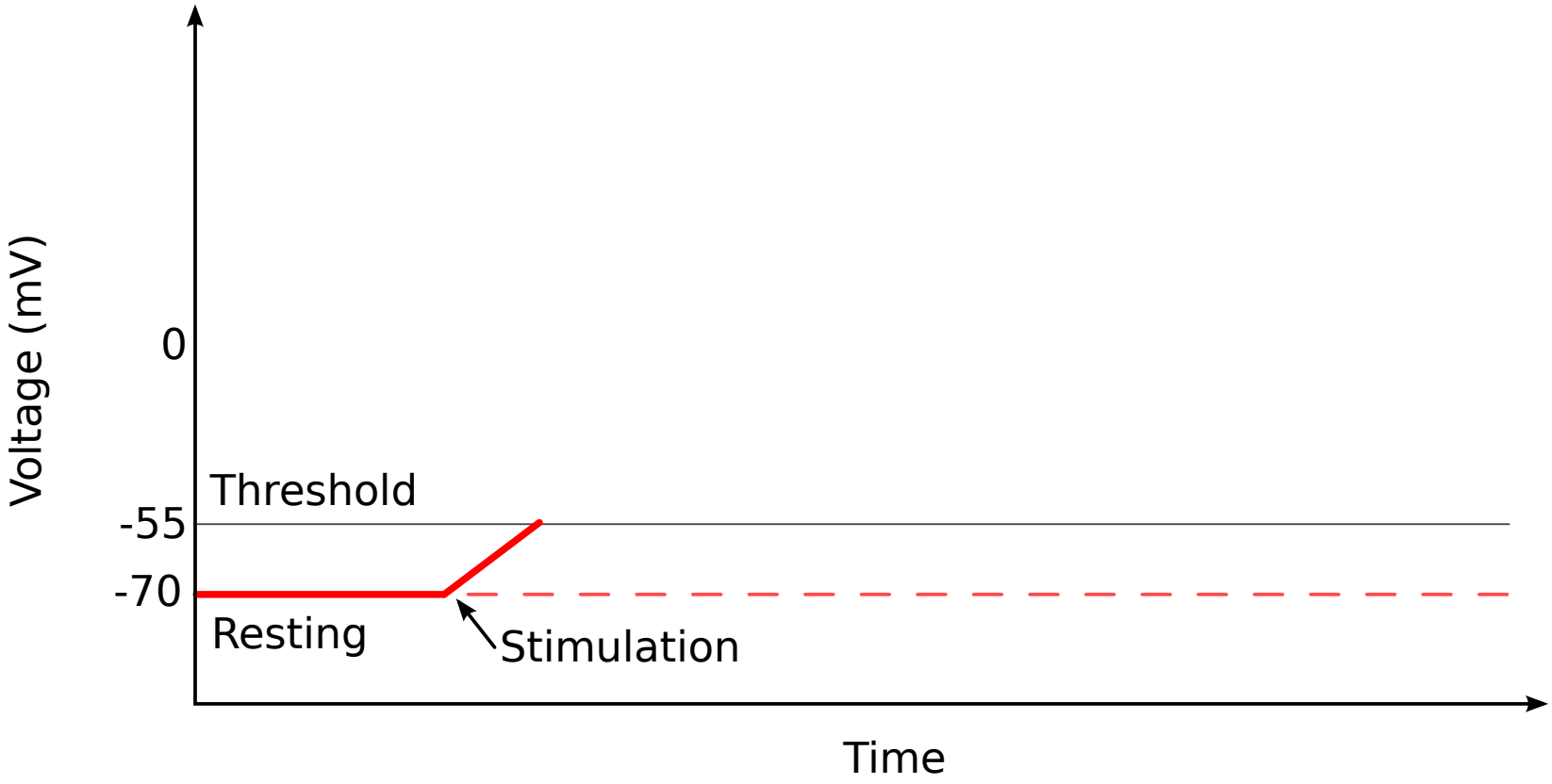

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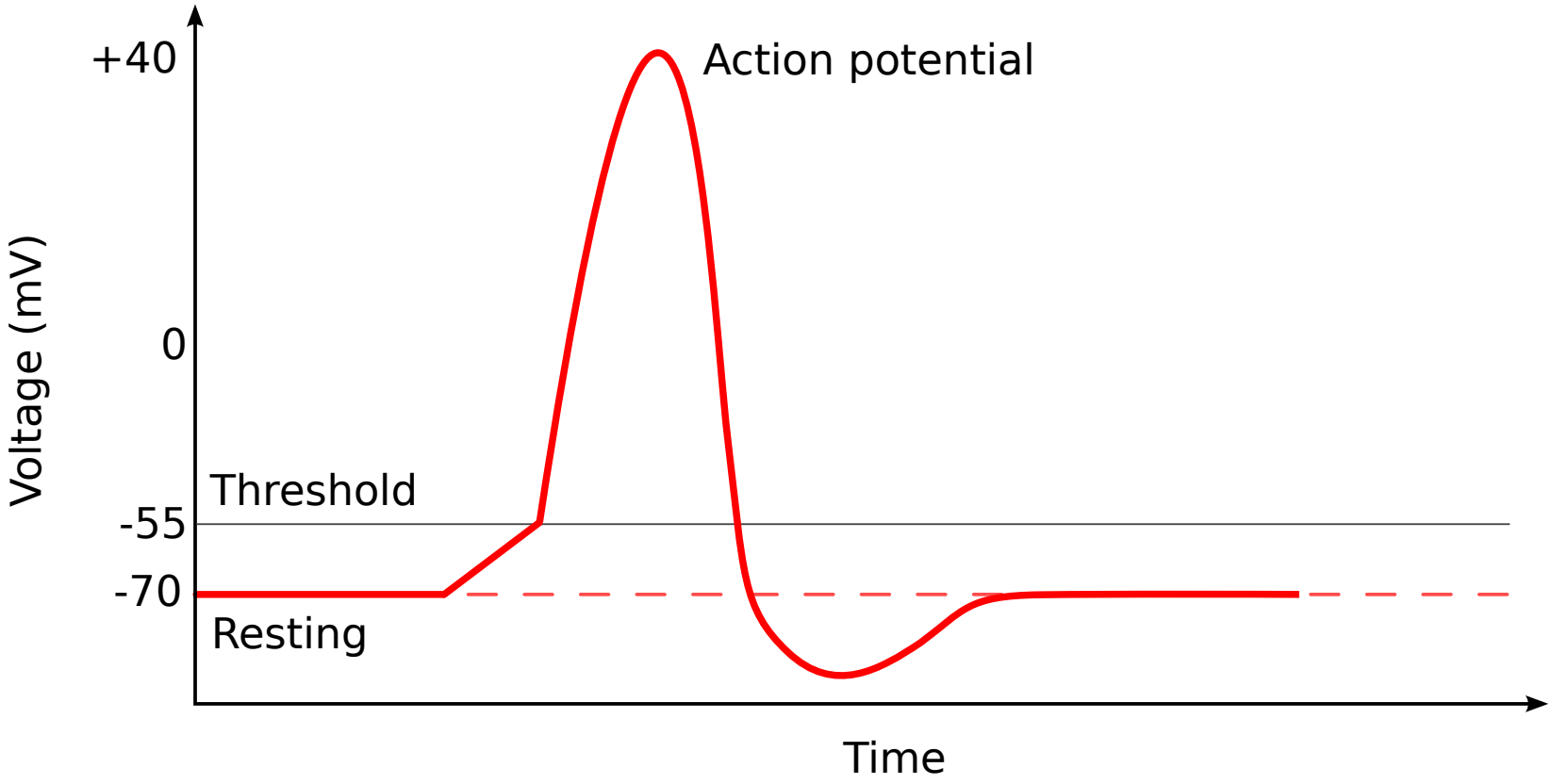

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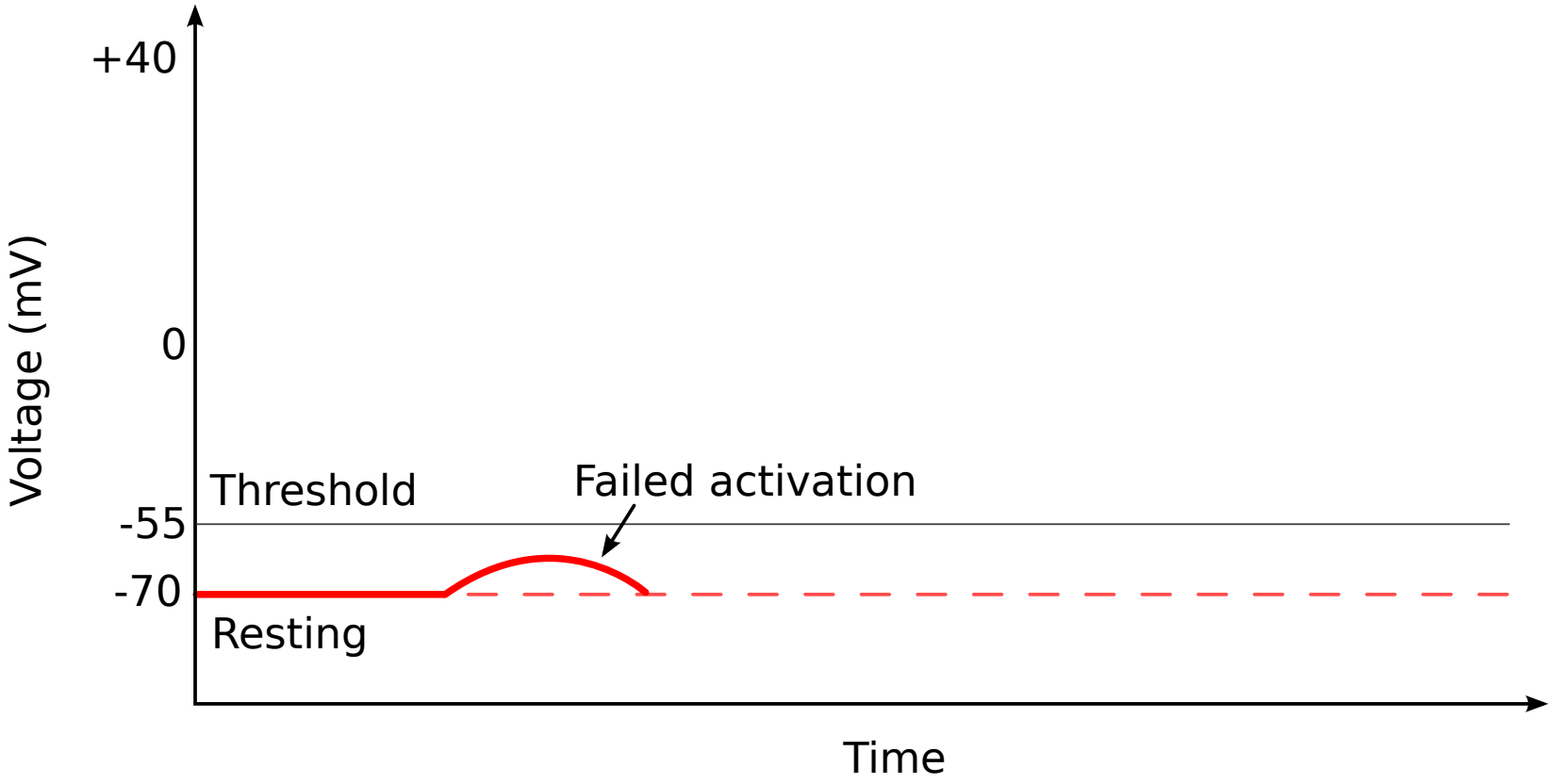

Why do cells fire?

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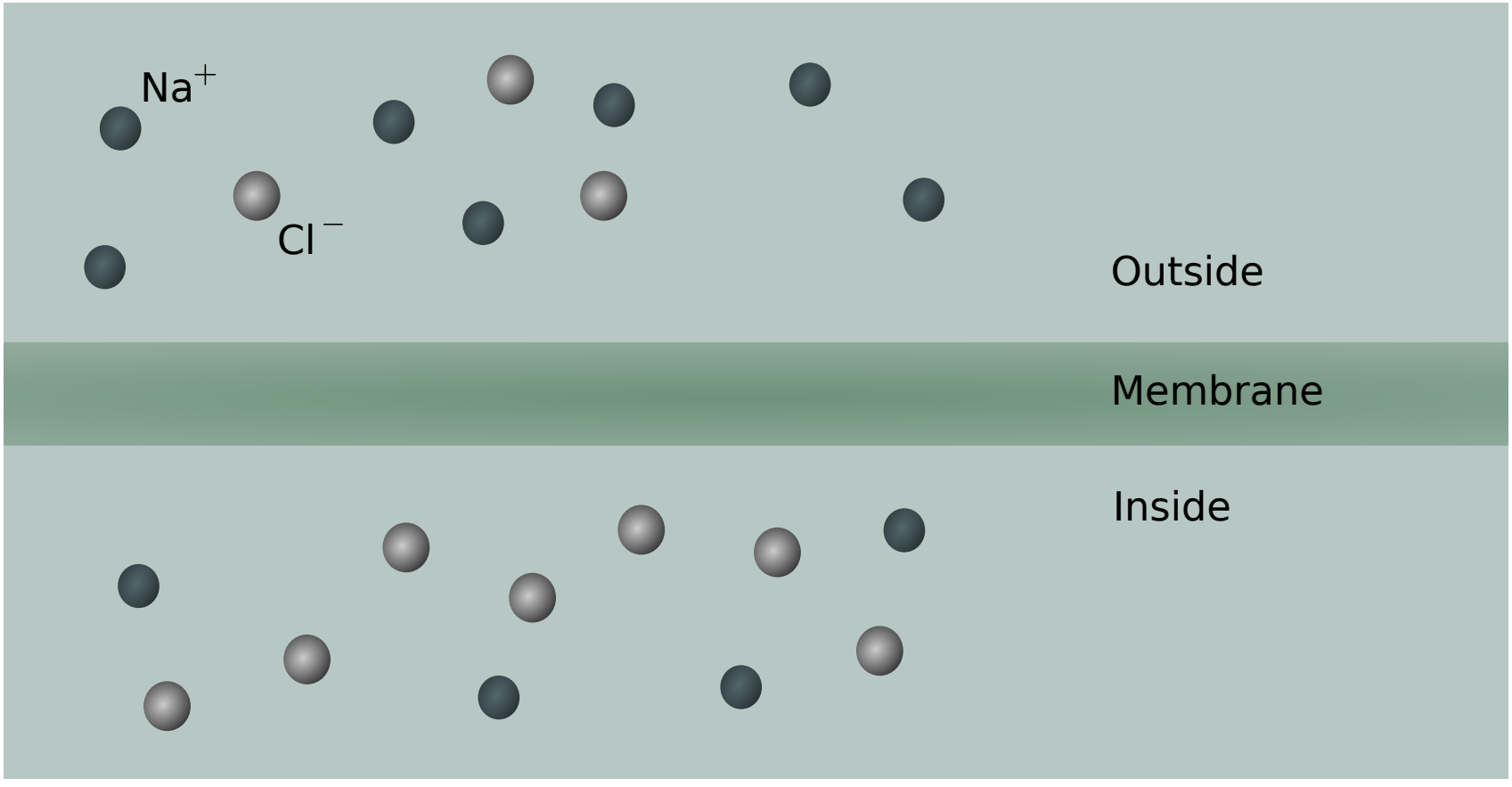

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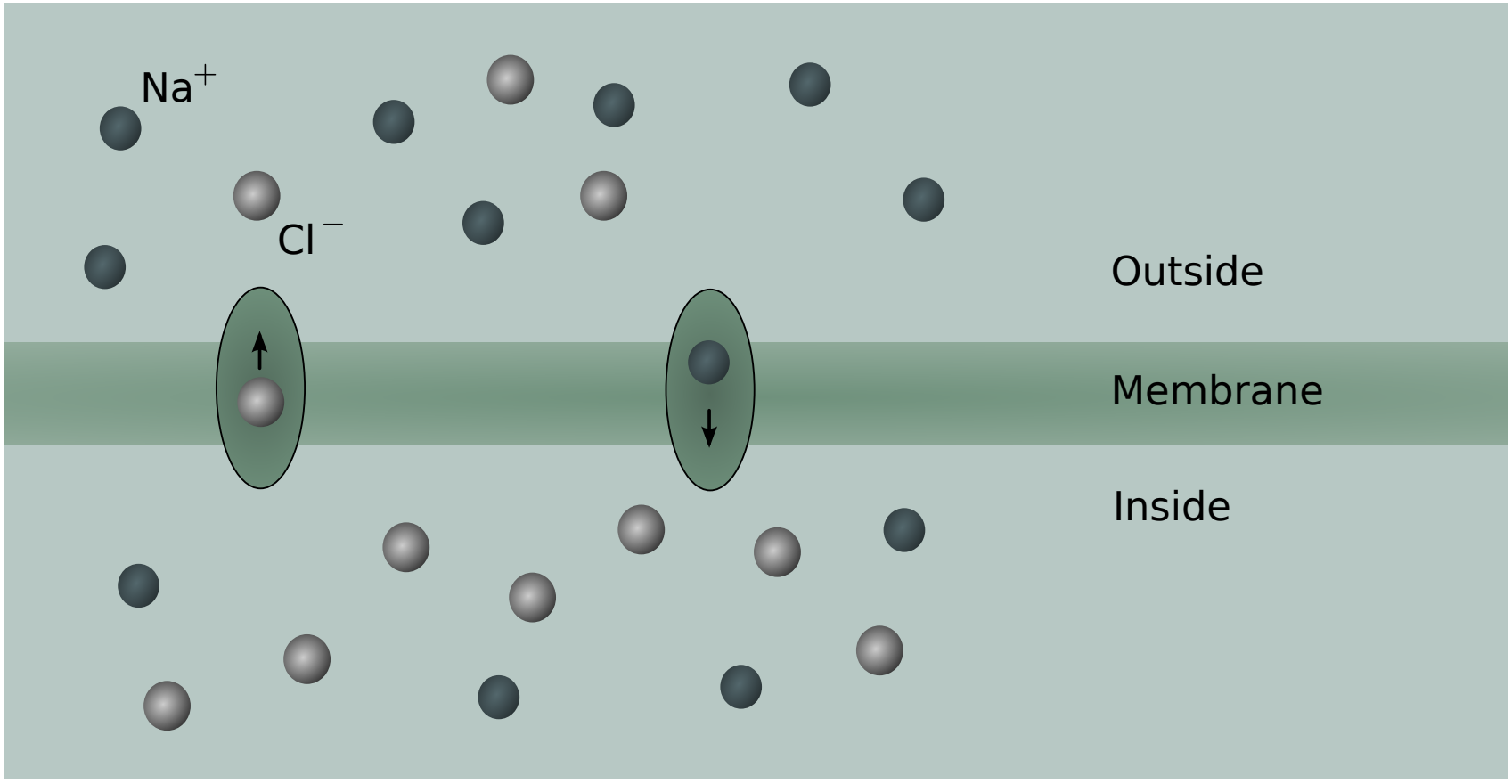
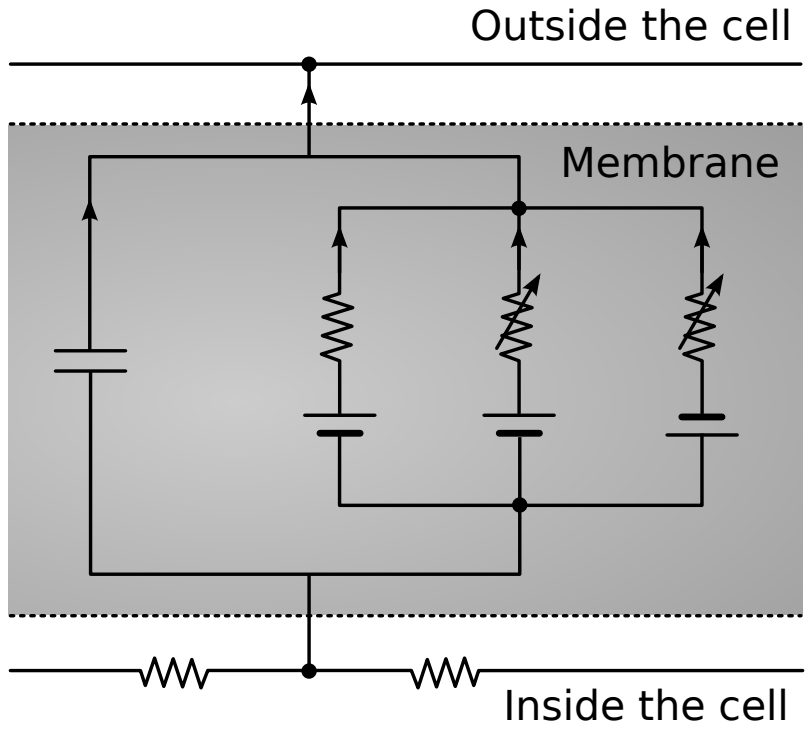


We can use Hodgekin-Huxley models to describe excitable cells



Leads to a set of highly non-linear ODEs.

There are an extreme amount of different cell models in the litterature.

A cell firing will affect nearby cells as the charge literally diffuses between cells

This is an example of a reaction-diffusion phenomenon.

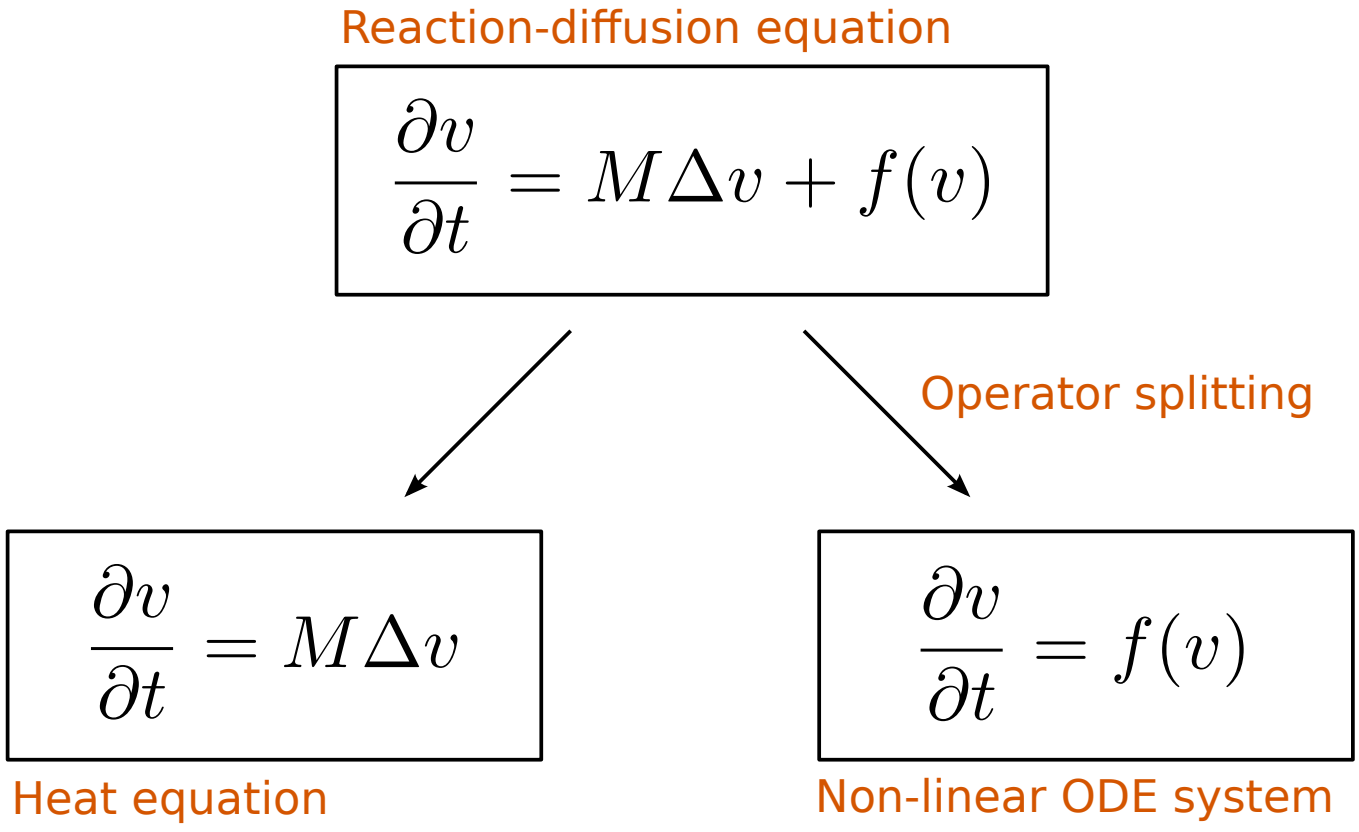
The reaction-diffusion leads to a wavefront propagating through the tissue

We can use operator splitting to seperate the reaction-diffusion equation

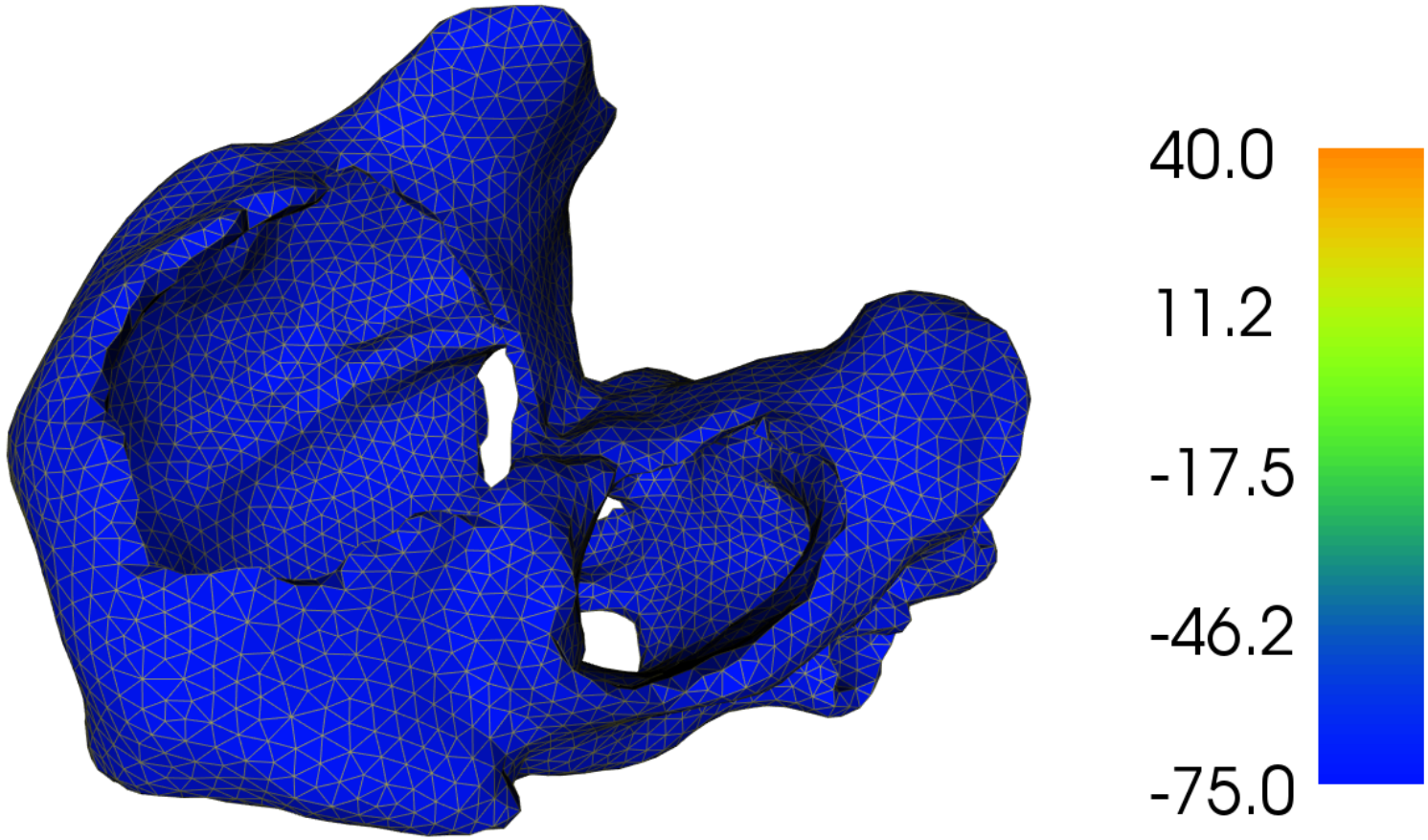
Reaction-diffusion equation

$$\frac{\partial v}{\partial t} = M\Delta v + f(v)$$

We can use operator splitting to seperate the reaction-diffusion equation



We then solve the equations in a 2D or 3D mesh



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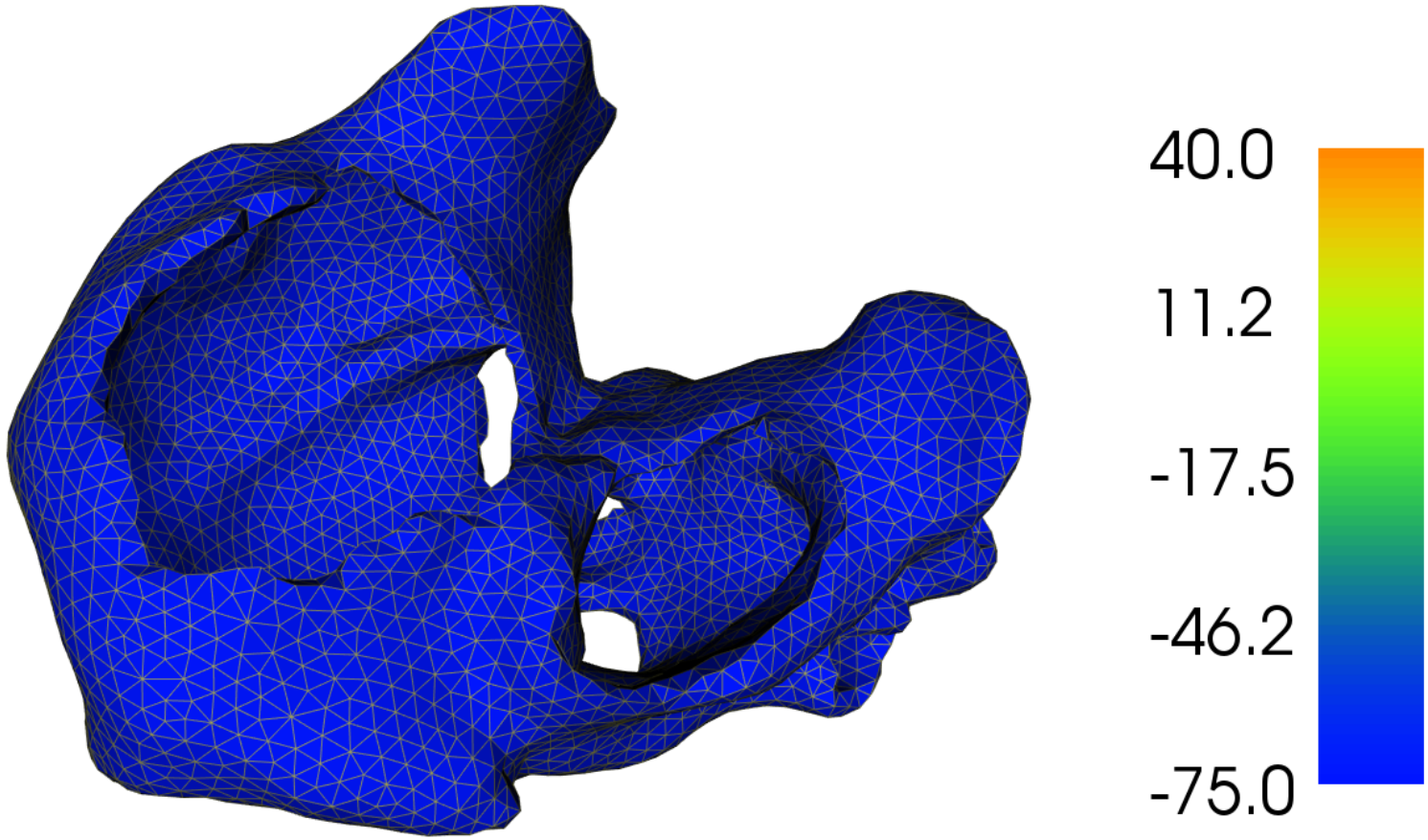
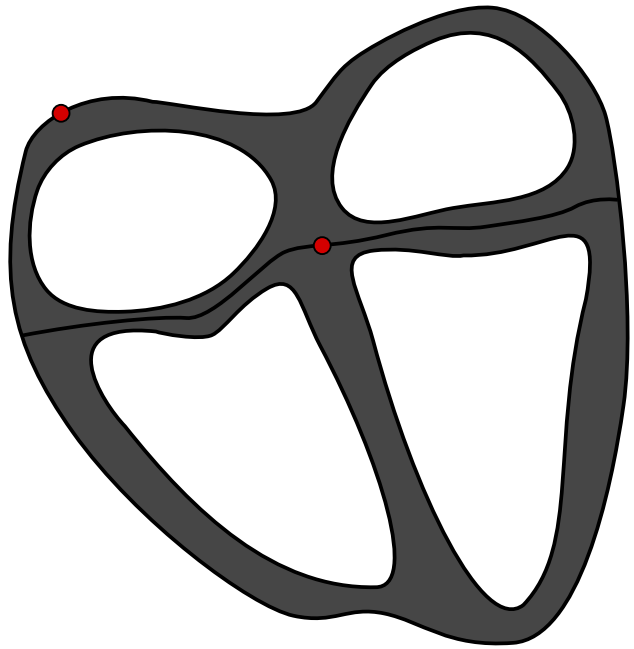
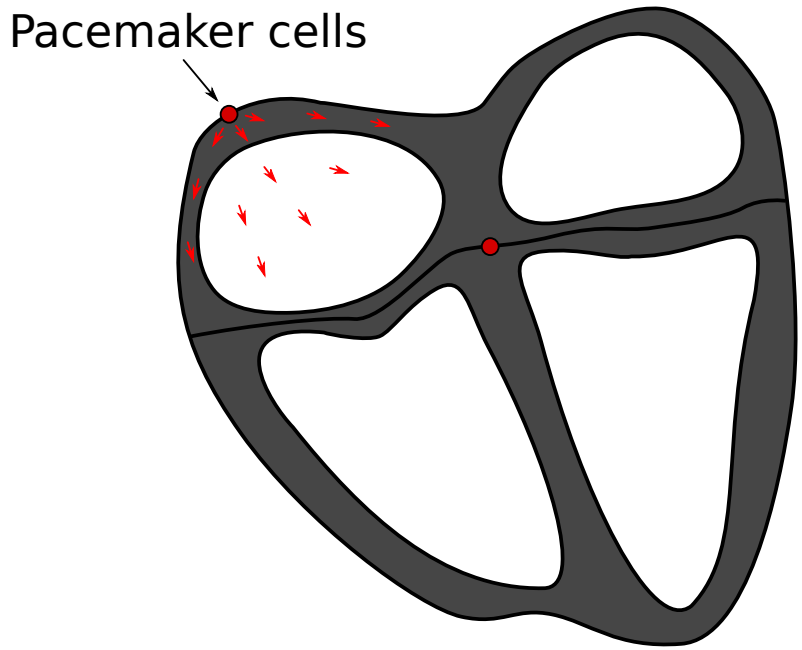
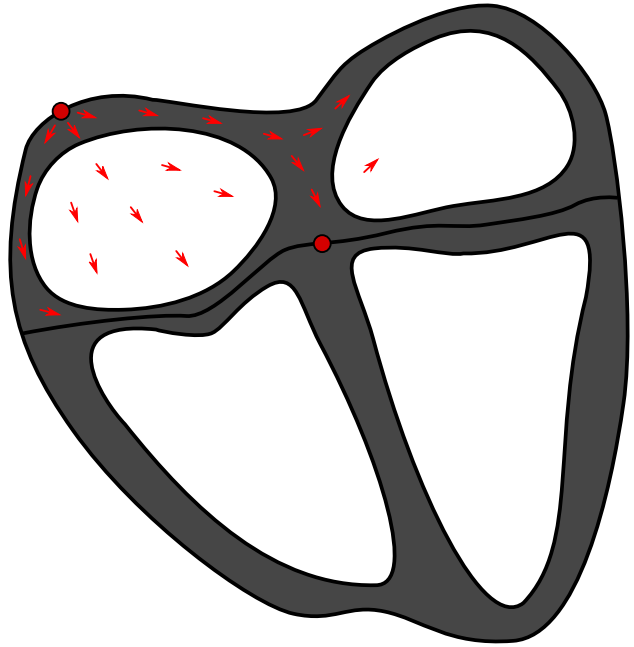
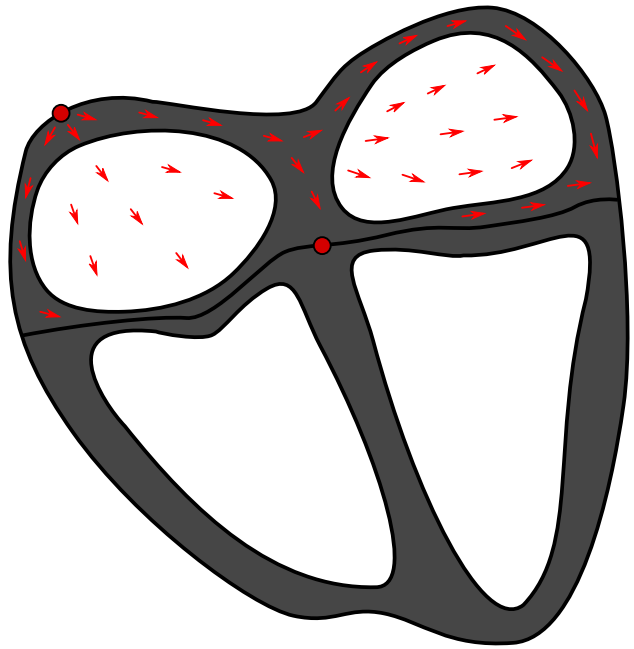


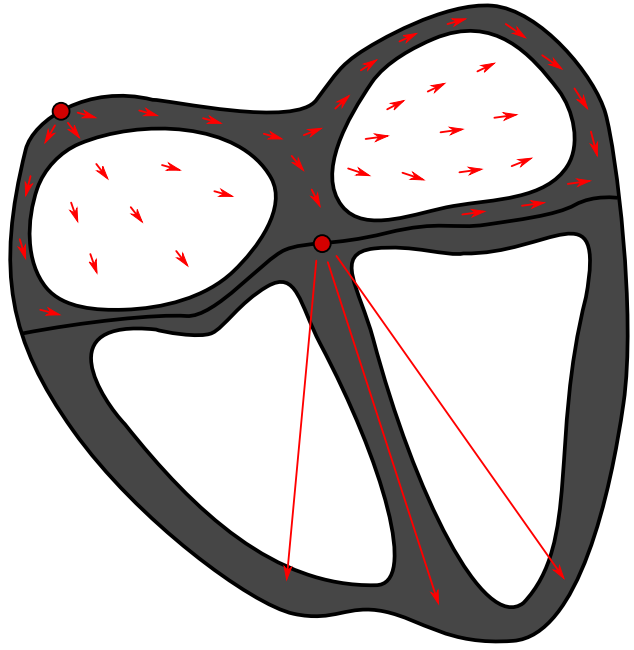
[Movie]

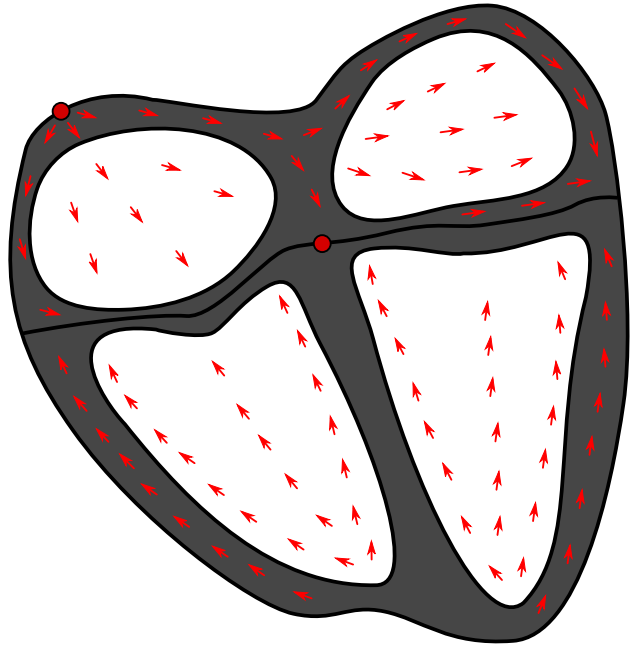



Pacemaker cells



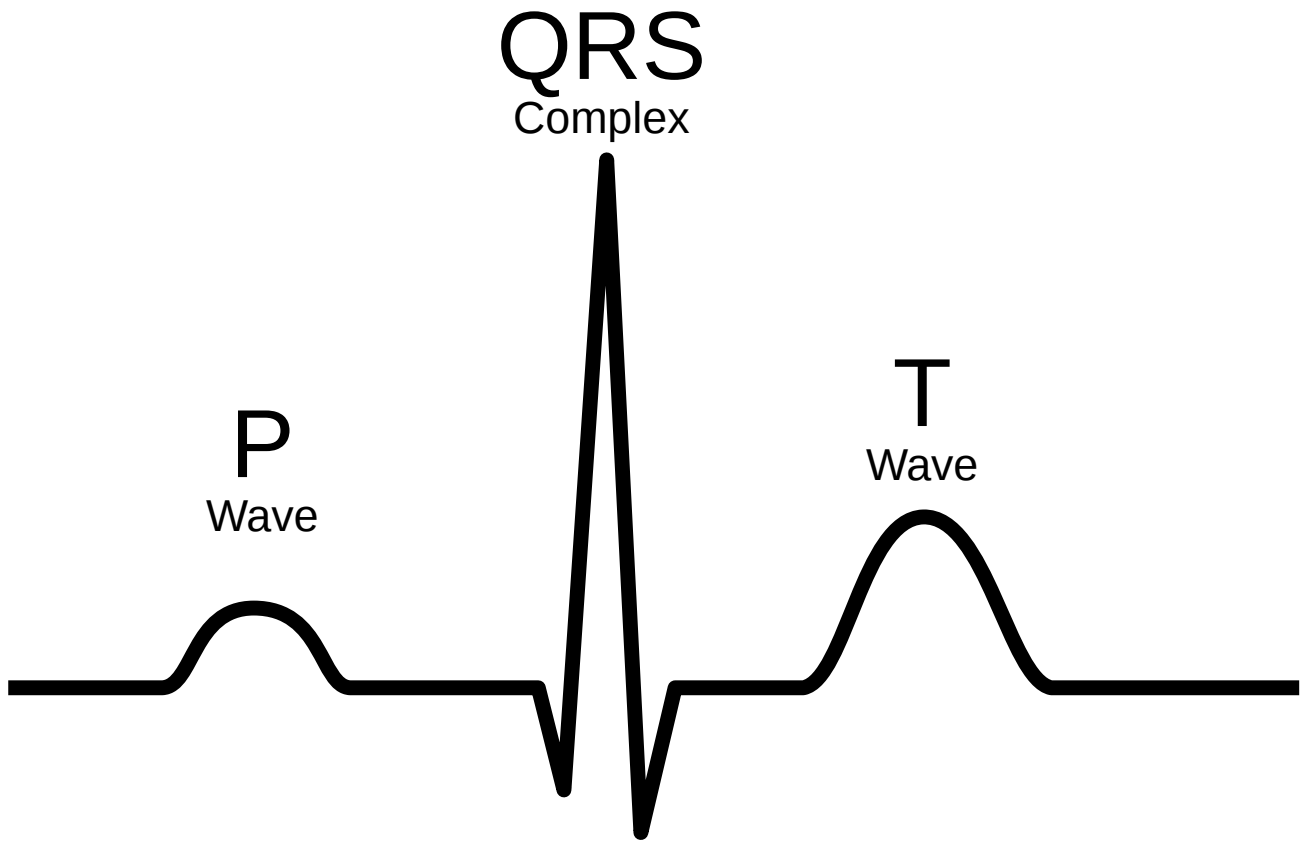






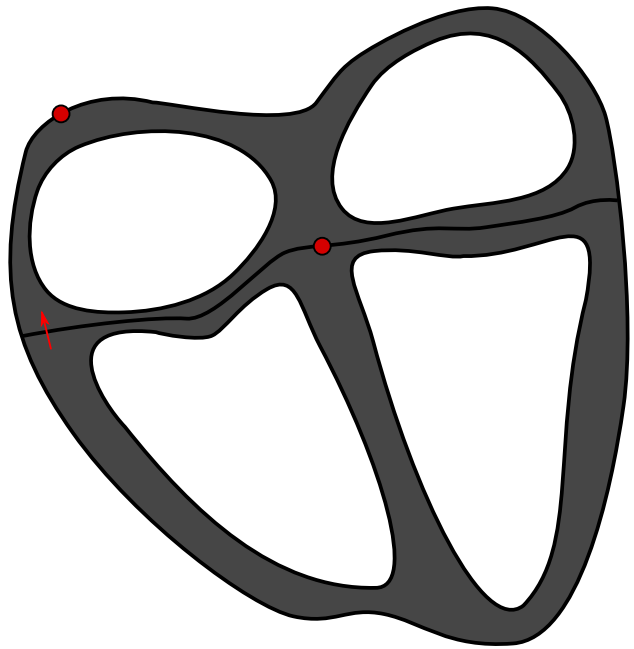
During a heart cycle, the heart depolarizes and becomes an electric dipole

An electrocardiogram (EKG) measures the dipole field



Fibrillation is rapid, unscynchronized contraction of muscle cell

It is often caused by reentrant waves



These waves never die out and so the heart doesn't contract as one.

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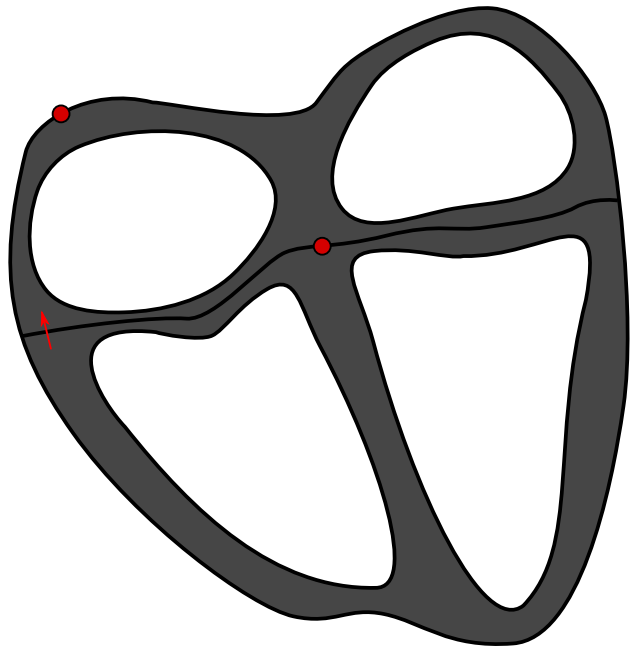

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[Movie] + [Gifs]

Ventricular fibrillation is always deadly, but atrial fibrillation is not

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The Maze procedure is a surgical treatment of atrial fibrillation

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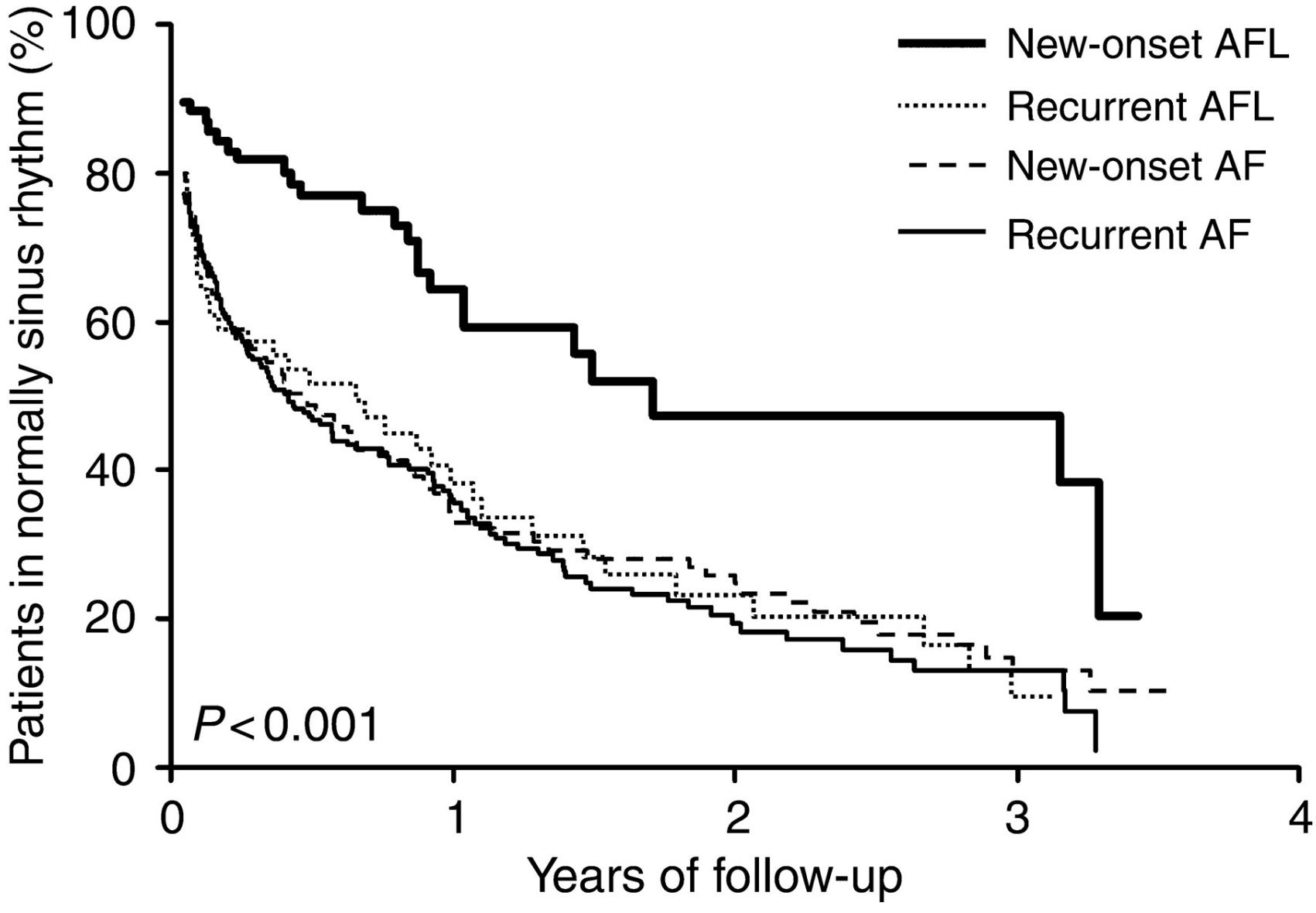
The causes of atrial fibrillation and these procedures are not well understood


Patients in normally sinus rhythm (%)
100
80
60
40
20
0
0
1
2
3
4
Years of follow-up
New-onset AFL
Recurrent AFL
New-onset AF
Recurrent AF
P<0.001

Patient-specific modelling can make treatments of atrial fibrillation more effective

Cardiac modelling is one of the most important tools in developing new treatment for heart conditions such as atrial fibrillation

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By using measurements from ECG, MRI and similar, our simulations can be adapted on a patient-by-patient basis.

Computational Physiology (INF5560) gives a good introduction to cardiac modelling