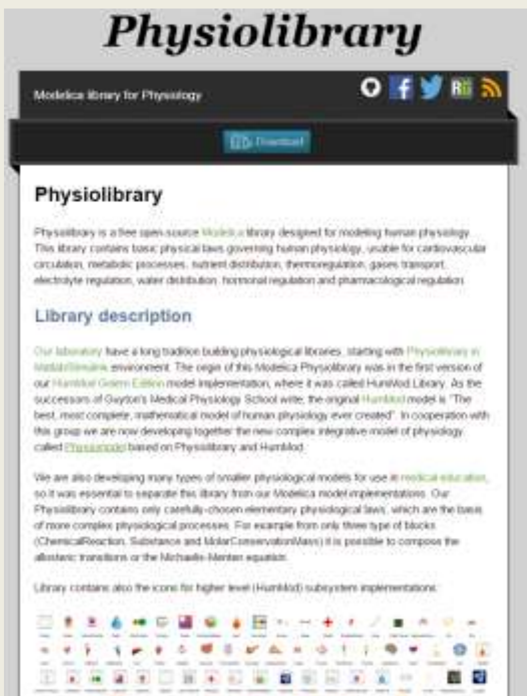
Physiolibrary a další užitečné knihovny

Studijní materiály

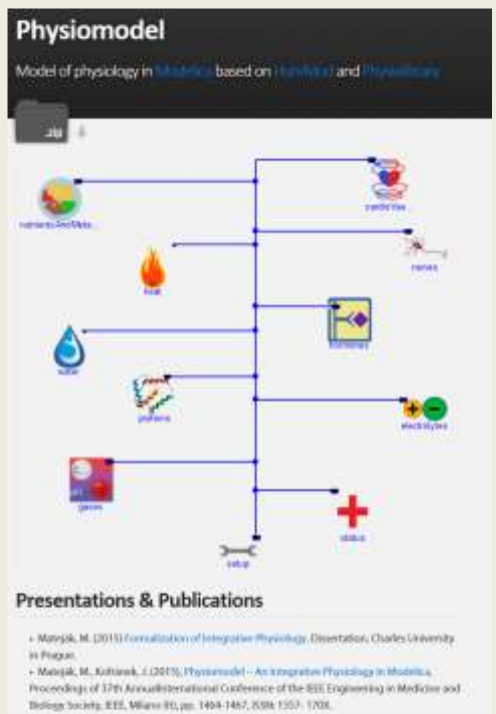
Fritson: Modelica

http://patf-biokyb.lf1.cuni.cz/wiki/cvut/mos_materialy

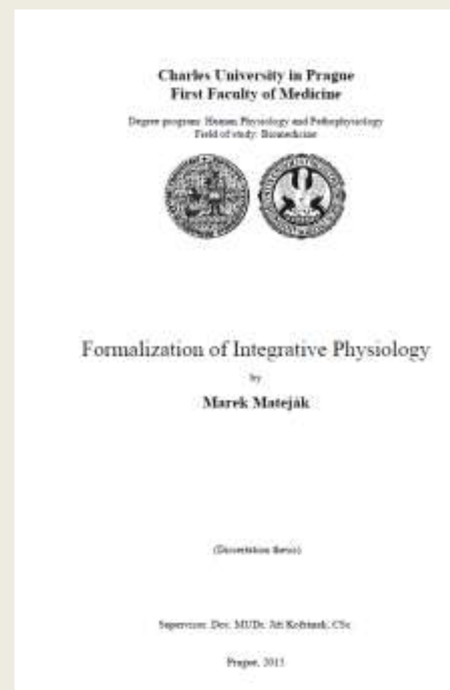
www.Physiolibrary.org



www.Physiomodel.org



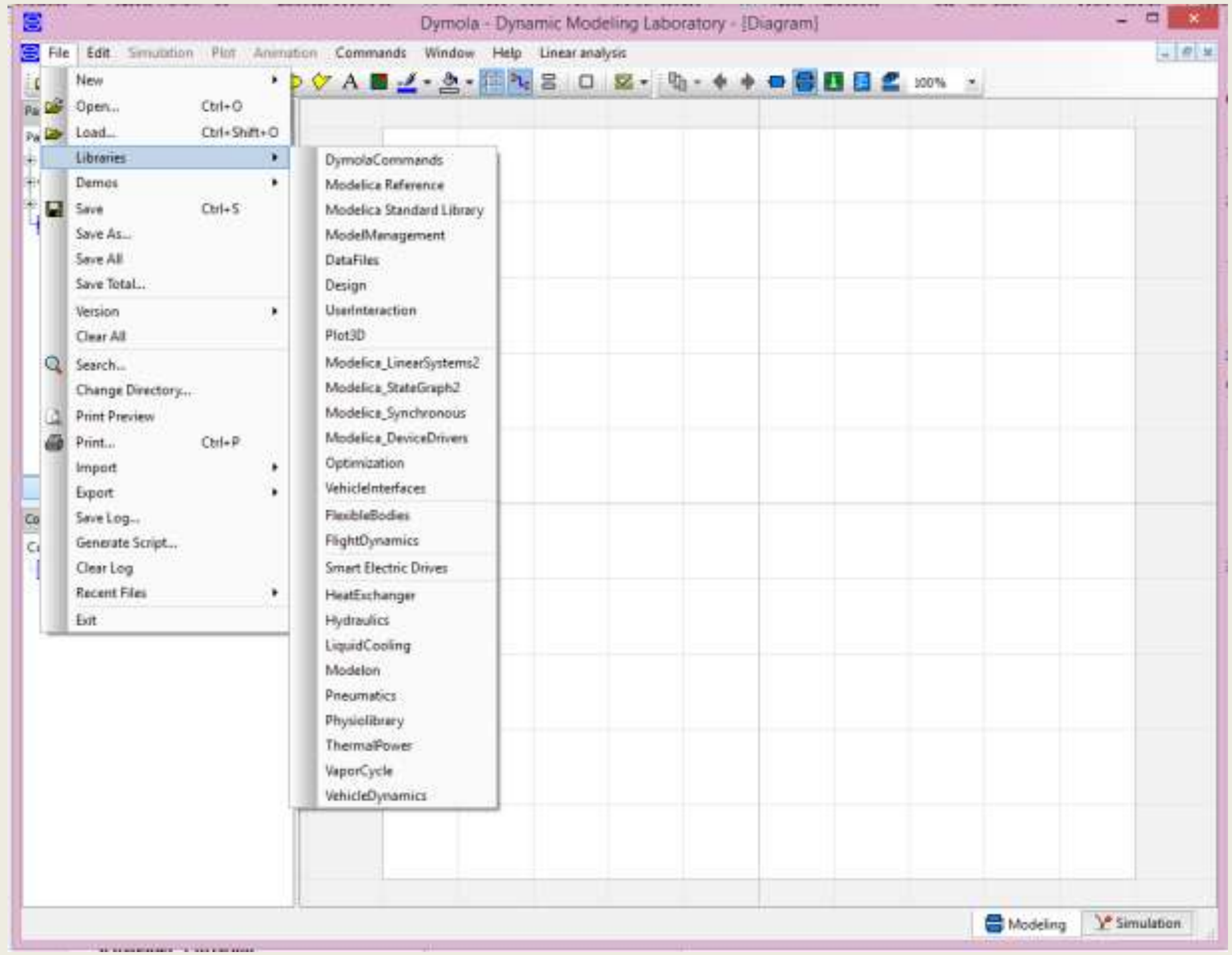
https://www.modelica.org/publications



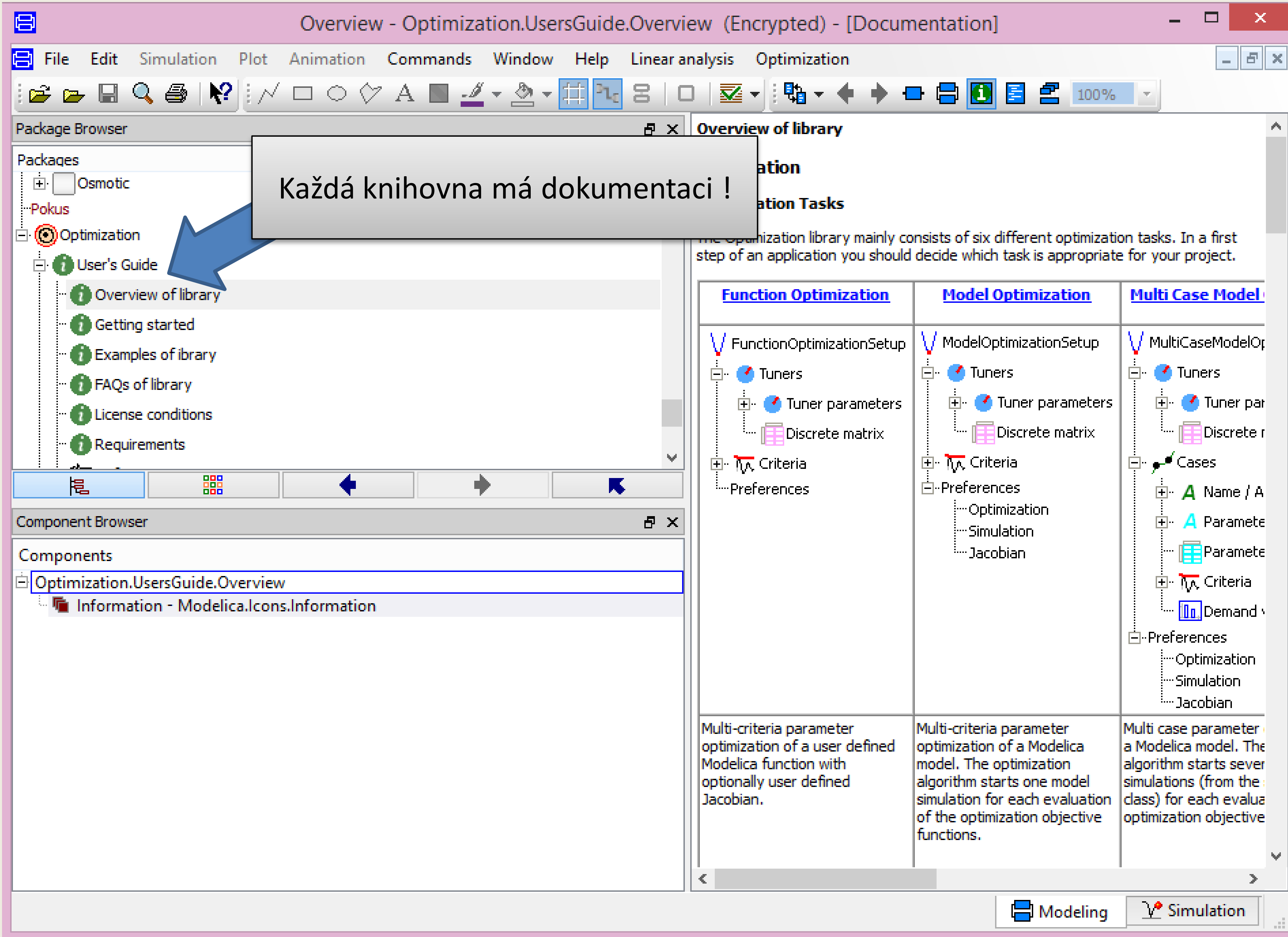
Knihovny Modeliky

Základní knihovny

Aplikační knihovny



Každá knihovna má dokumentaci !



Knihovny Modeliky

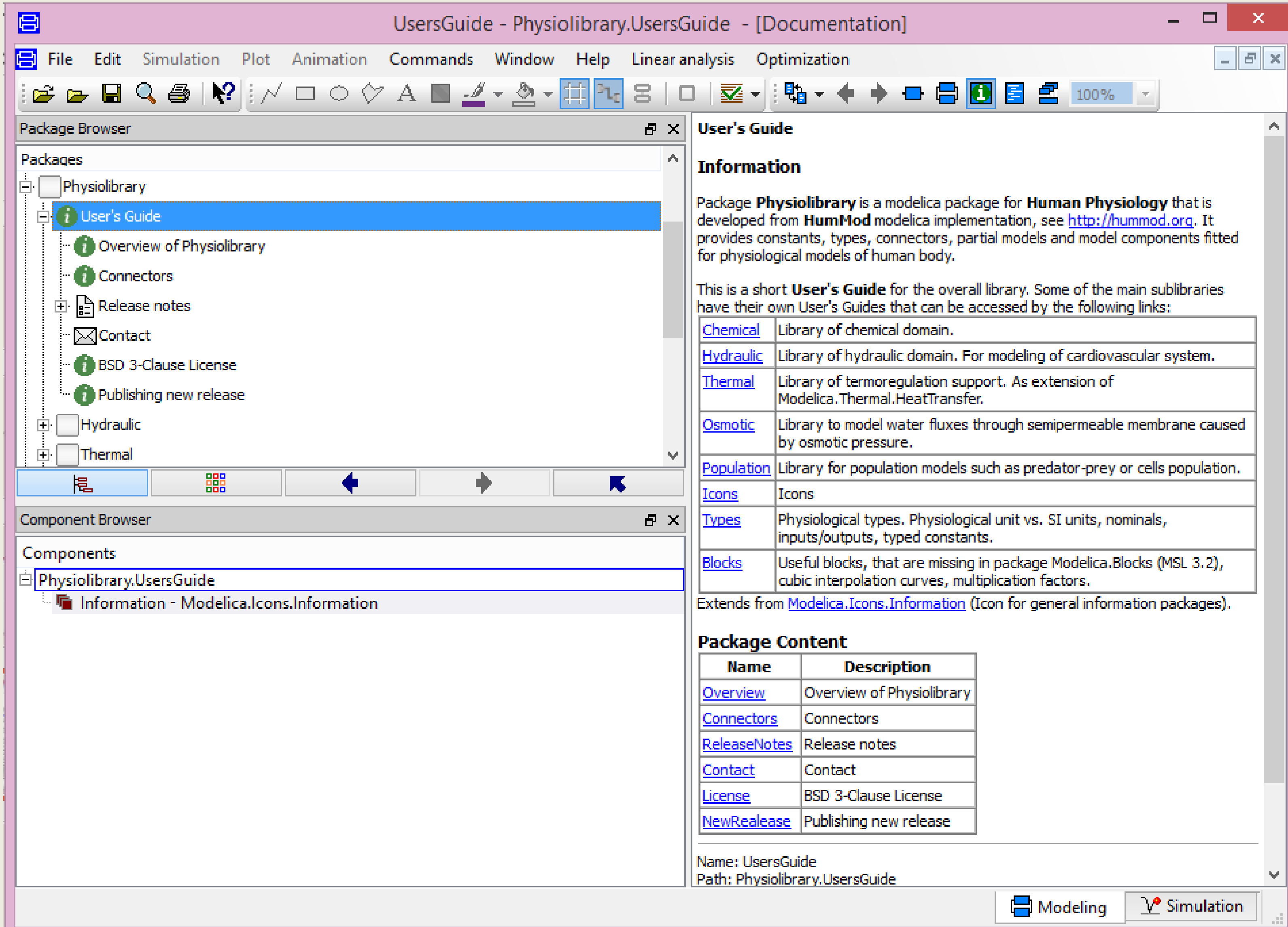
Veškeré jednotky v knihovnách vnitřně v SI!

Problém v OM – zatím nefunguje DisplayUnit

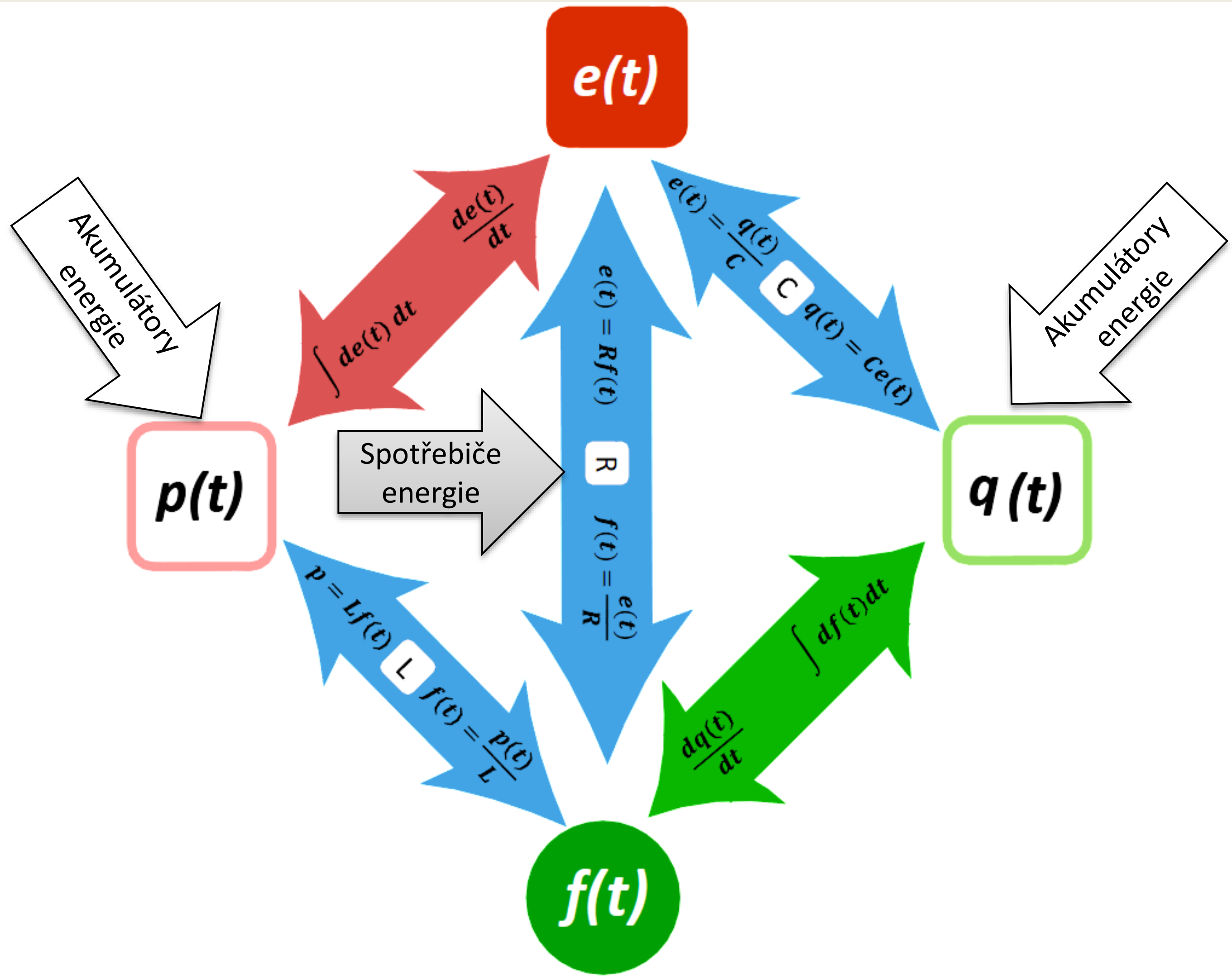
Přepočty jednotek nutno dělat ručně (pro přepočty vhodné využít dědičnost)

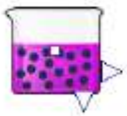
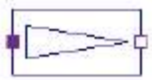
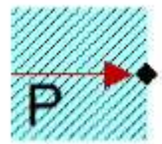
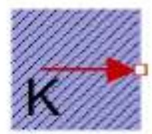
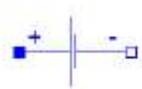
Knihovna Physiolibrary

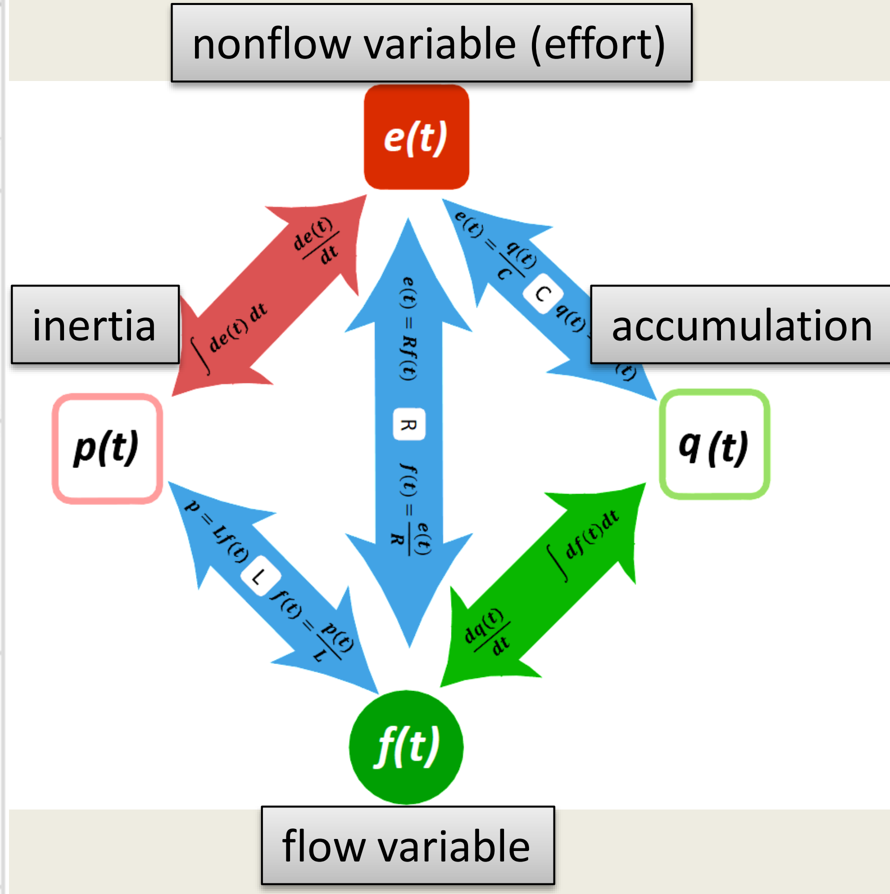
www.Physiolibrary.org



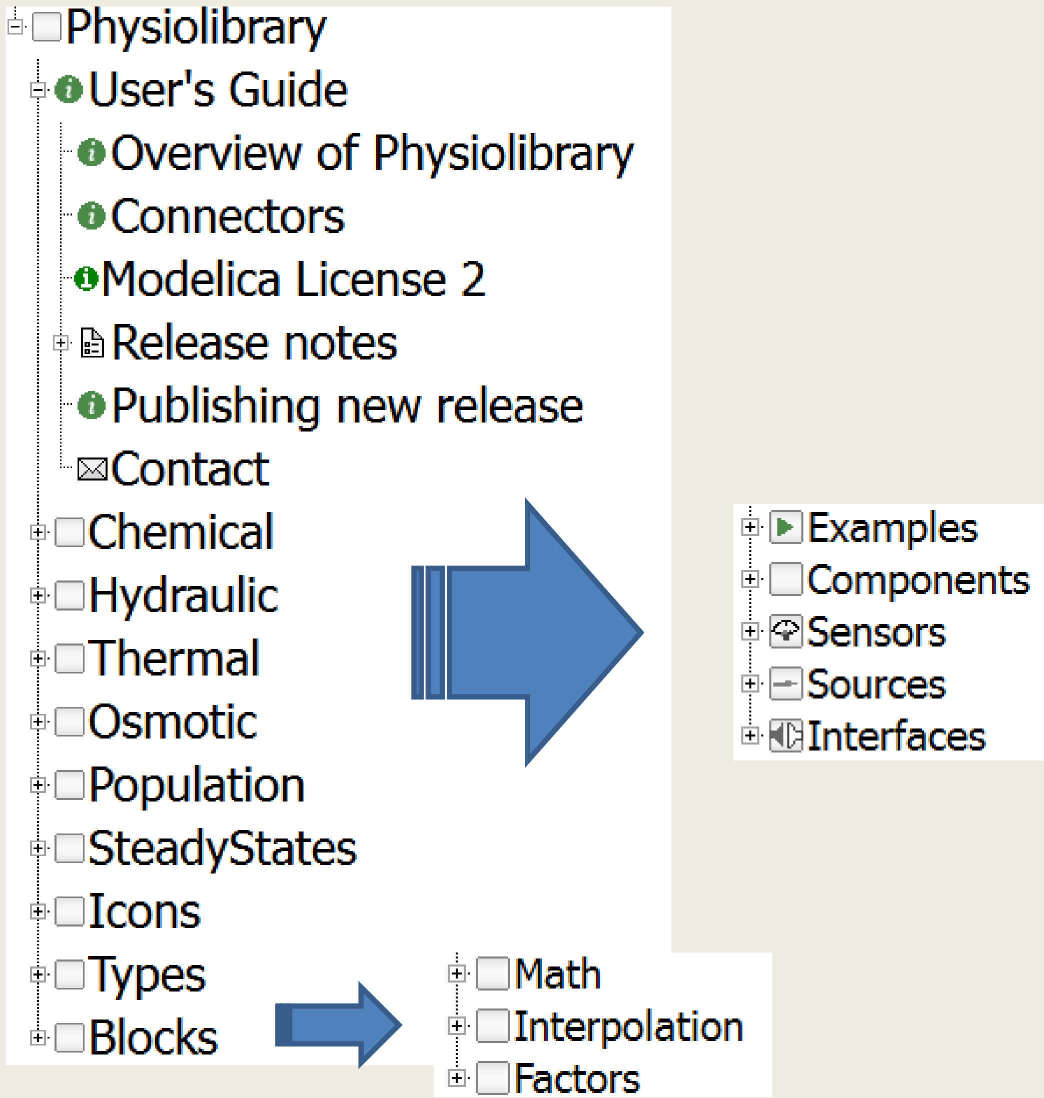
Zobecněné úsilí (effort)	Zobecněná hybnost	Zobecněný tok (flow)	Zobecněná akumulace
$e(t)$	$p(t)$	$f(t)$	$q(t)$
napětí	indukční tok	proud	náboj
síla	impuls síly	rychlost	poloha
moment	impuls momentu síly	úhlová rychlost	úhel
tlak	průtočná hybnost	objemový průtok	objem
koncentrace		molární průtok	množství
teplota		tepelný tok	teplo
teplota		entropický průtok	entropie


e(t)
p(t)
q (t)
f(t)
Akumulátory energie
Akumulátory energie
Spotřebiče energie
$\frac{de(t)}{dt}$
$\int de(t)\,dt$
$e(t) = \frac{q(t)}{C}$
C
$q(t) = Ce(t)$
$e(t) = Rf(t)$
R
$f(t) = \frac{e(t)}{R}$
$p = Lf(t)$
L
$f(t) = \frac{p(t)}{L}$
$\int df(t)dt$
$\frac{dq(t)}{dt}$

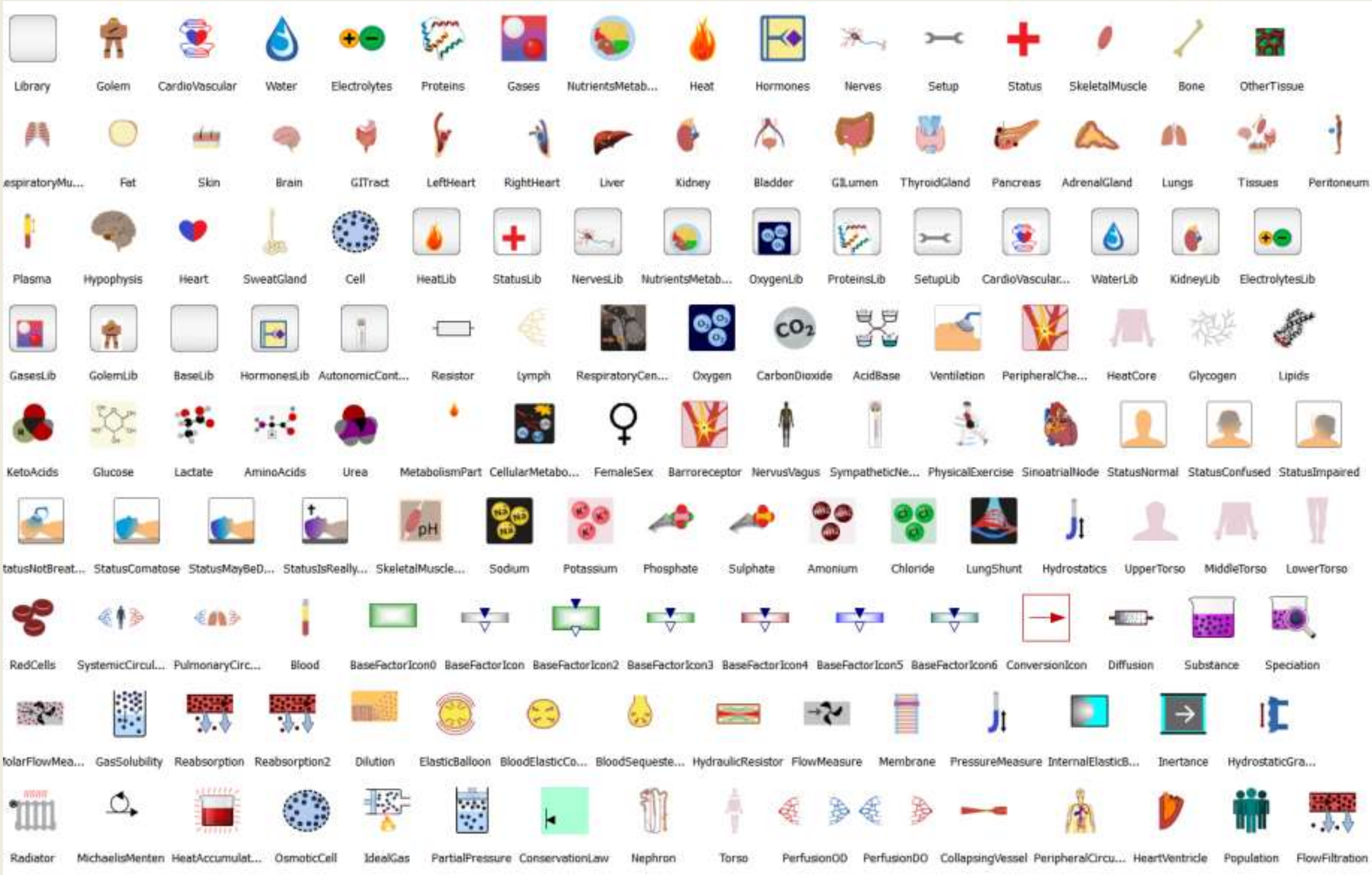
Resistance	Accumulation	Stream	Inertia	Effort source
$f_1=G*(e_1-e_2)$ $f_1+f_2=0$	$\int f = a$ $a=C*e$	$f_1 = \begin{cases} F\,e_1, & F \ge 0 \\ F\,e_2, & F < 0 \end{cases}$ $f_1+f_2=0$	$f_1 = \int \frac{e_1-e_2}{L}$ $f_1+f_2=0$	e = E
G… conductance	C…capacitance	F…stream flow	L…intertia	E..effort
 *Chemical diffusion*	 *Chemical substance*	 *Solution stream*	not applicable	 *Mole Fraction*
 *Hydraulic resistance*	 *Elastic vessel*	not applicable	 *Inertia*	 *Pressure*
 *Heat convection*	 *Heat accumulation*	 *Heated mass flow*	not applicable	 *Temperature*
not applicable	 *Population*	 *Growth, Differentiation*	not applicable	not applicable
 Electrical resistor	 Electrical capacitor	not applicable	 Inductor	 Voltage

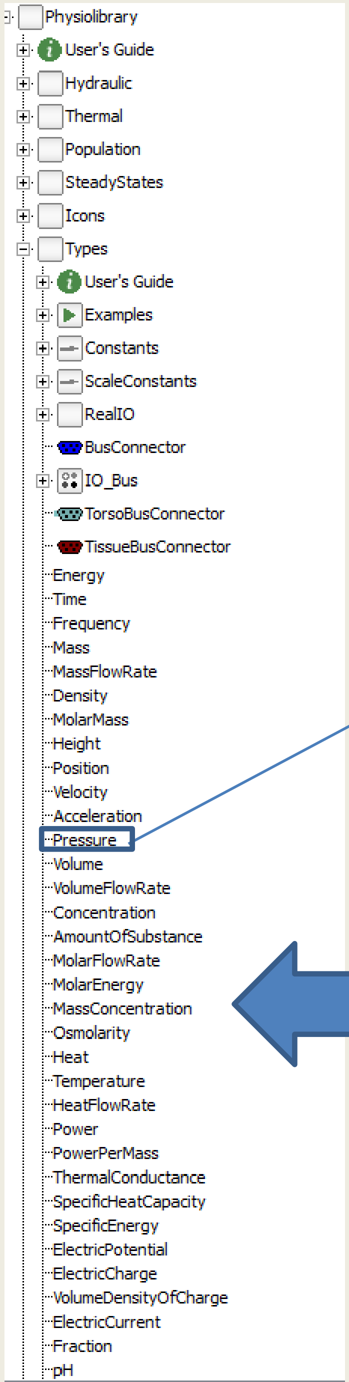


Physiolibrary Structure



Icons


Library
Golem
CardioVascular
Water
Electrolytes
Proteins
Gases
NutrientsMetab...
Heat
Hormones
Nerves
Setup
Status
SkeletalMuscle
Bone
OtherTissue
espiratoryMu...
Fat
Skin
Brain
GITract
LeftHeart
RightHeart
Liver
Kidney
Bladder
GILumen
ThyroidGland
Pancreas
AdrenalGland
Lungs
Tissues
Peritoneum
Plasma
Hypophysis
Heart
SweatGland
Cell
HeatLib
StatusLib
NervesLib
NutrientsMetab...
OxygenLib
ProteinsLib
SetupLib
CardioVascular...
WaterLib
KidneyLib
ElectrolytesLib
GasesLib
GolemLib
BaseLib
HormonesLib
AutonomicCont...
Resistor
Lymph
RespiratoryCen...
Oxygen
CarbonDioxide
AcidBase
Ventilation
PeripheralChe...
HeatCore
Glycogen
Lipids
KetoAcids
Glucose
Lactate
AminoAcids
Urea
MetabolismPart
CellularMetabo...
FemaleSex
Barroreceptor
NervusVagus
SympatheticNe...
PhysicalExercise
SinoatrialNode
StatusNormal
StatusConfused
StatusImpaired
tatusNotBreat...
StatusComatose
StatusMayBeD...
StatusIsReally...
SkeletalMuscle...
Sodium
Potassium
Phosphate
Sulphate
Amonium
Chloride
LungShunt
Hydrostatics
UpperTorso
MiddleTorso
LowerTorso
RedCells
SystemicCircul...
PulmonaryCirc...
Blood
BaseFactorIcon0
BaseFactorIcon
BaseFactorIcon2
BaseFactorIcon3
BaseFactorIcon4
BaseFactorIcon5
BaseFactorIcon6
ConversionIcon
Diffusion
Substance
Speciation
lolarFlowMea...
GasSolubility
Reabsorption
Reabsorption2
Dilution
ElasticBalloon
BloodElasticCo...
BloodSequeste...
HydraulicResistor
FlowMeasure
Membrane
PressureMeasure
InternalElasticB...
Inertance
HydrostaticGra...
Radiator
MichaelisMenten
HeatAccumulat...
OsmoticCell
IdealGas
PartialPressure
ConservationLaw
Nephron
Torso
PerfusionOD
PerfusionDO
CollapsingVessel
PeripheralCircu...
HeartVentricle
Population
FlowFiltration



Types - SI

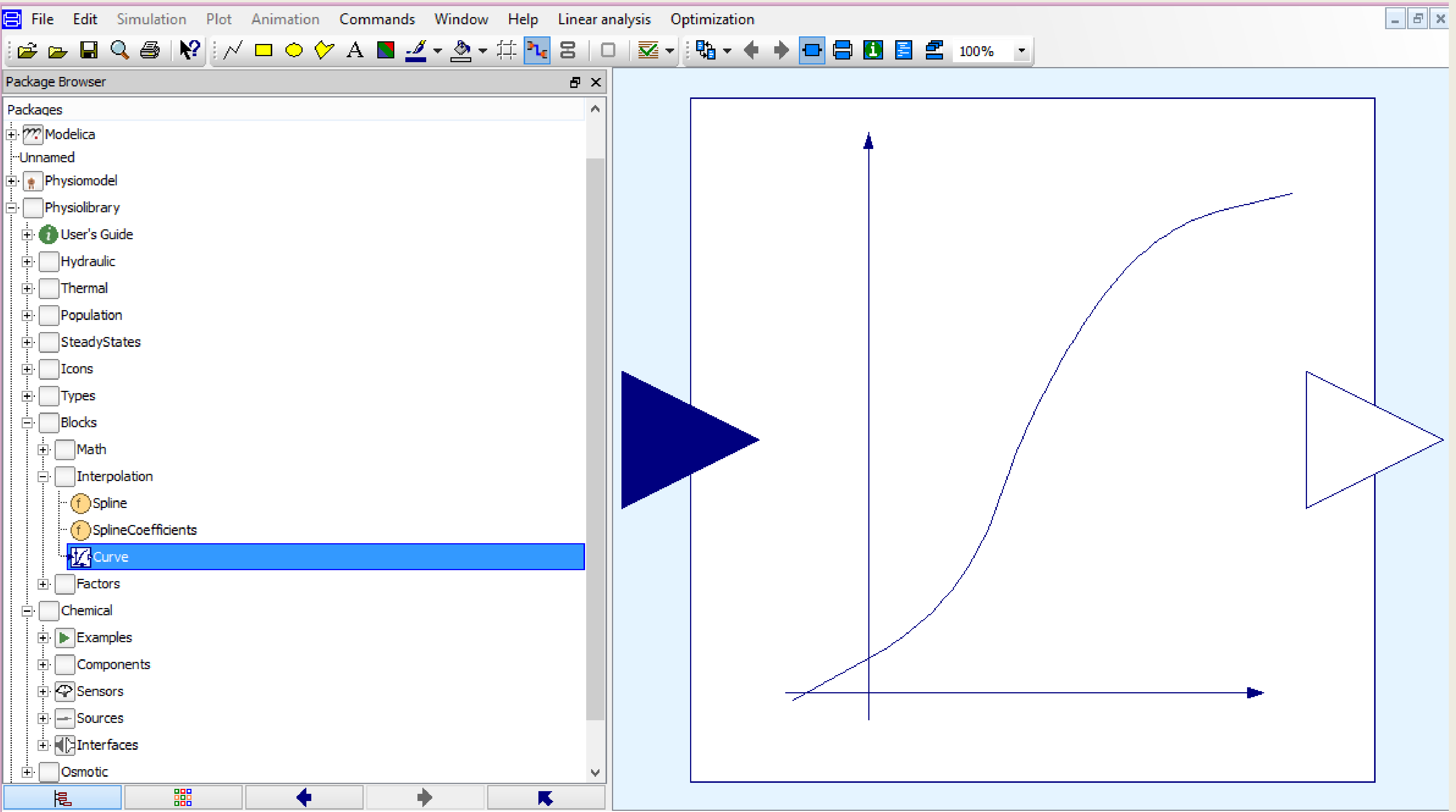
```
type Pressure =  Modelica.SIunits.Pressure(displayUnit="mmHg", nominal=133.322387415);
```

Veškeré jednotky jsou v SI
Automatický přepočet - DisplayValues

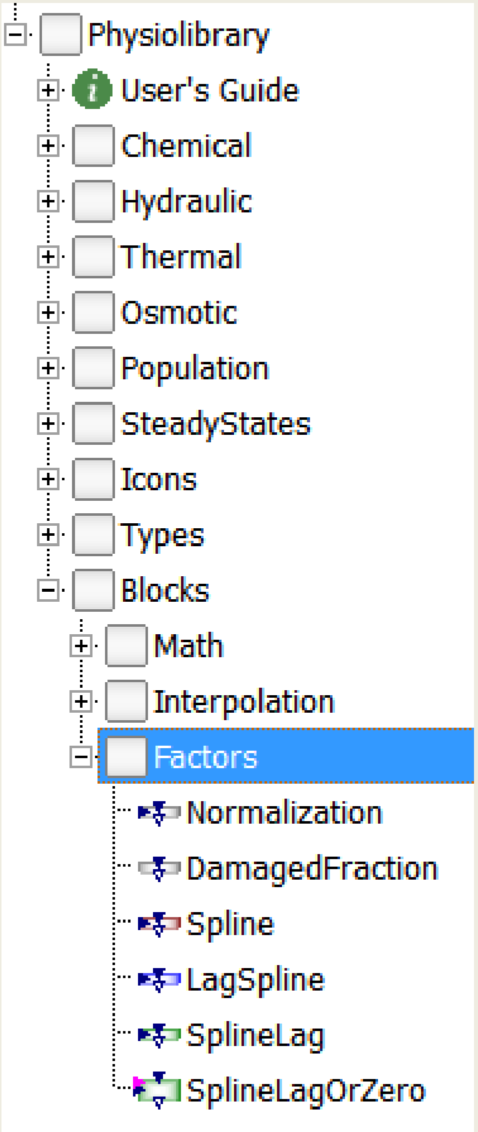
Problém v OM – zatím nefunguje DisplayUnit

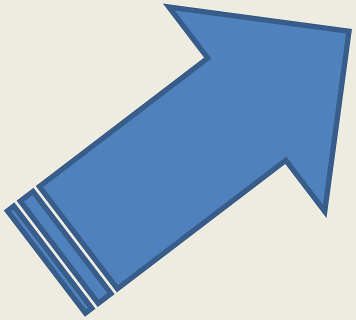
Přepočty jednotek nutno dělat ručně (pro přepočty vhodné využít dědičnost)

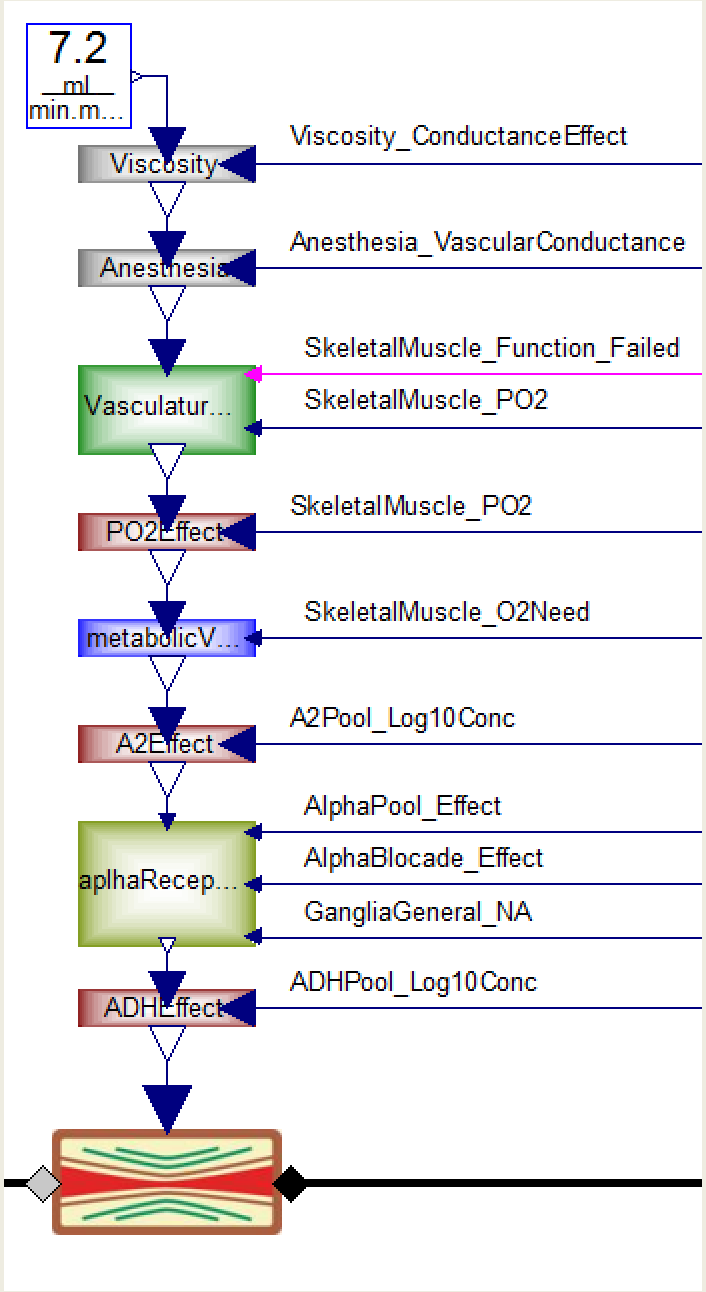
Blocks.Interpolation



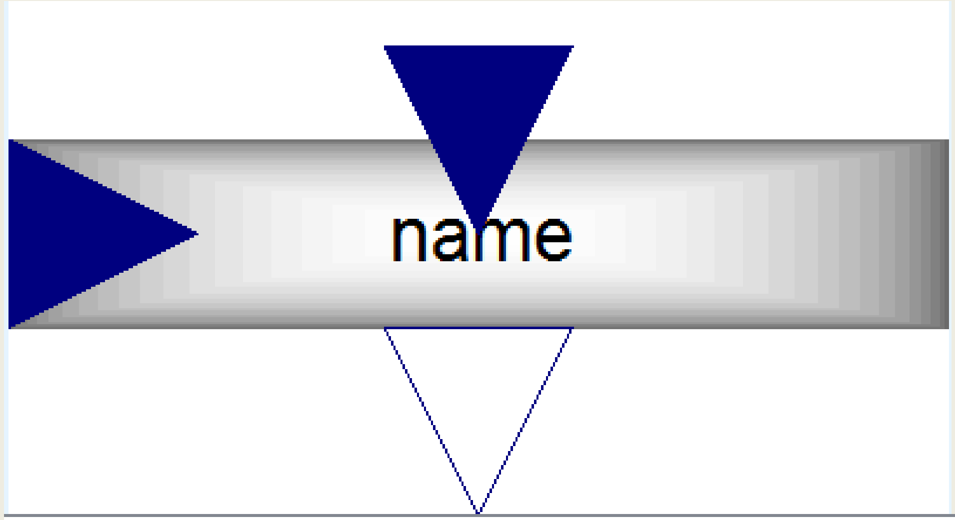
Blocks.Factors







Normalisation



effect = u/NormalValue

Information

y = yBase * u

Extends from Icons.BaseFactorIcon.

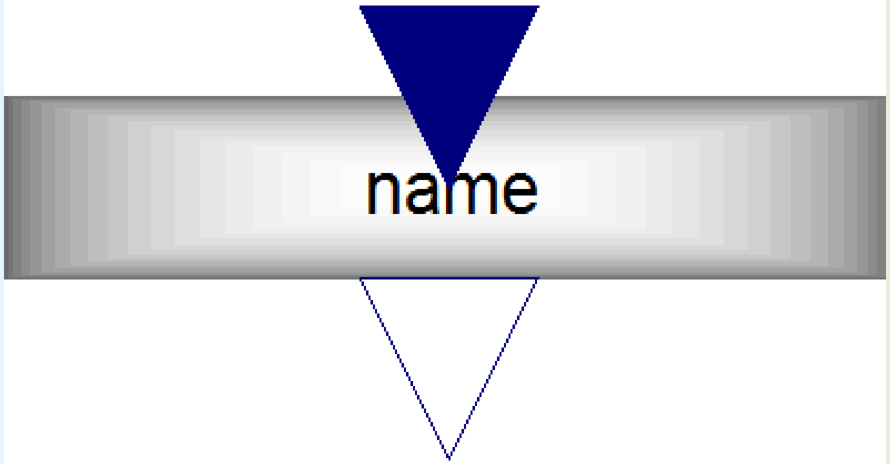
Parameters

Type	Name	Default	Description
Real	NormalValue	1	Normal value of u, because y=(u/NormalValue)*yBase.
Boolean	enabled	true	disabled => y=yBase

Connectors

Type	Name	Description
input RealInput	yBase	
output RealOutput	y	
input RealInput	u	

DamagedFraction



effect = 1 - DamagedAreaFraction

Information

Extends from Icons.BaseFactorIcon.

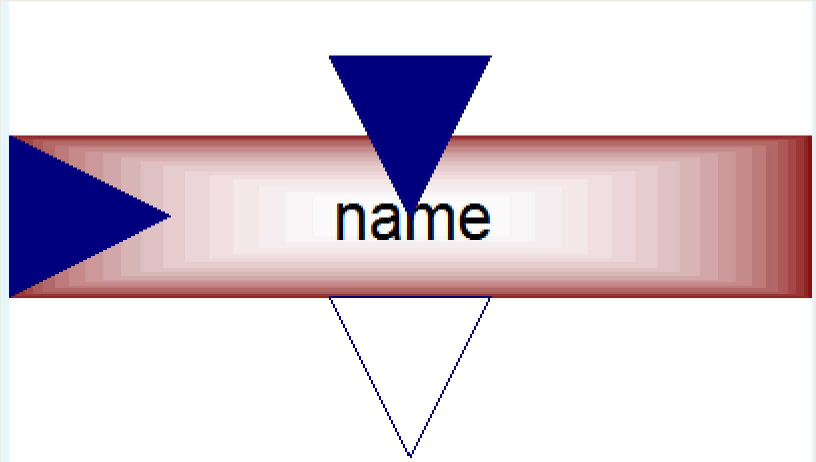
Parameters

Type	Name	Default	Description
Fraction	DamagedAreaFraction	0	[1]

Connectors

Type	Name	Description
input RealInput	yBase	
output RealOutput	y	

Spline



effect = spline(data,u)

Information

Extends from Icons.BaseFactorIcon4.

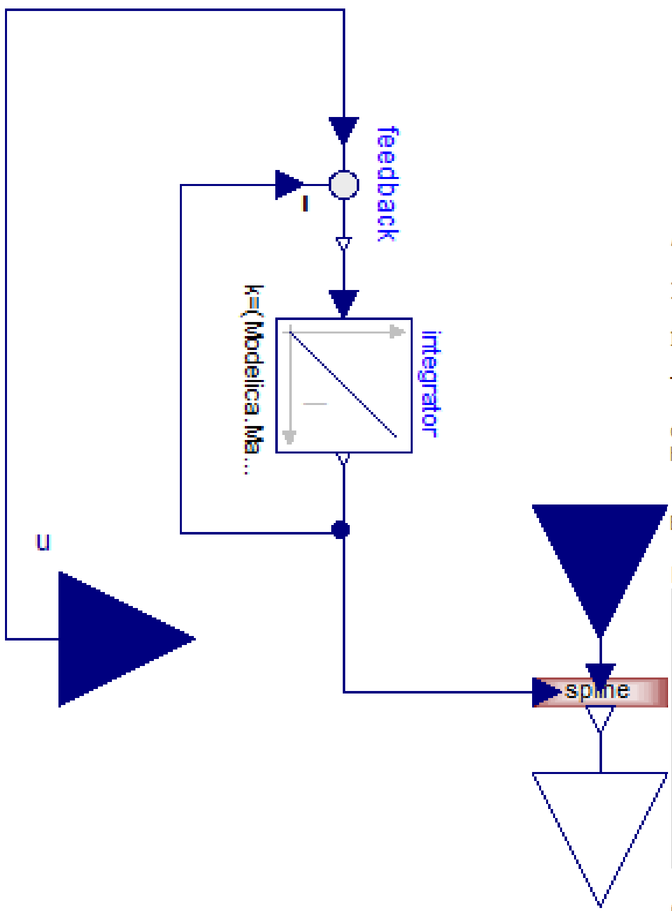
Parameters

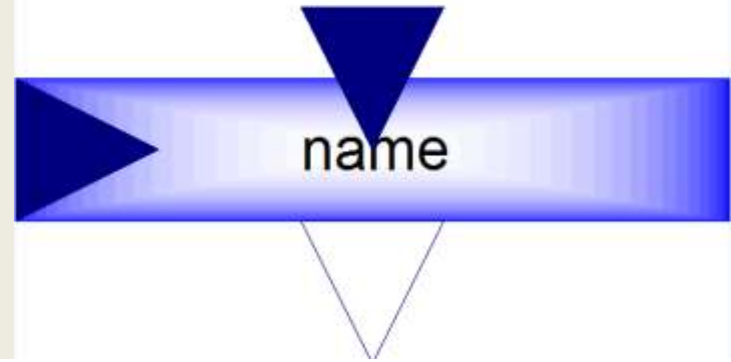
Type	Name	Default	Description
Boolean	enabled	true	disabled => y=yBase
Real	data[:, 3]		Array of interpolating points as {x,y,slope}
Real	Xscale	1	conversion scale to SI unit of x values
Real	Yscale	1	conversion scale to SI unit of y values
Boolean	UsePositiveLog10	false	x = if u/scaleX <=1 then 0 else log10(u/scaleX)

Connectors

Type	Name	Description
input RealInput	yBase	
output RealOutput	y	
input RealInput	u	

LagSpline





Adapt the input signal before interpolation

Information

If the input signal u is constant and it is different from starting delayed input d, the middle value between u and d will be reached after HalfTime.

The mathematical background:

d'(t) = k*(u(t) - d(t)) => The solution of d(t) in special case, if u(t) is constant at each time t: d(t)=u+(d(0)-u)*e^(-k*t), where the definition of HalfTime is d(HalfTime) = d(0) + (d(0)-u)/2.

Extends from Icons.BaseFactorIcon5.

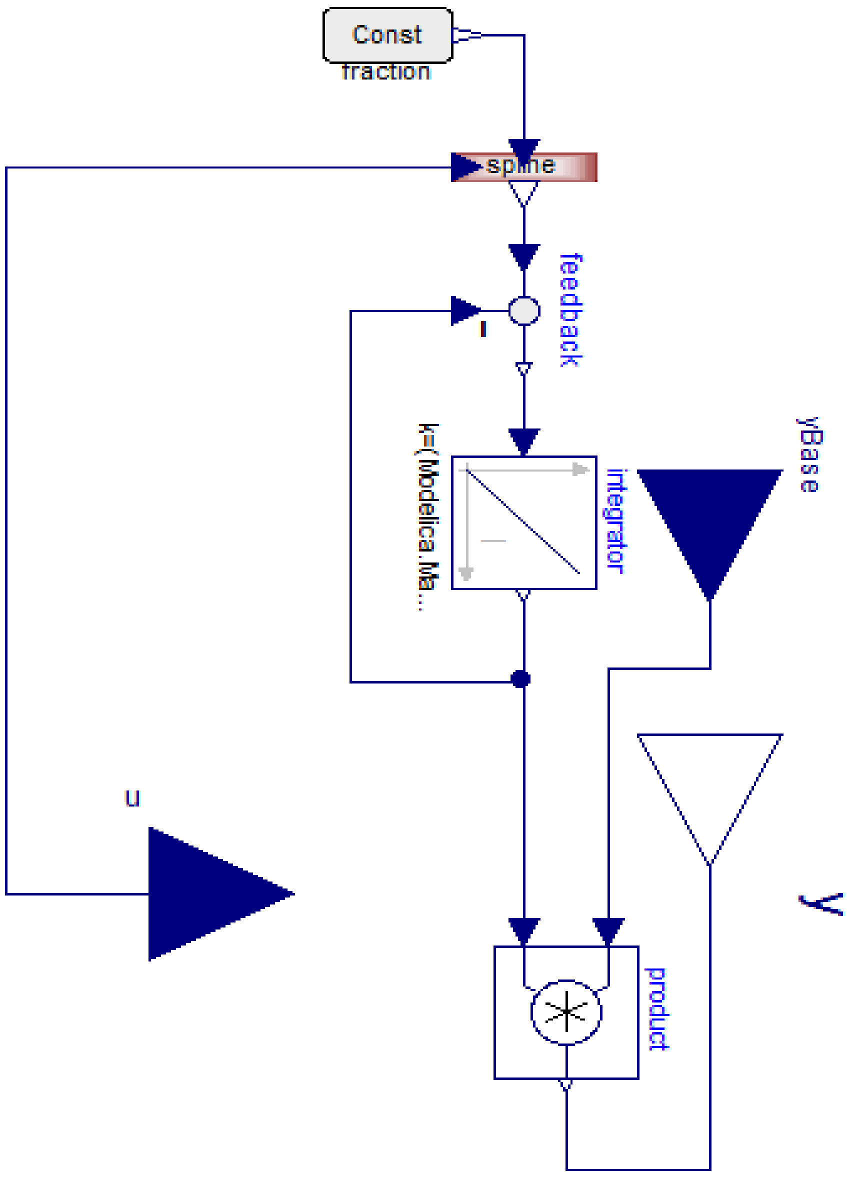
Parameters

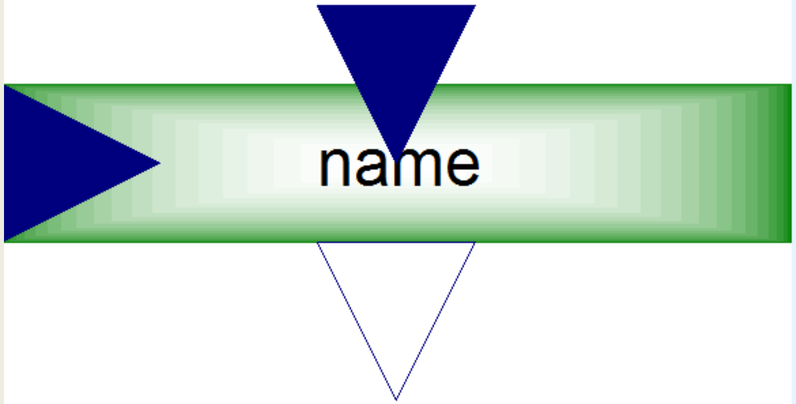
Type	Name	Default	Description
Boolean	enabled	true	disabled => y=yBase
Time	HalfTime		[s]
Real	initialValue	1	as u/Xscale
Real	Xscale	1	conversion scale to SI unit of x values
Real	Yscale	1	conversion scale to SI unit of y values
Boolean	UsePositiveLog10	false	x = if u_delayed/scaleX <=1 then 0 else log10(u_delayed/scaleX)
Real	data[:, 3]		

Connectors

Type	Name	Description
input RealInput	yBase	
output RealOutput	y	
input RealInput	u	

SplineLag





Adapt the effect after interpolation

Information

Extends from Icons.BaseFactorIcon3.

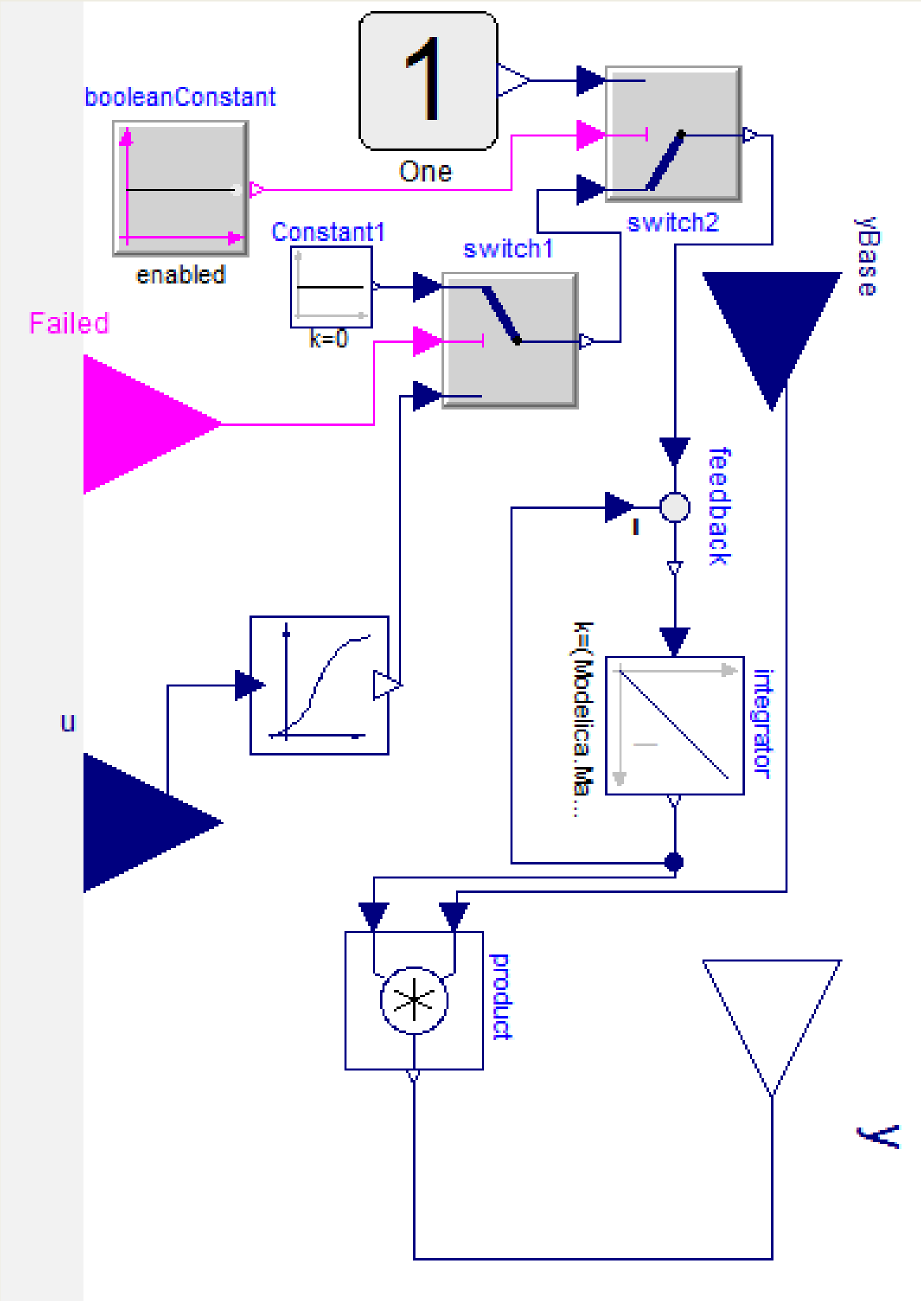
Parameters

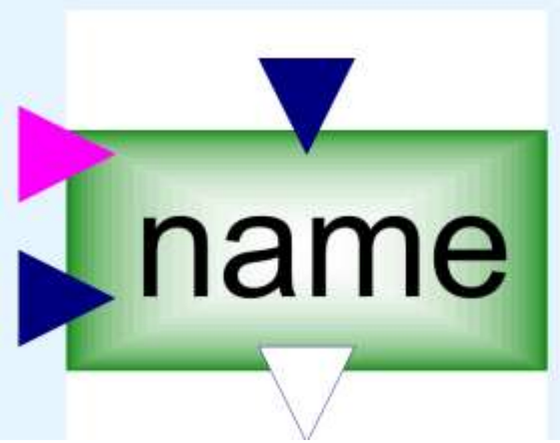
Type	Name	Default	Description
Boolean	enabled	true	disabled => y=yBase
Time	HalfTime		[s]
Real	Xscale	1	conversion scale to SI unit of x values
Boolean	UsePositiveLog10	false	x = if u/scaleX <=1 then 0 else log10(u/scaleX)
Real	data[:, 3]		
IO			
Value I/O			
String	stateName	getInstanceName()	Name in Utilities input/output function

Connectors

Type	Name	Description
input RealInput	yBase	
output RealOutput	y	
input RealInput	u	

SplineLagOrZero





LagSpline if not Failed

Information

Extends from Icons.BaseFactorIcon2.

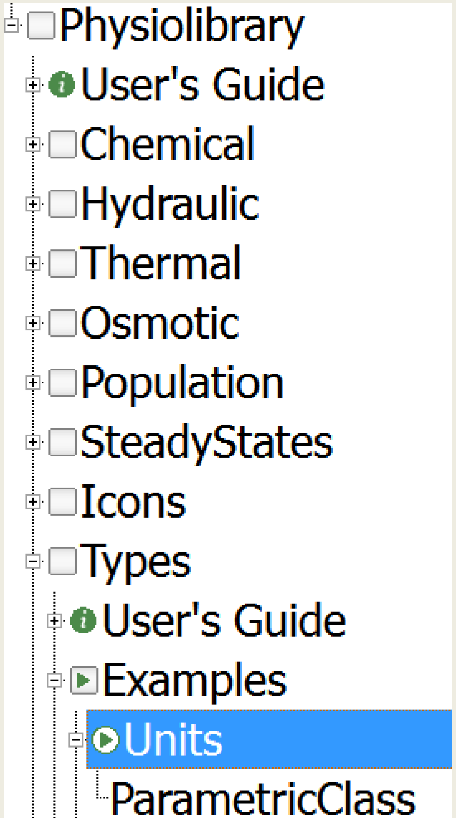
Parameters

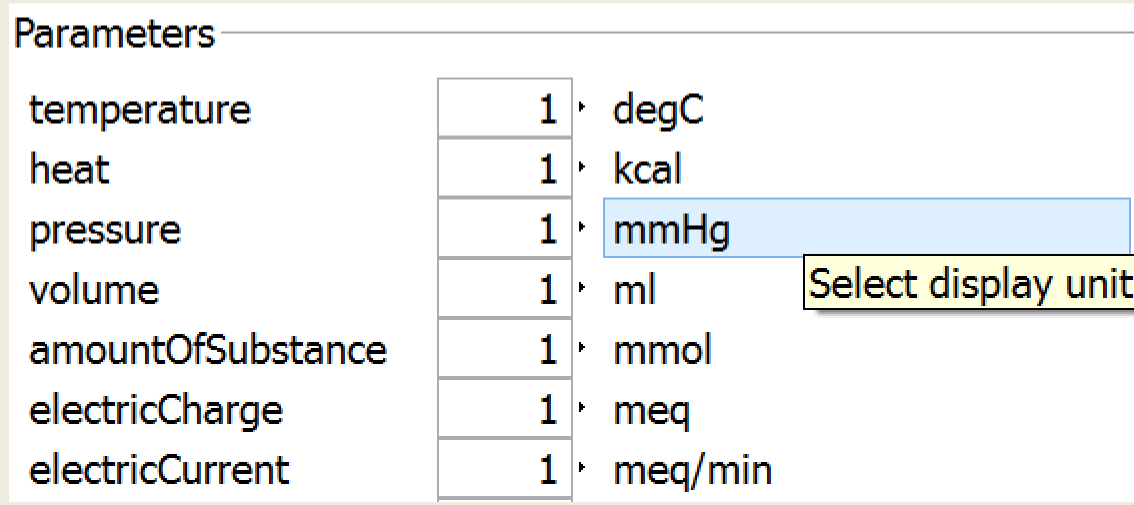
Type	Name	Default	Description
Boolean	enabled	true	disabled => y=yBase
Time	HalfTime		[s]
Real	data[:, 3]		
Real	Xscale	1	conversion scale to SI unit of x values
IO			
Value I/O			
String	stateName	getInstanceName()	Name in Utilities input/output function

Connectors

Type	Name	Description
input RealInput	yBase	
output RealOutput	y	
input RealInput	u	
input BooleanInput	Failed	

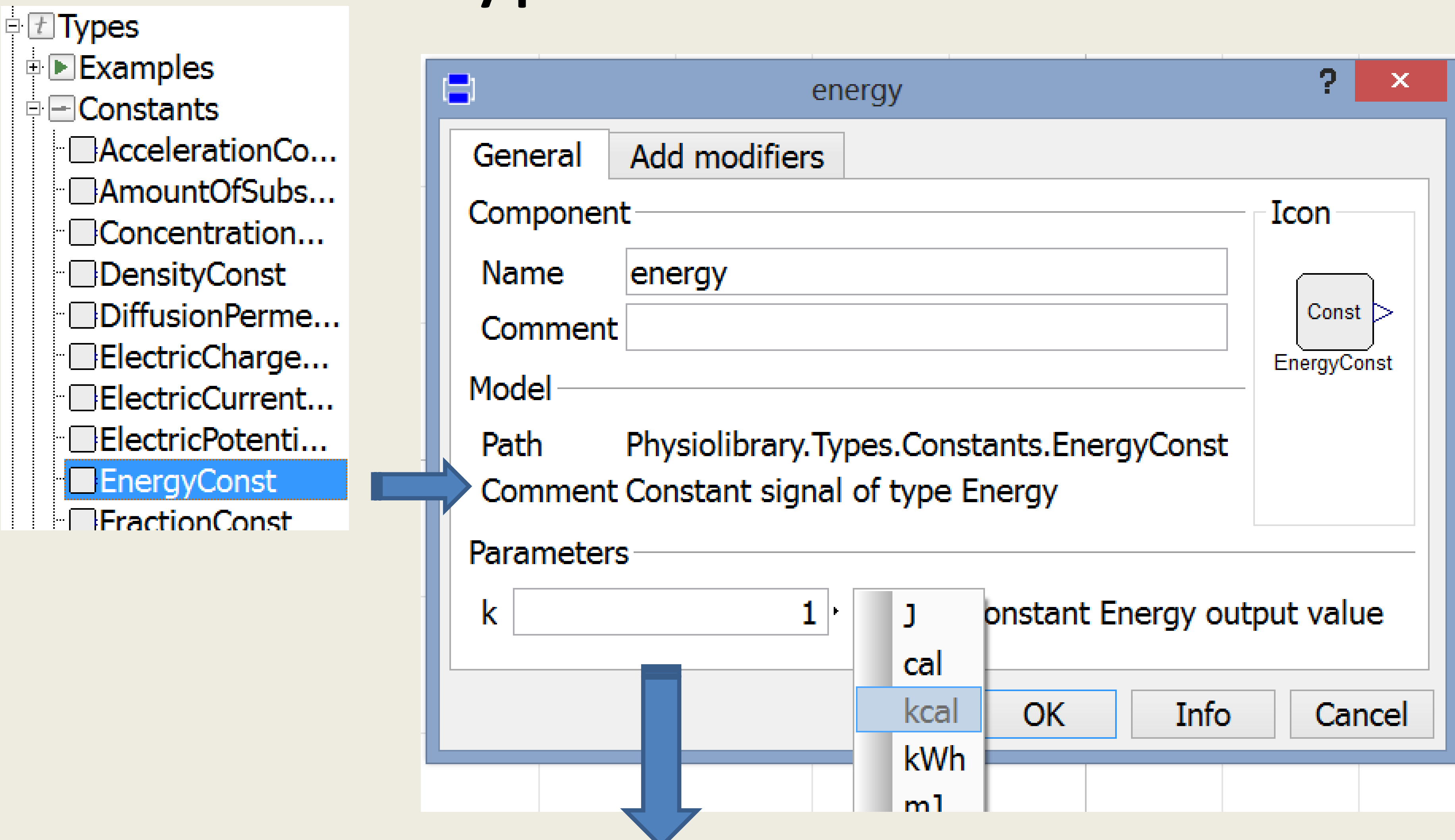
Types





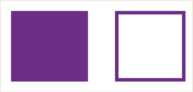

```
model Units
 ParametricClass parametricClass(
   temperature(displayUnit="degC") = 274.15,
   heat(displayUnit="kcal") = 4186.8,
   pressure(displayUnit="mmHg") = 133.322387415,
   volume(displayUnit="ml") = 1e-06,
   amountOfSubstance(displayUnit="mmol") = 0.001,
   electricCharge(displayUnit="meq") = 96.4853399,
   electricCurrent(displayUnit="meq/min") = 1.6080889983333,
```

Types.Constants



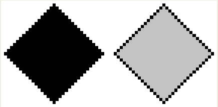

```
Physiolibrary.Types.Constants.EnergyConst energy(k=4186.8)
  ;
```

Connectors



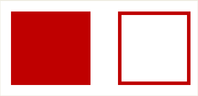
ChemicalPort

– molar concentration, molar flow



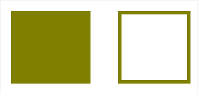
HydraulicPort

– pressure, volumetric flow



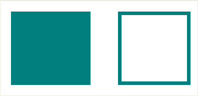
ThermalPort

– temperature, heat flow



OsmoticPort

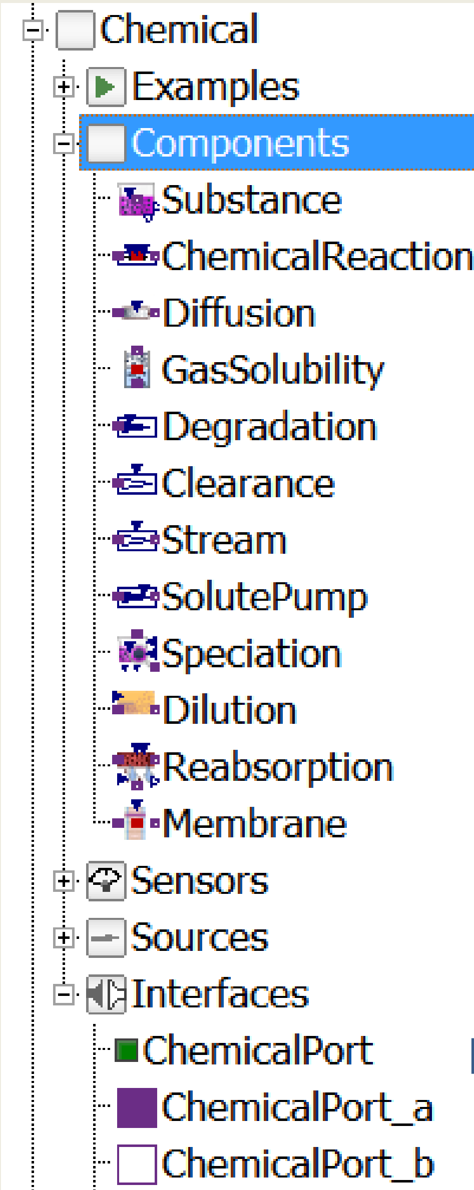
– osmolarity, osmotic volumetric flow

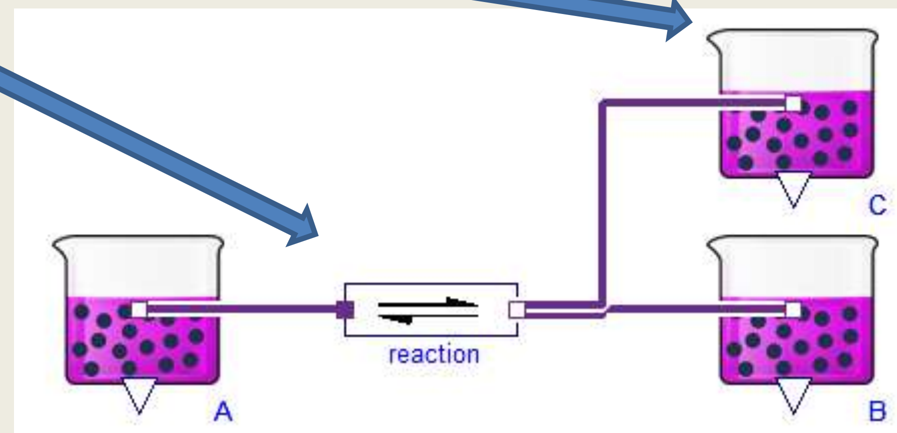


PopulationPort

– size of population, change of population

Chemical



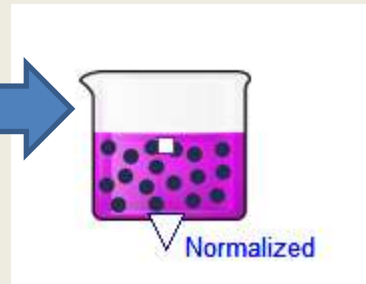



```
connector ChemicalPort
  Types.Concentration conc;
  flow Types.MolarFlowRate q;

end ChemicalPort;
```

CONDITIONAL INPUTS

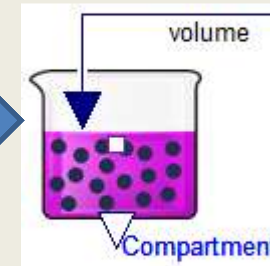
External inputs/outputs

useNormalizedVolume ☑



External inputs/outputs

useNormalizedVolume ☐



Parameters

Conductance 100 ml/min

External inputs/outputs

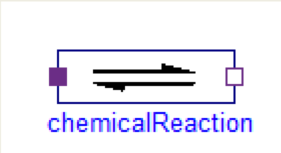
useConductanceInput ☐

Parameters

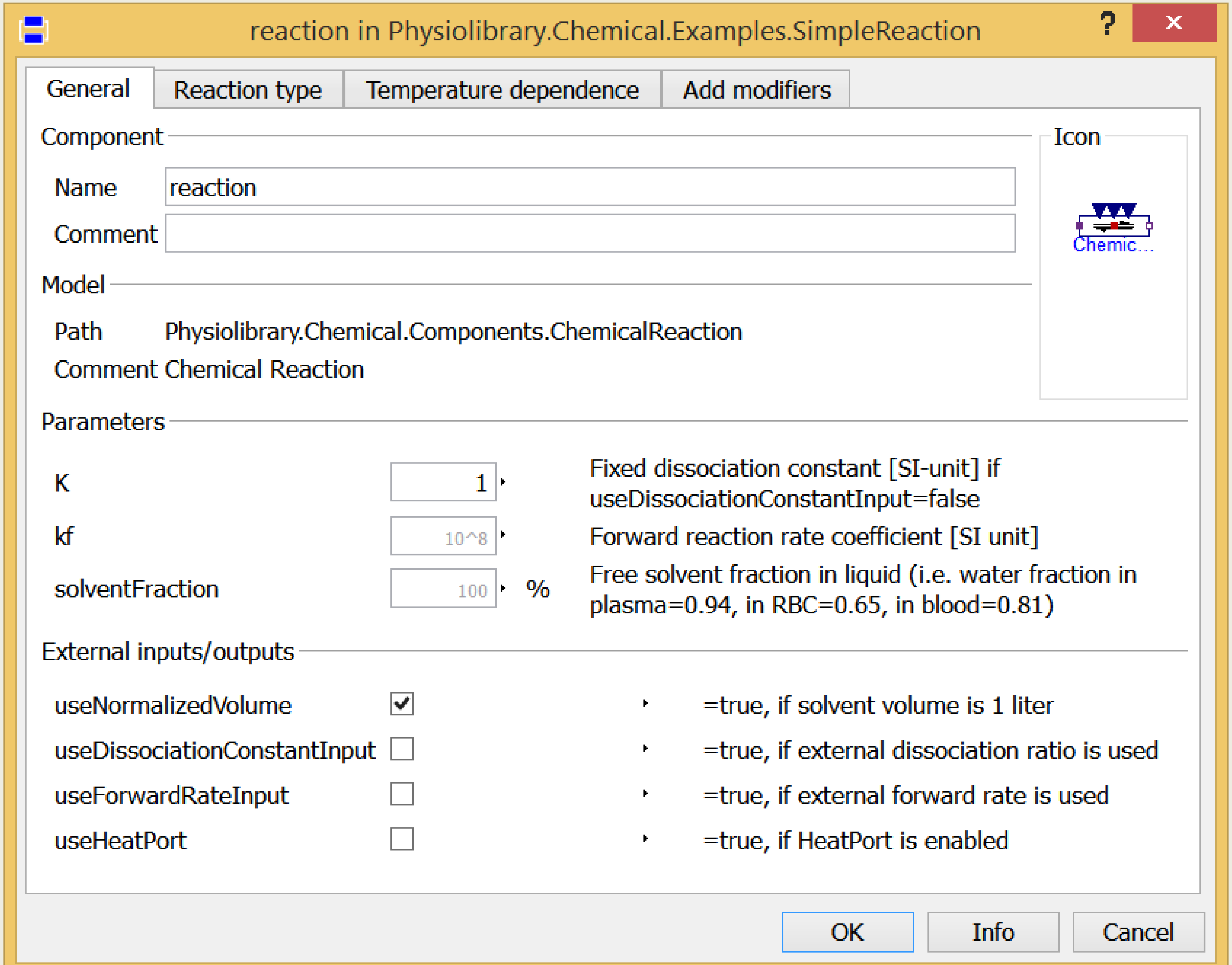
Conductance 0 ml/min

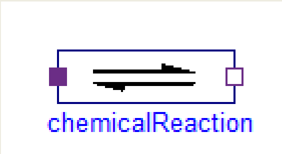
External inputs/outputs

useConductanceInput ☑

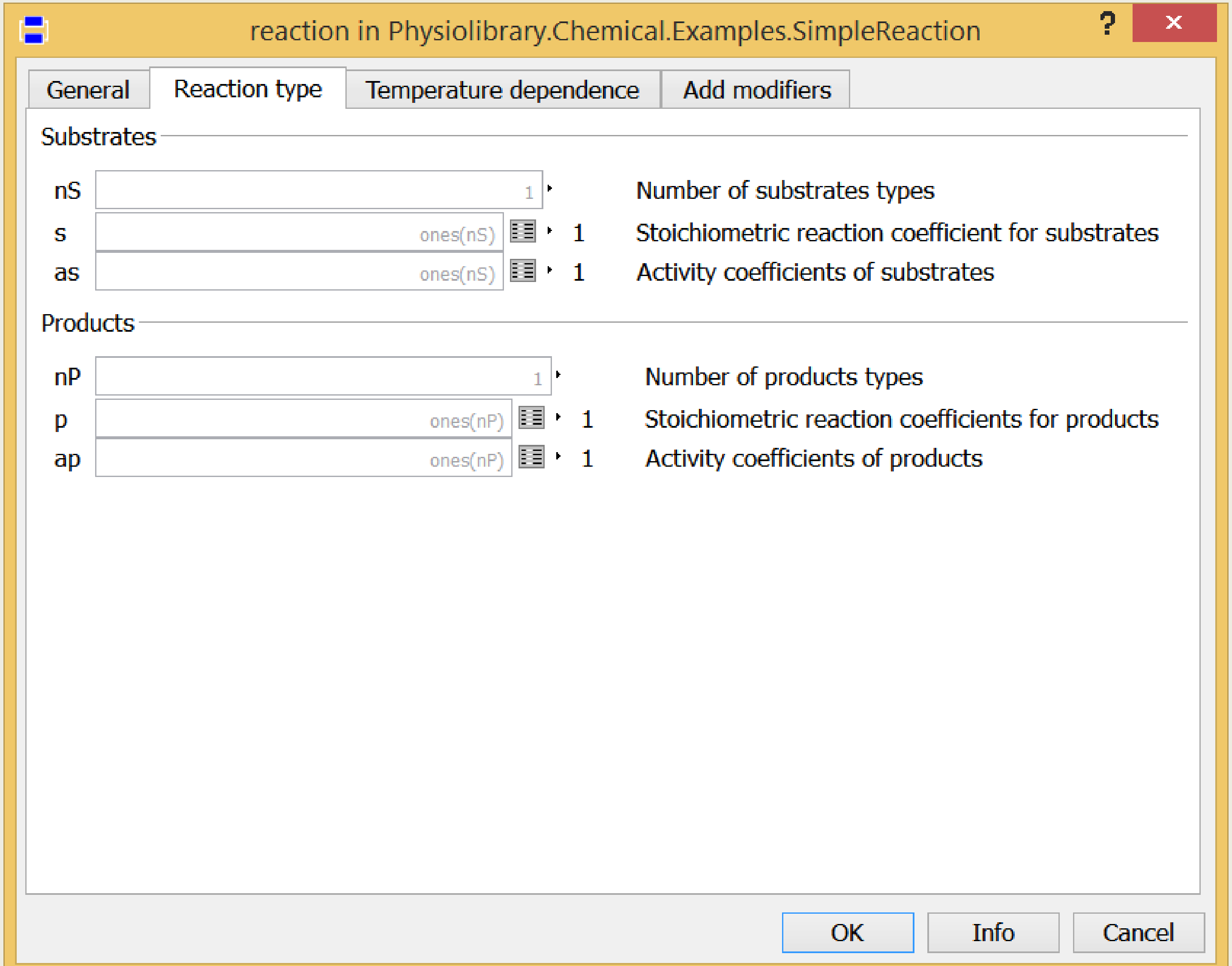


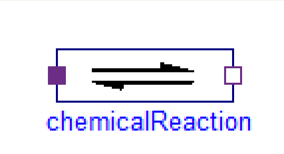
Chemical Reaction



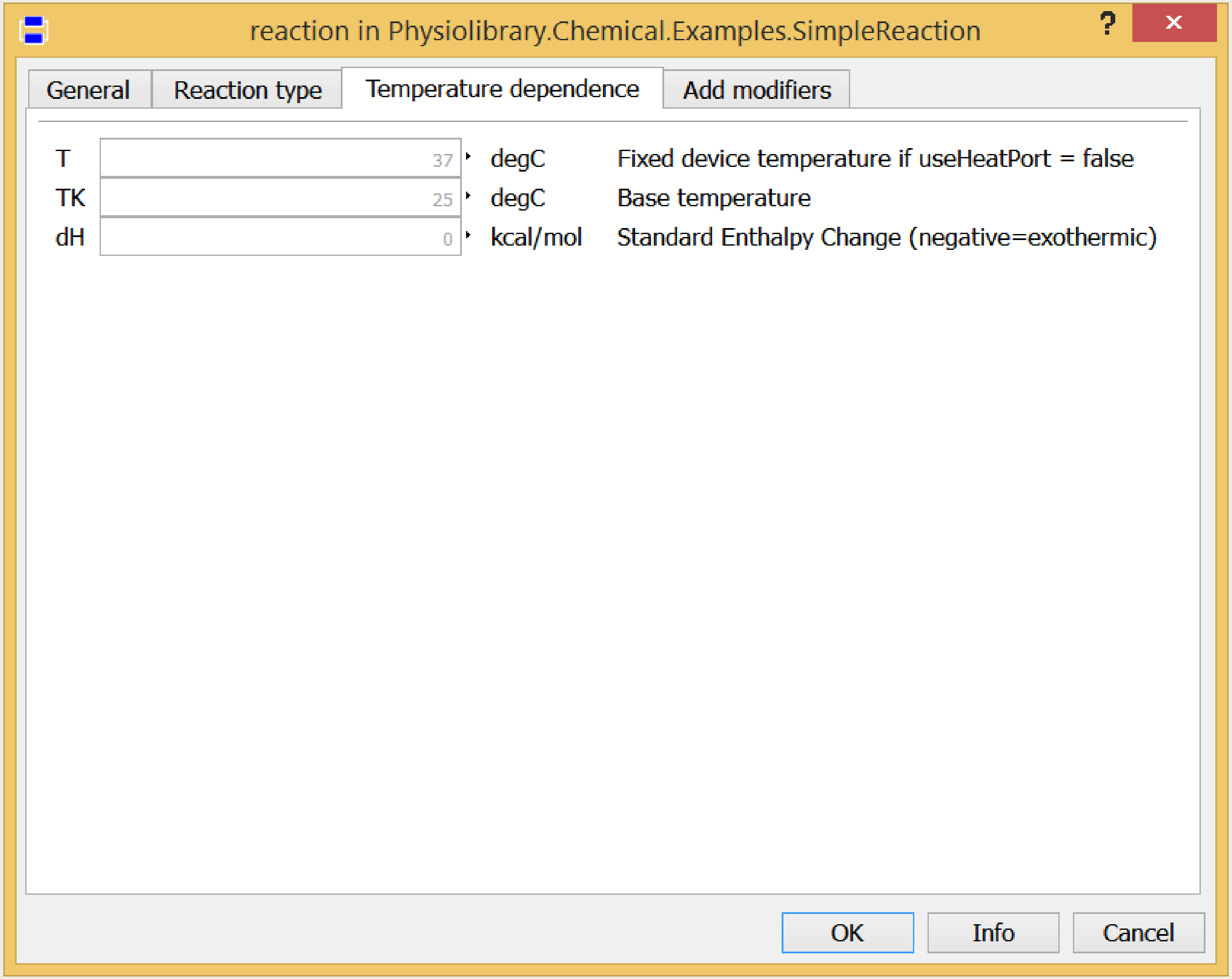


Chemical Reaction

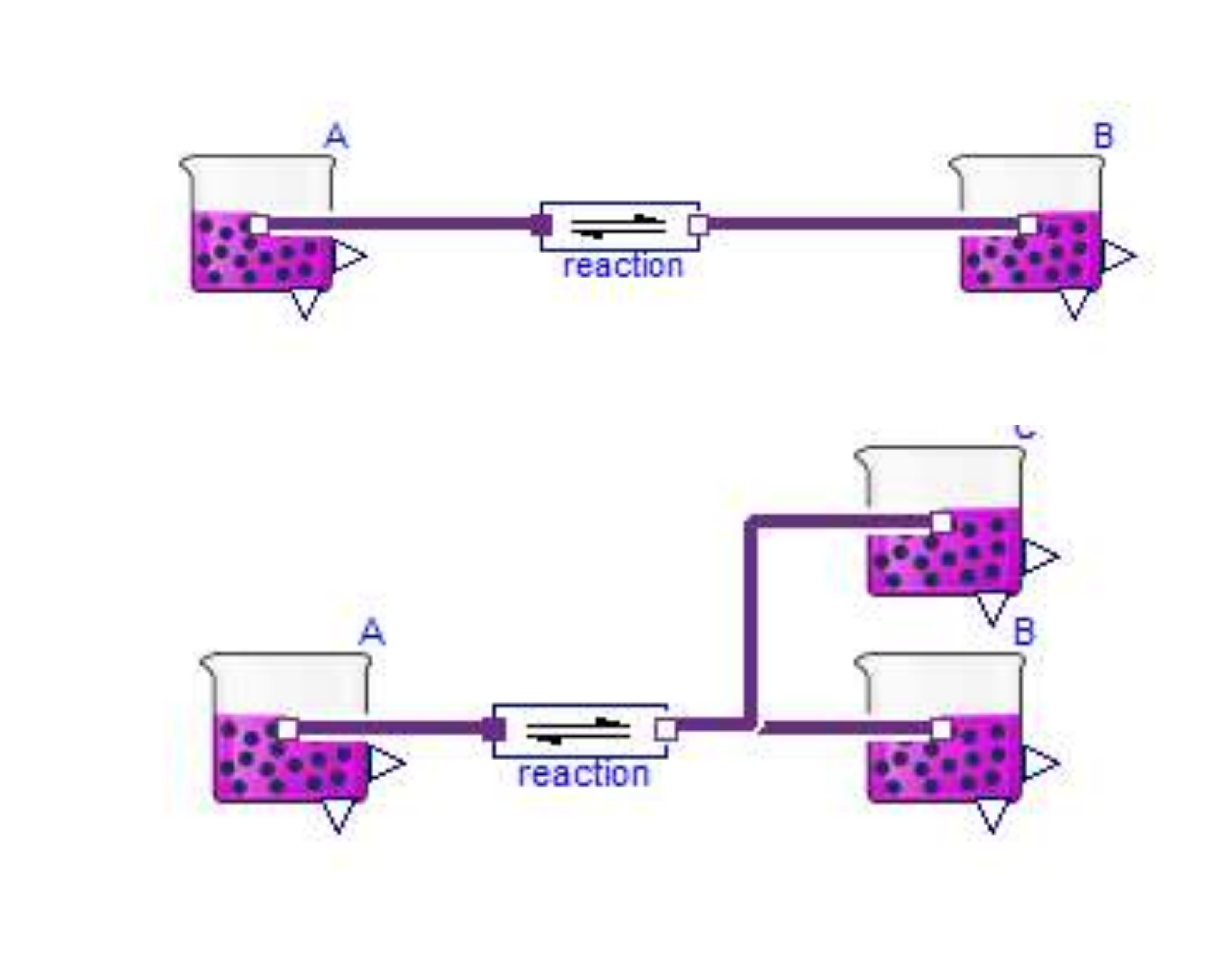




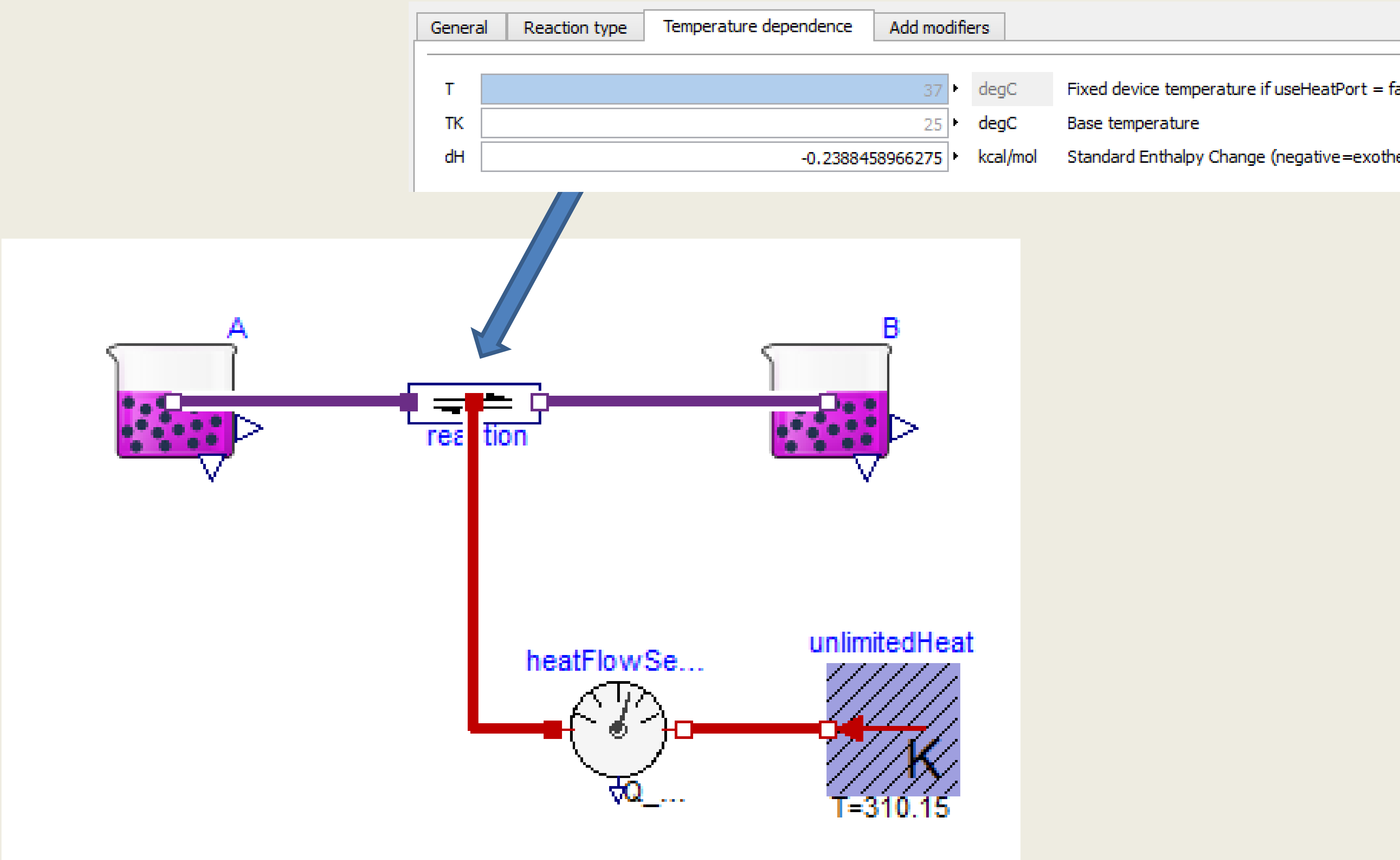
Chemical Reaction



Simple Reaction

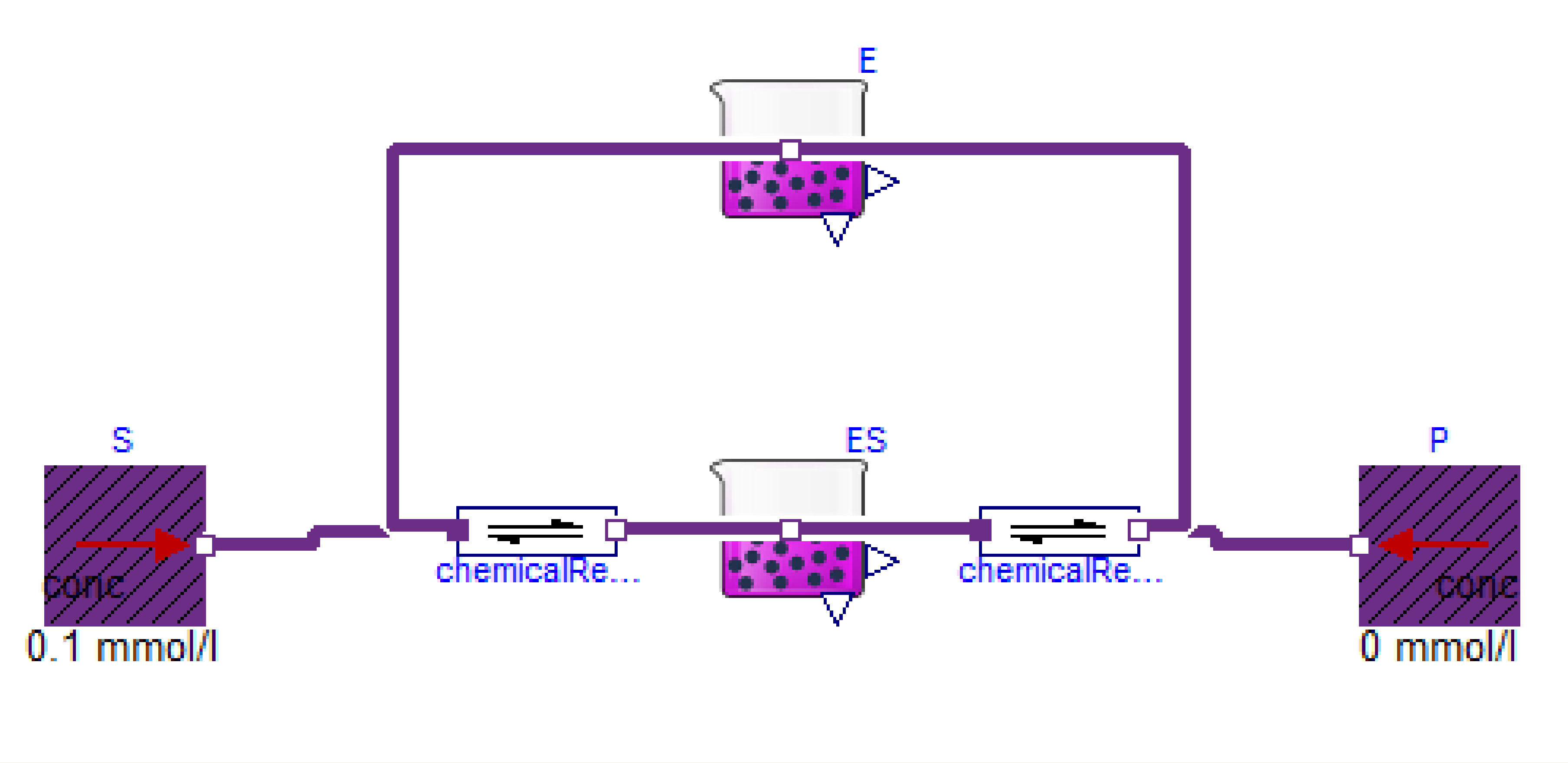


Exothermic Reaction

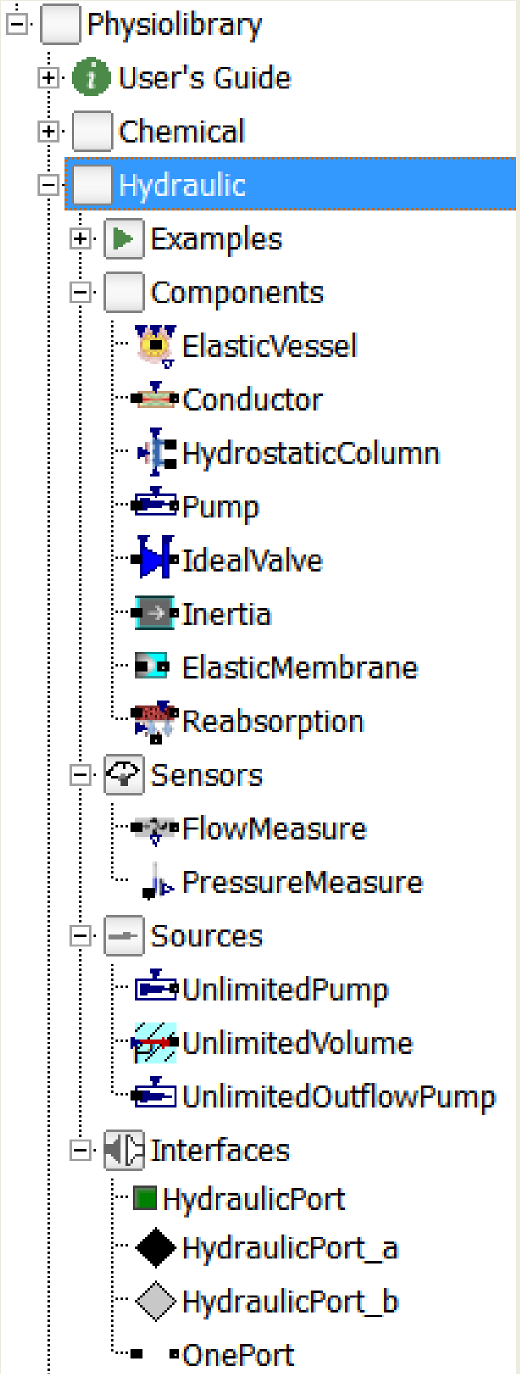


Michaelis-Menten

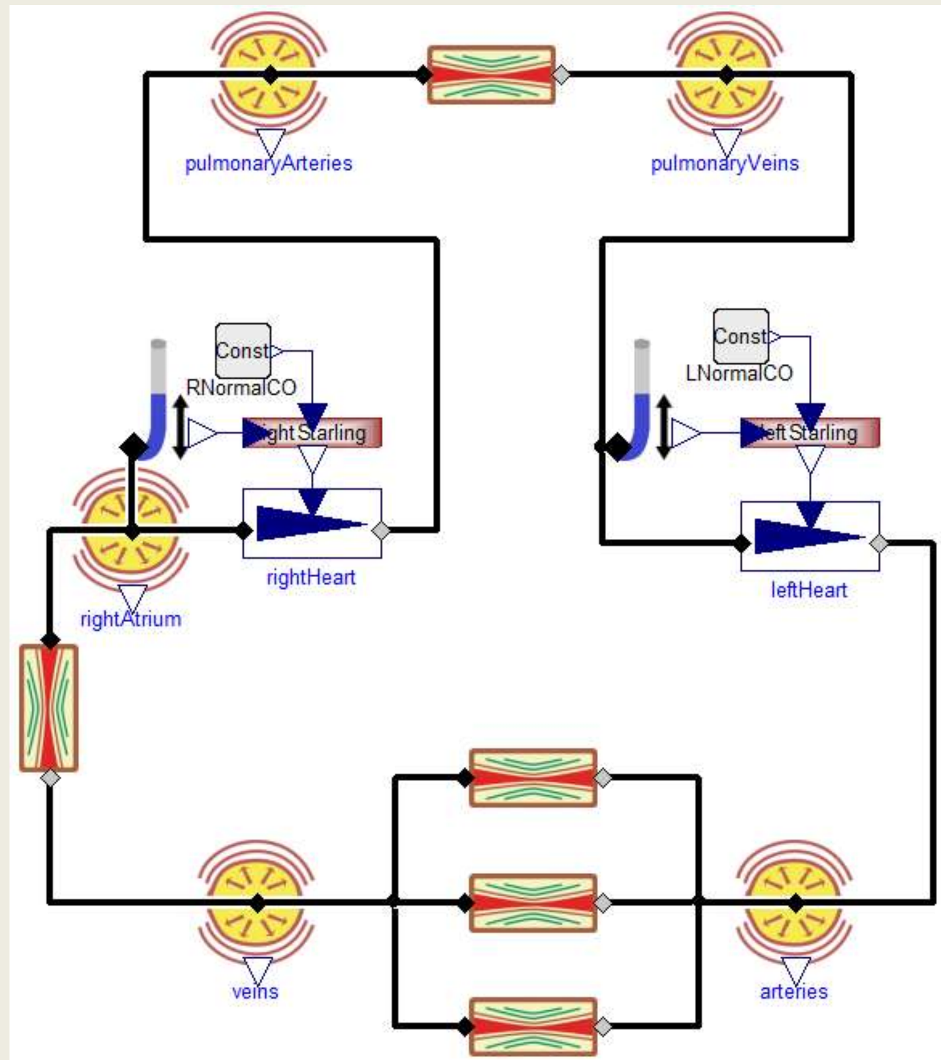
$$S + E \underset{K_{1-}}{\overset{K_{1+}}{\rightleftarrows}} ES \xrightarrow{K_2} E + P$$



Hydraulic

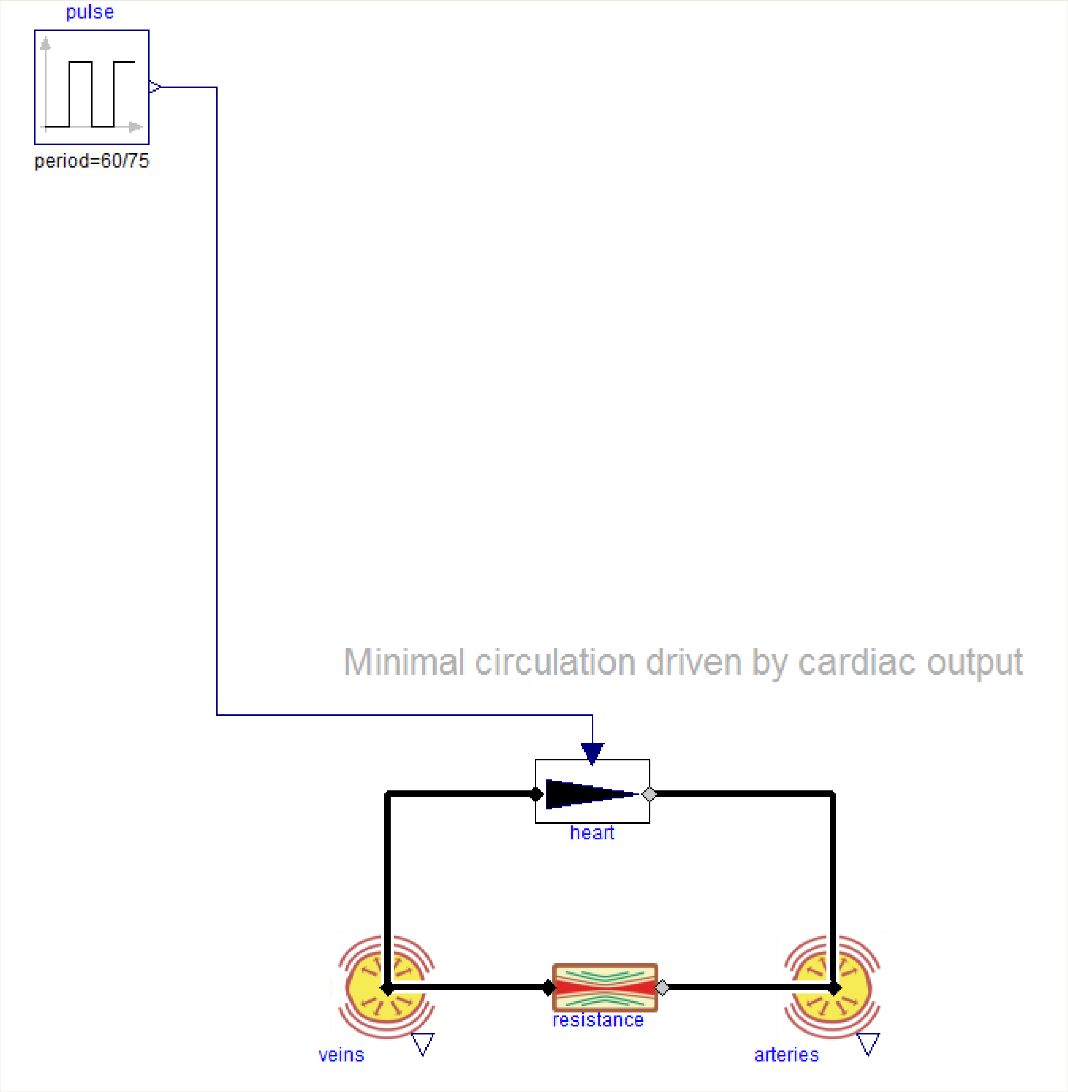


Physiolibrary
User's Guide
Chemical
Hydraulic
Examples
Components
ElasticVessel
Conductor
HydrostaticColumn
Pump
IdealValve
Inertia
ElasticMembrane
Reabsorption
Sensors
FlowMeasure
PressureMeasure
Sources
UnlimitedPump
UnlimitedVolume
UnlimitedOutflowPump
Interfaces
HydraulicPort
HydraulicPort_a
HydraulicPort_b
OnePort

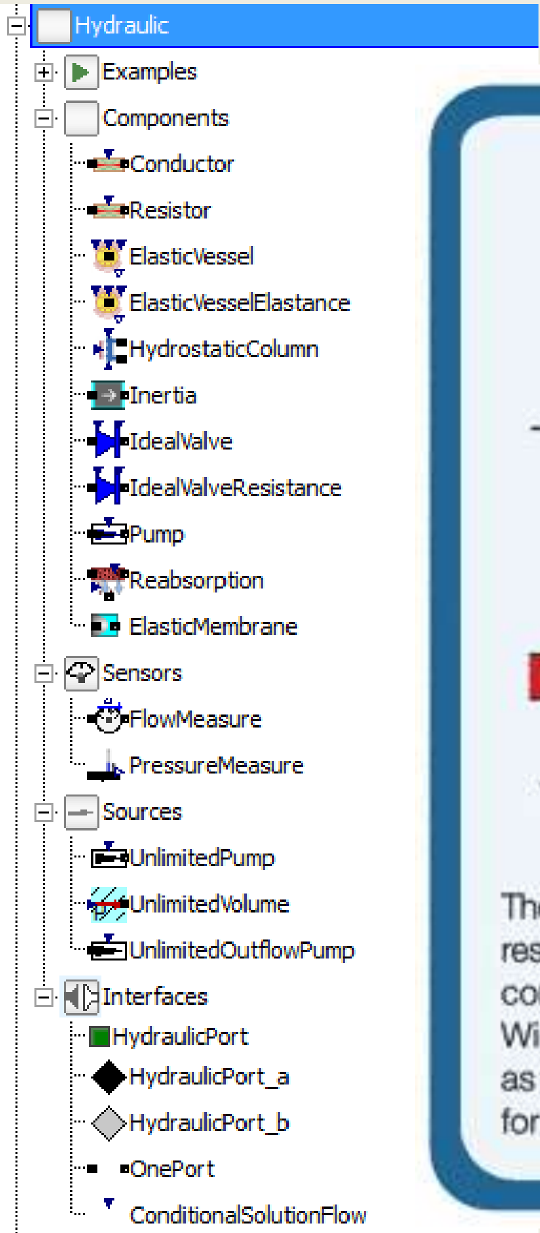


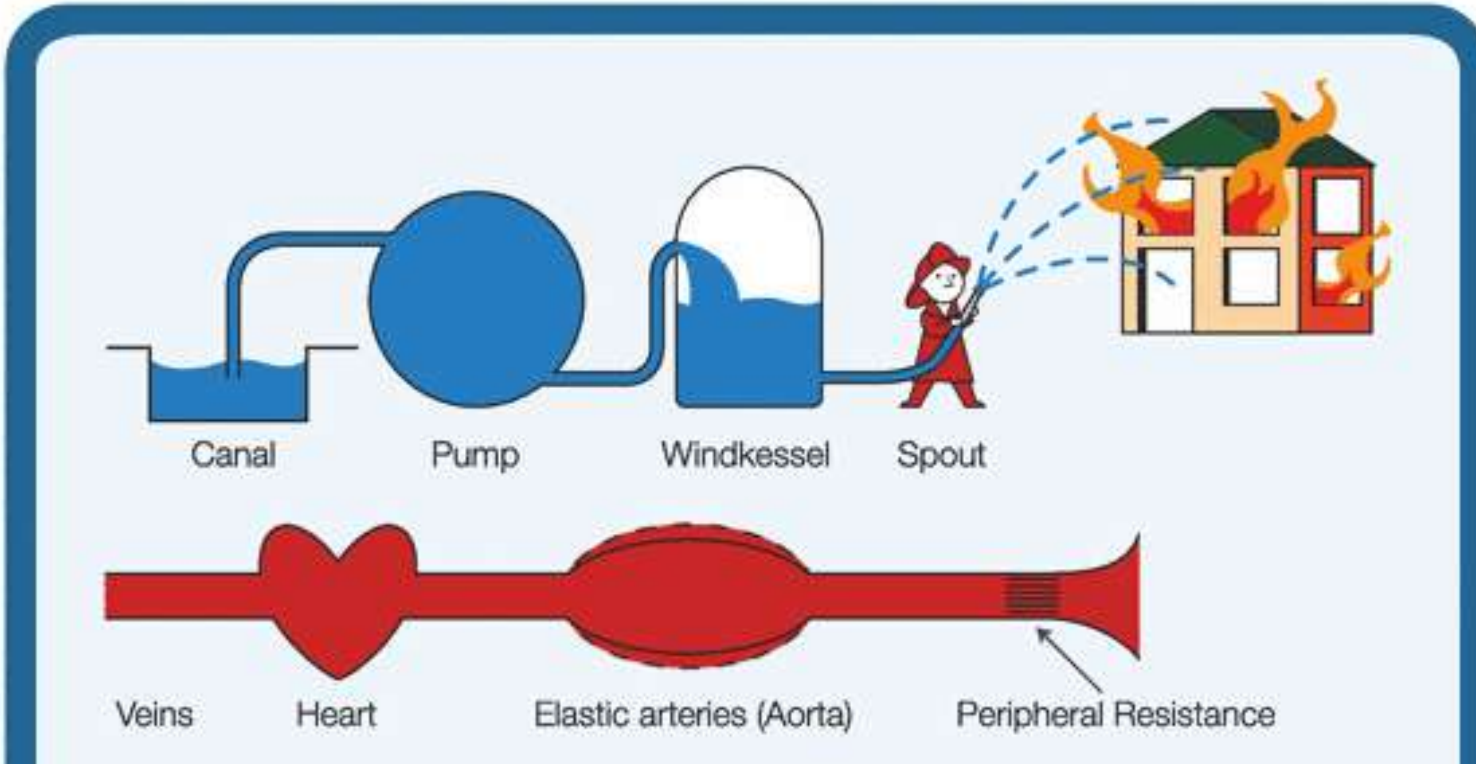
pulmonaryArteries
pulmonaryVeins
Const
RNormalCO
ight Starling
Const
LNormalCO
eft Starling
rightHeart
leftHeart
rightAtrium
veins
arteries

Minimal circulation



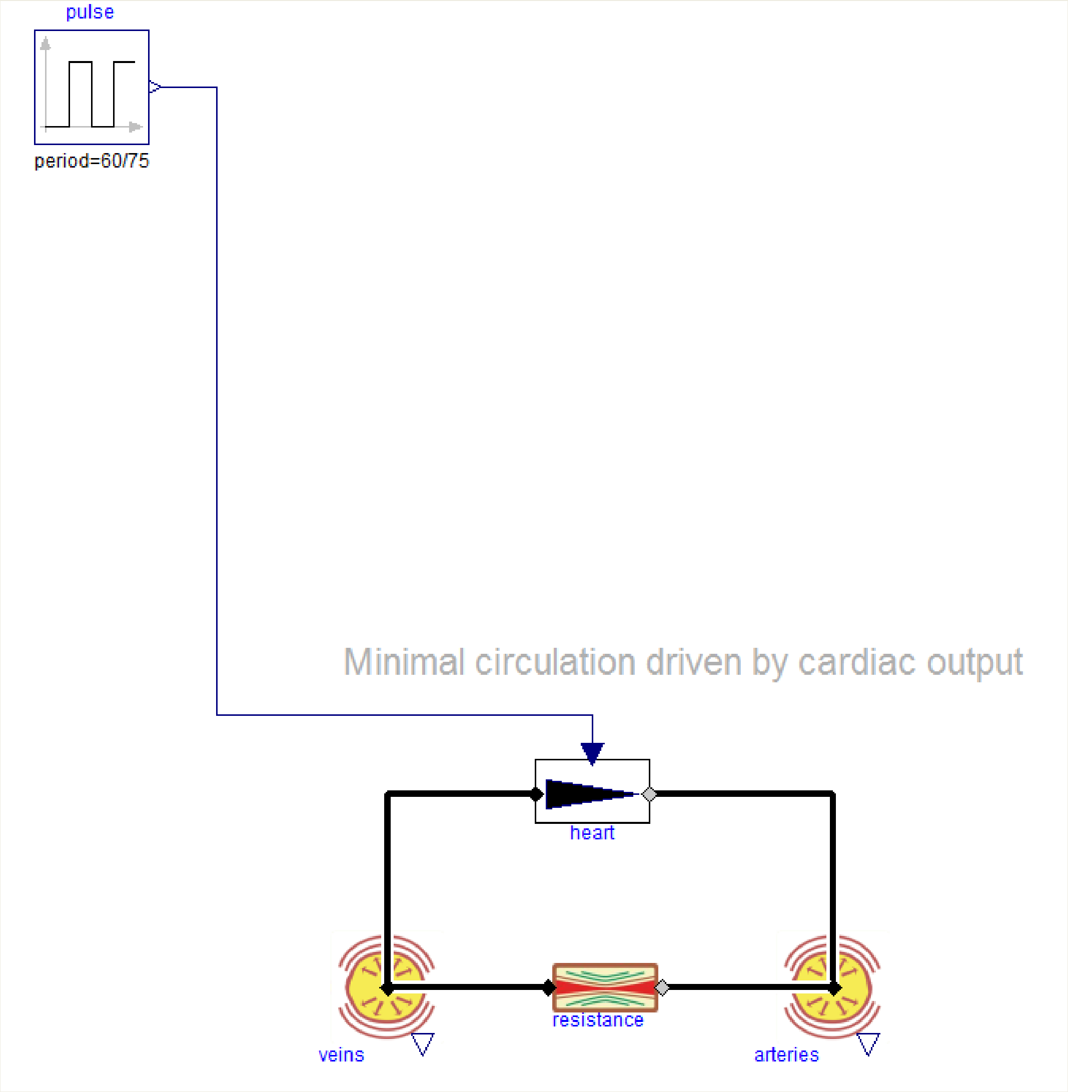
Windkessel model



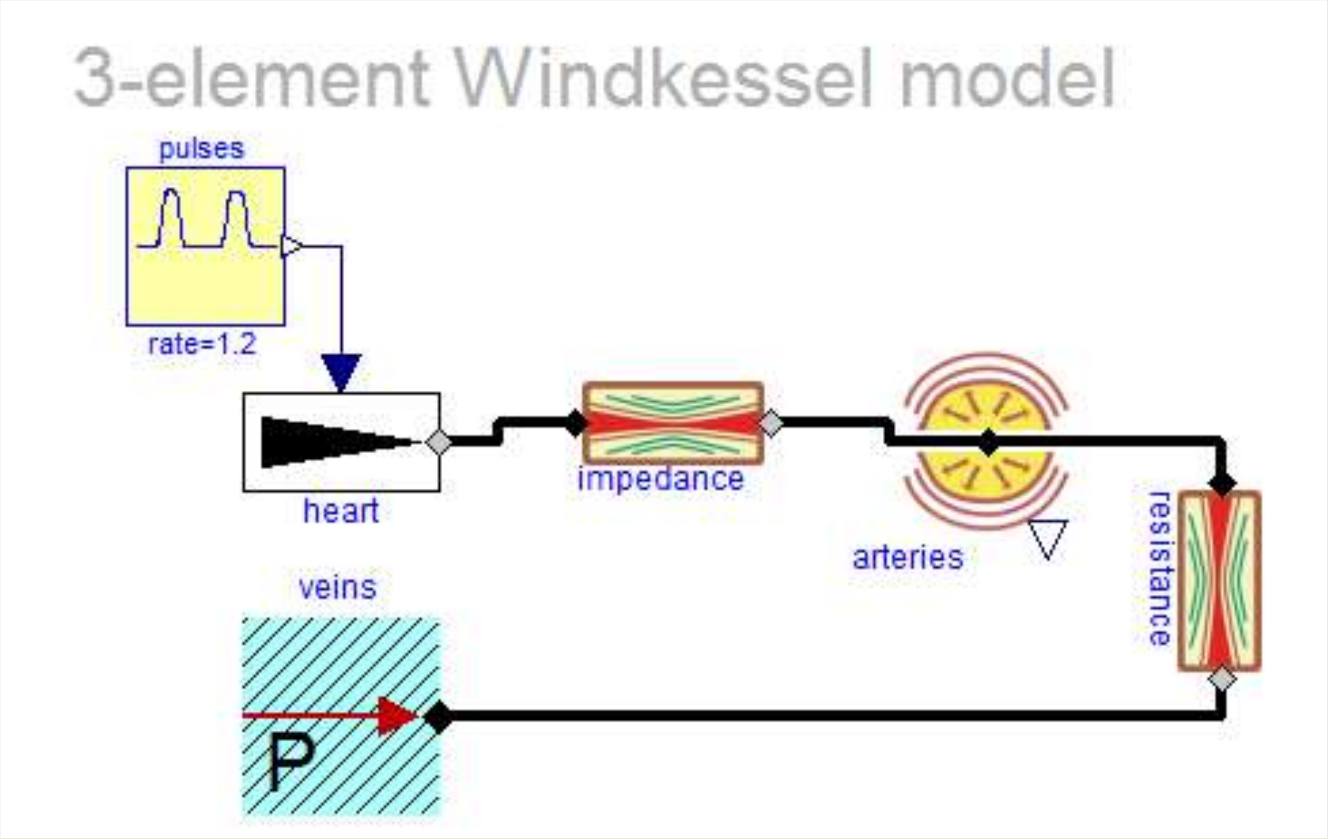


The analogy between the fire engine with the Windkessel and the arterial system. The peripheral resistance is the summed resistance of all small arteries, arterioles and capillaries. Total arterial compliance is the sum of the compliances of all arteries, mainly the conduit arteries. The Windkessel model can help us to understand how the arterial system functions, can be used as a realistic load in isolated heart studies, can be used in modeling, and can form the basis for estimating arterial system parameters. Adapted from [1], used by permission.

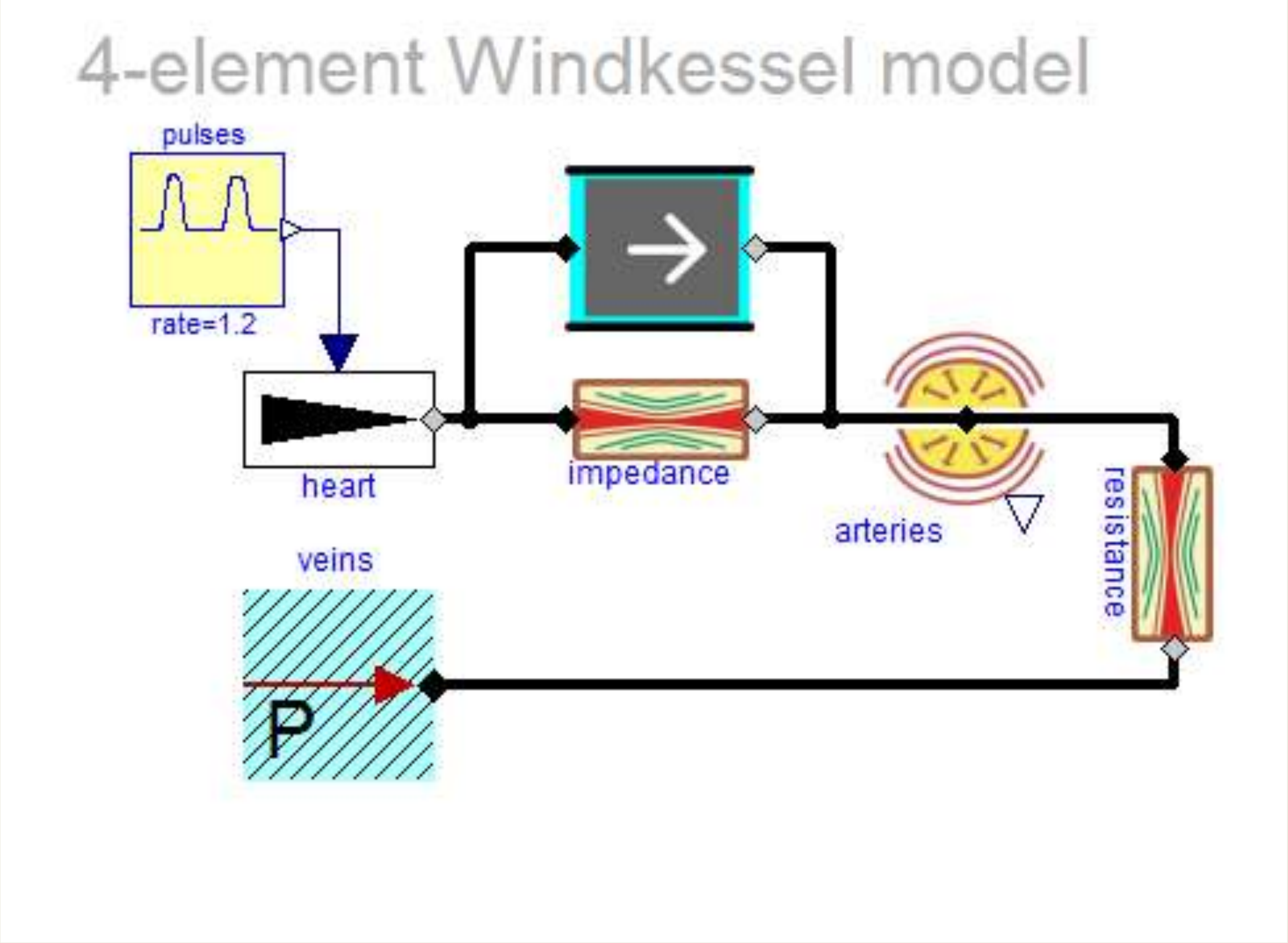
2-element Windkessel model



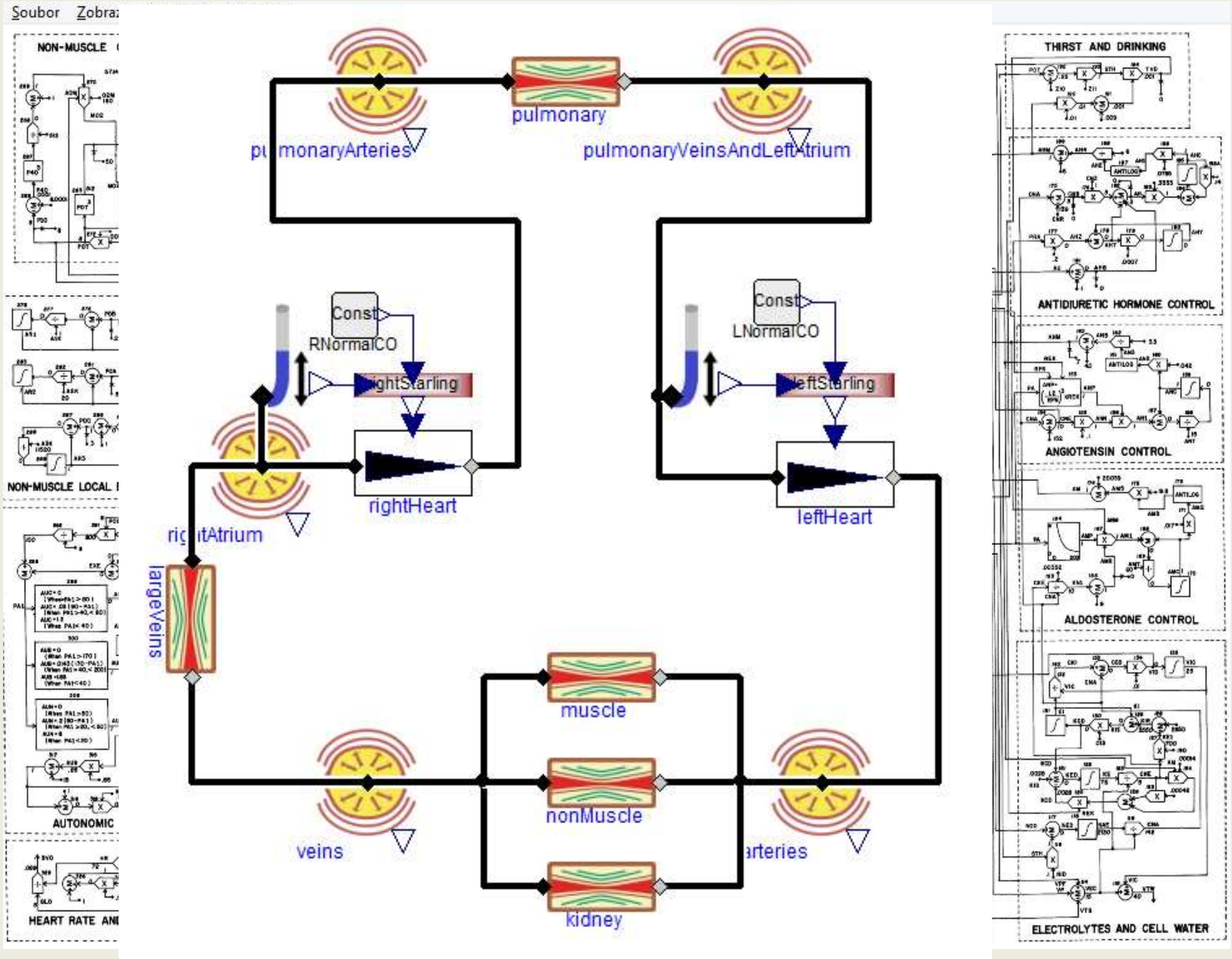
3-element Windkessel model



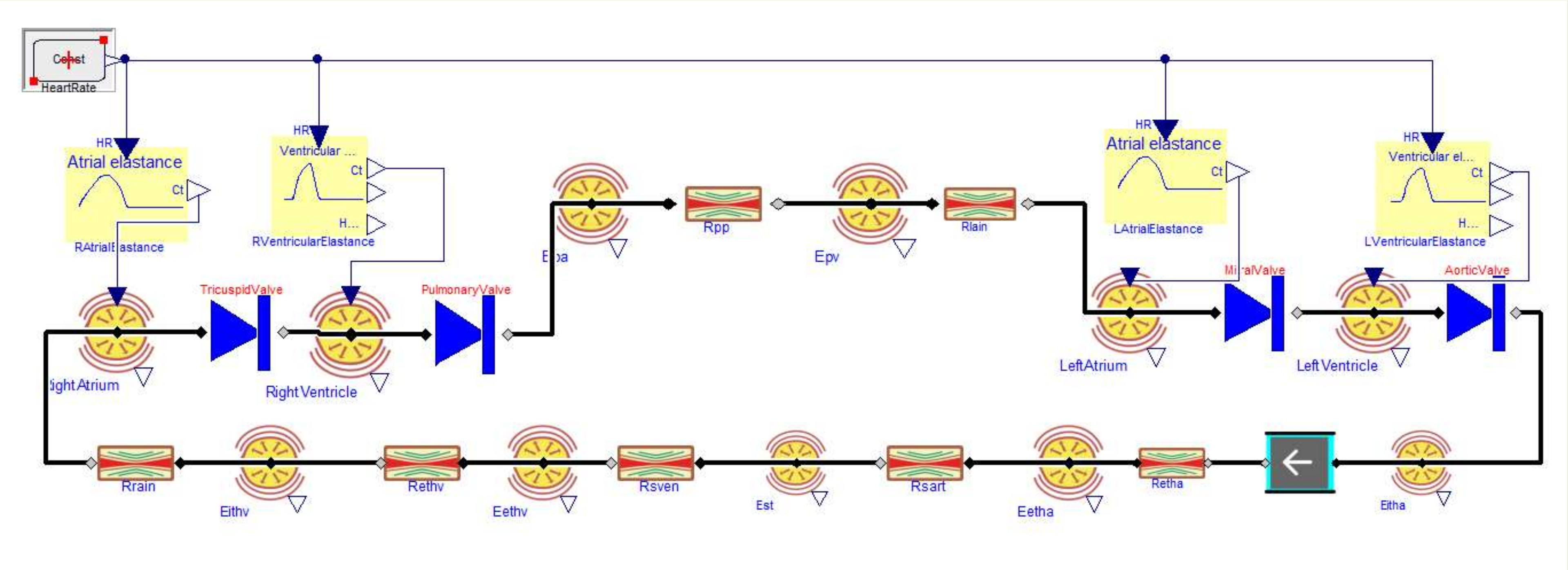
4-element Windkessel model



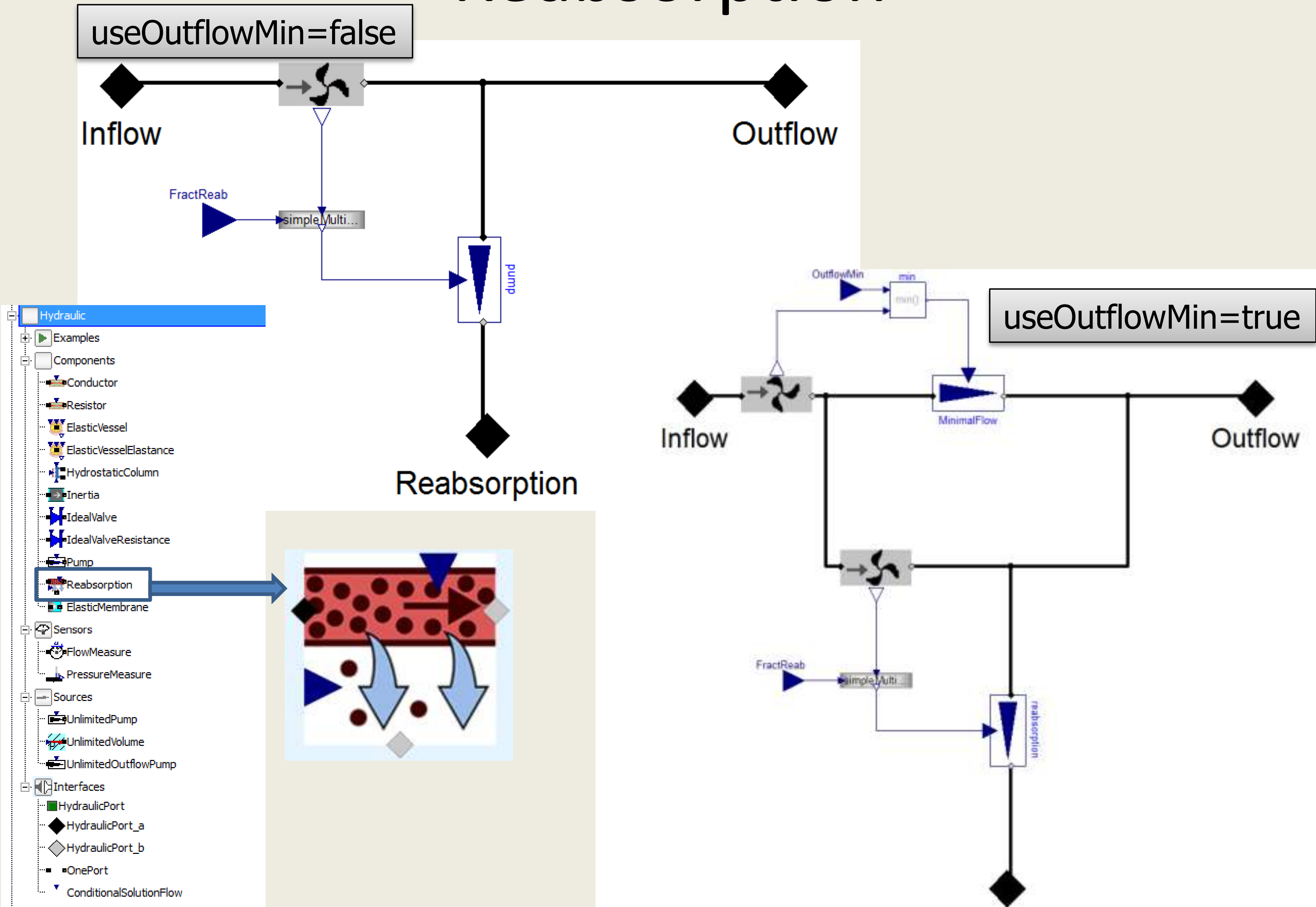
Circulation dynamics of Guyton-Coleman-Granger's model 1972



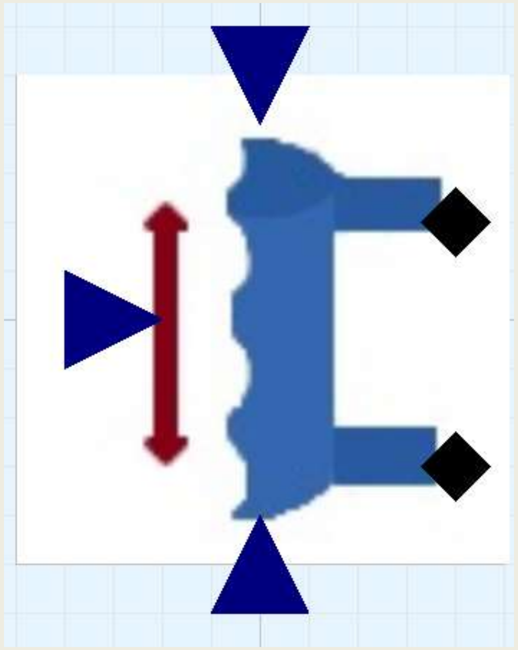
Hemodynamics Meurs model (flat model)



Reabsorption



Hydrostatic



Hydrostatic column pressure between two connectors (with specific muscle pump effect)

Information

The hydrostatic pressure is proportional to height of the column.

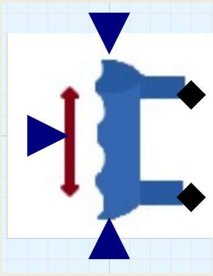
Extends from Icons.HydrostaticGradient.

Parameters

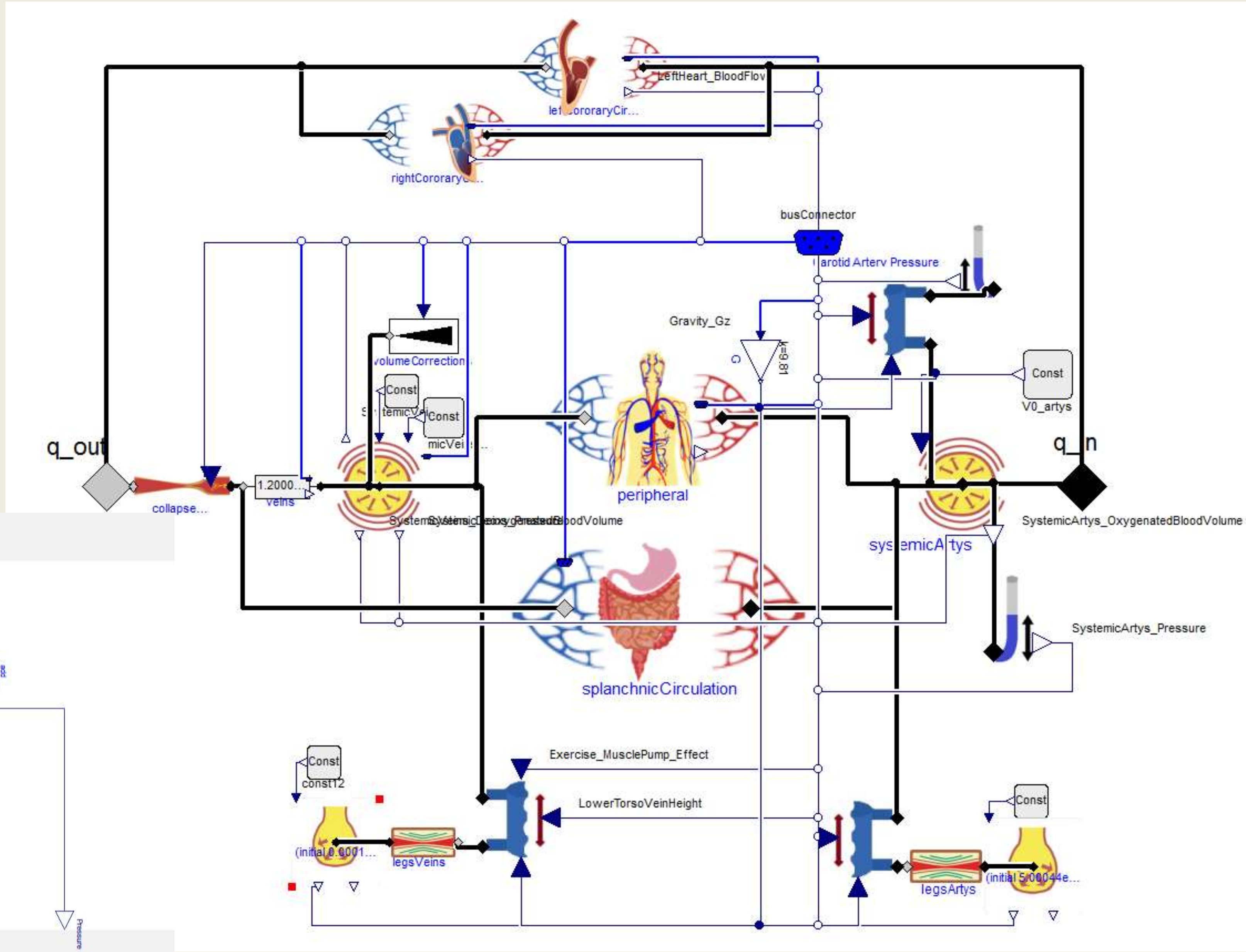
Type	Name	Default	Description
Height	H	0	Height of hydrostatic column if useHeightInput=false [m]
Density	ro	1060	[kg/m3]
Acceleration	GravityAcceleration	9.81	Gravity acceleration if useExternalG=false [m/s2]
External inputs/outputs			
Boolean	useHeightInput	false	=true, if height input is used
Boolean	useExternalG	false	=true, if external gravity acceleration is used
Boolean	usePumpEffect	false	=true, if musce pump effect is used

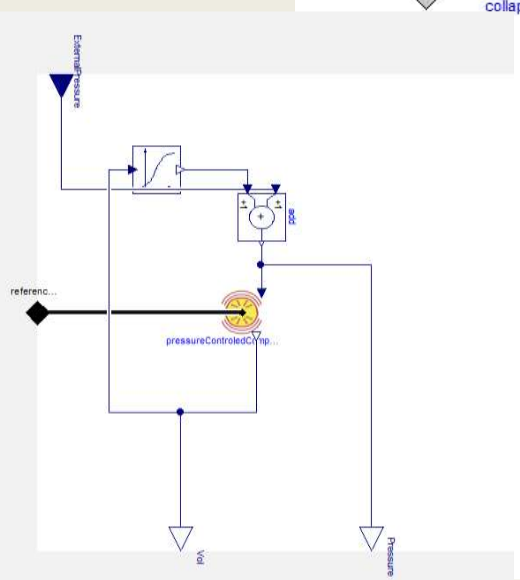
Connectors

Type	Name	Description
HydraulicPort_a	q_up	Top site
HydraulicPort_a	q_down	Bottom site
input HeightInput	height	Vertical distance between top and bottom connector [m]
input AccelerationInput	G	Gravity acceleration [m/s2]
input FractionInput	pumpEffect	[1]

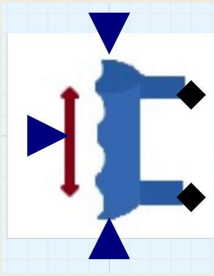


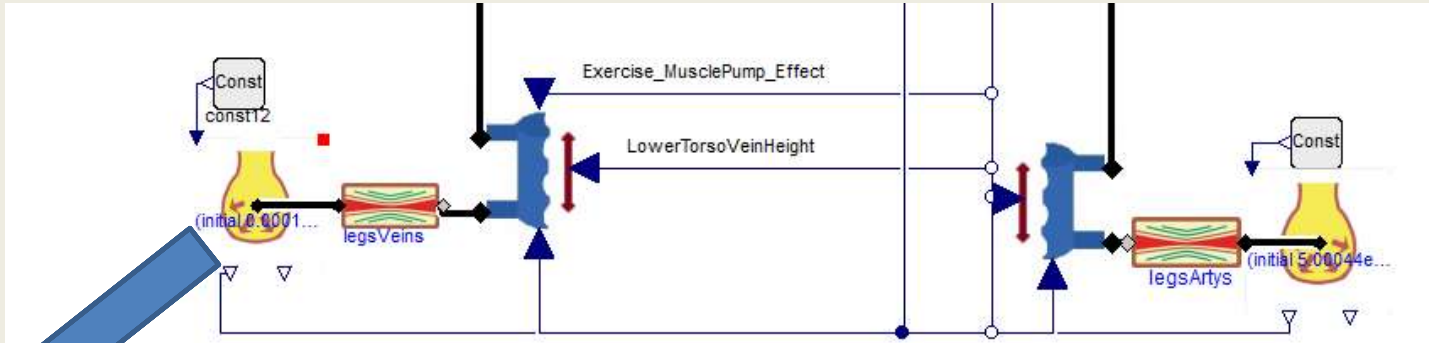
Hydrostatic

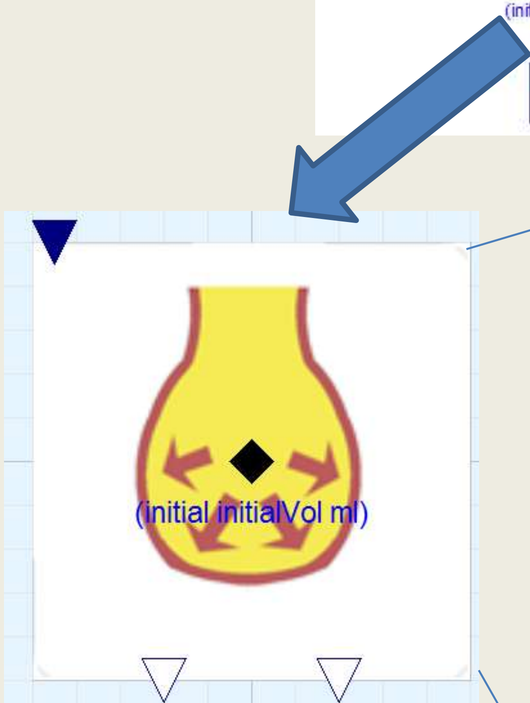




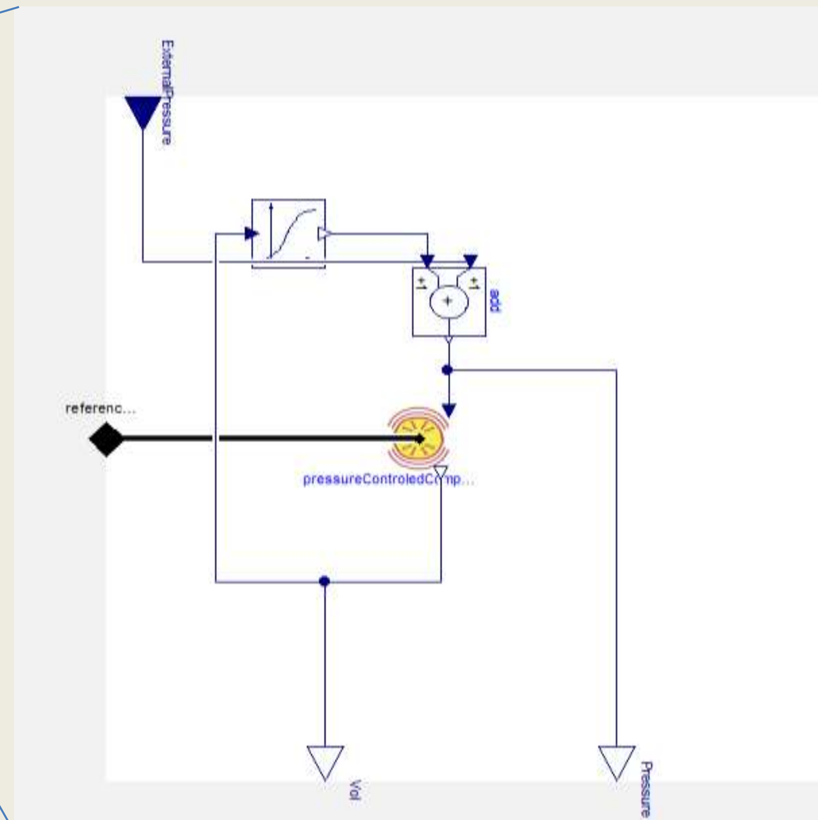
Hydrostatic



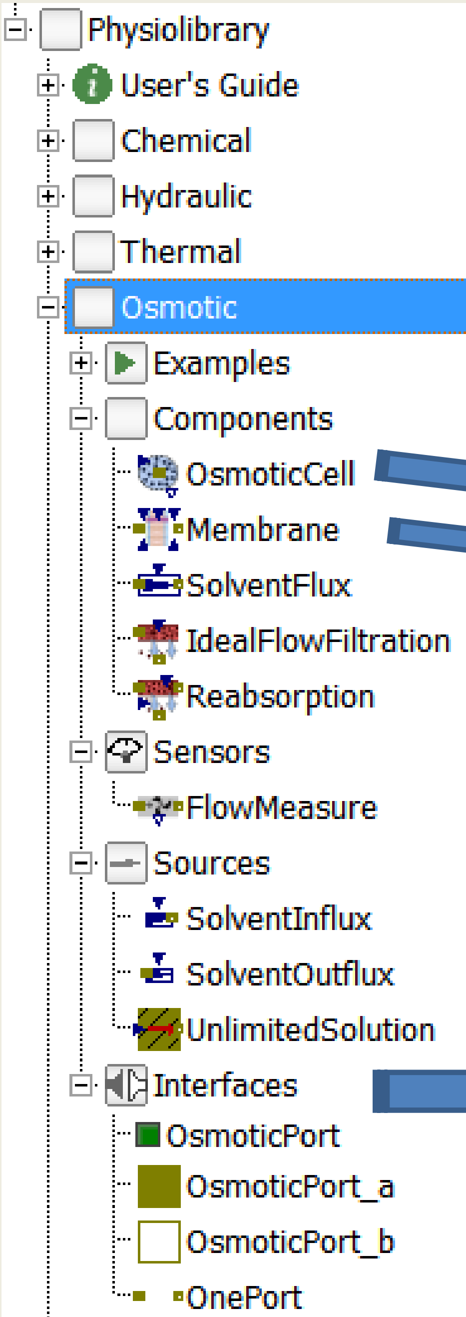


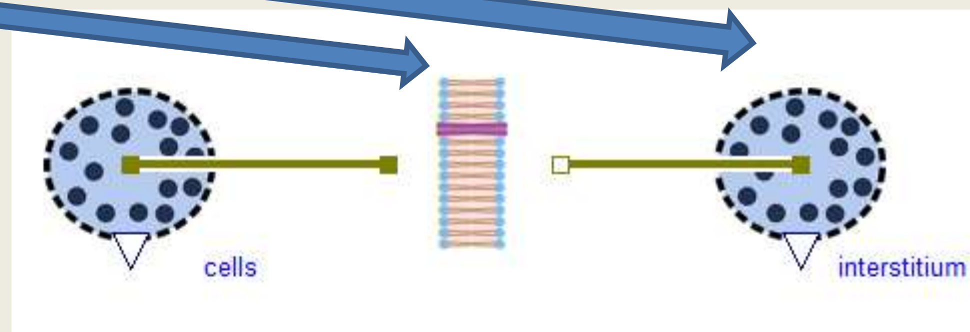


SequesteredBlood



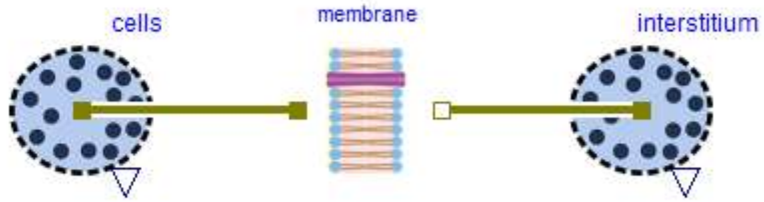
Osmotic



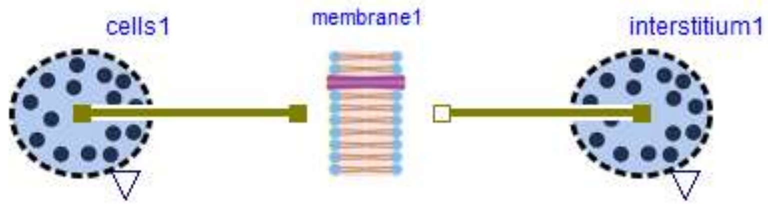


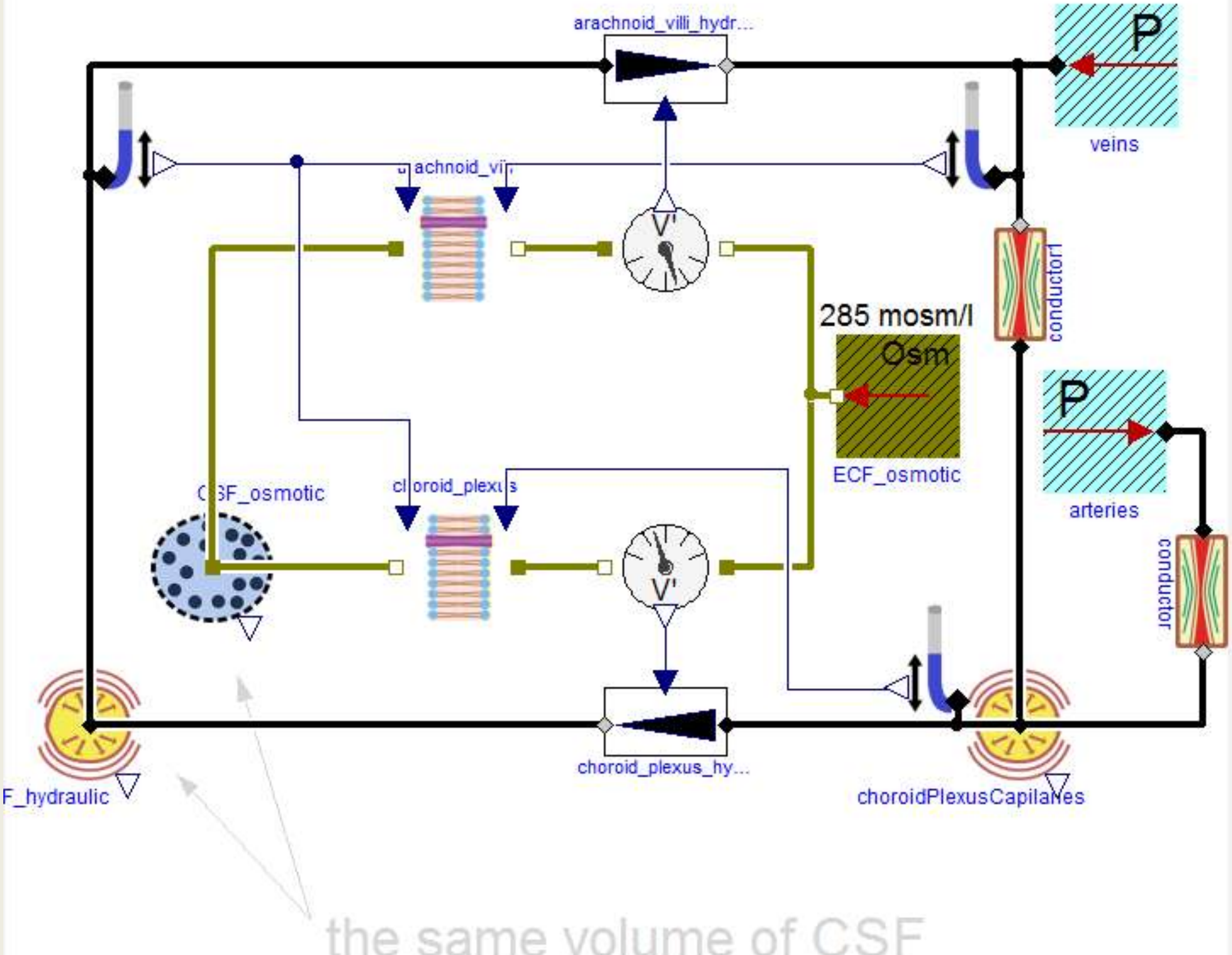

```
connector OsmoticPort
  "Osmolarity and osmotic flux"
 Types.Concentration o "Osmolarity";
 flow Types.VolumeFlowRate q "Osmotic flux";

end OsmoticPort;
```

Cells in hypotonic environment

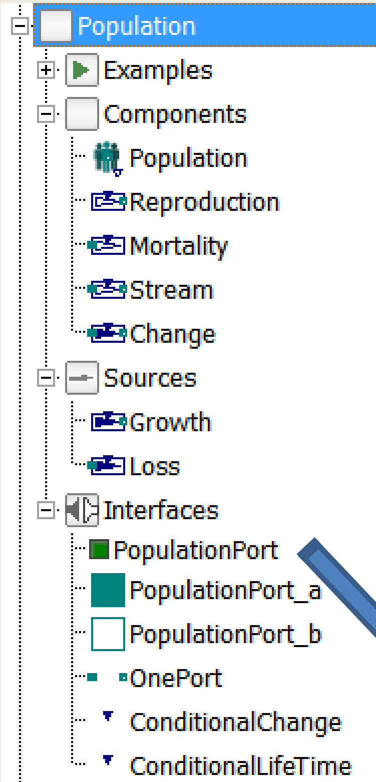


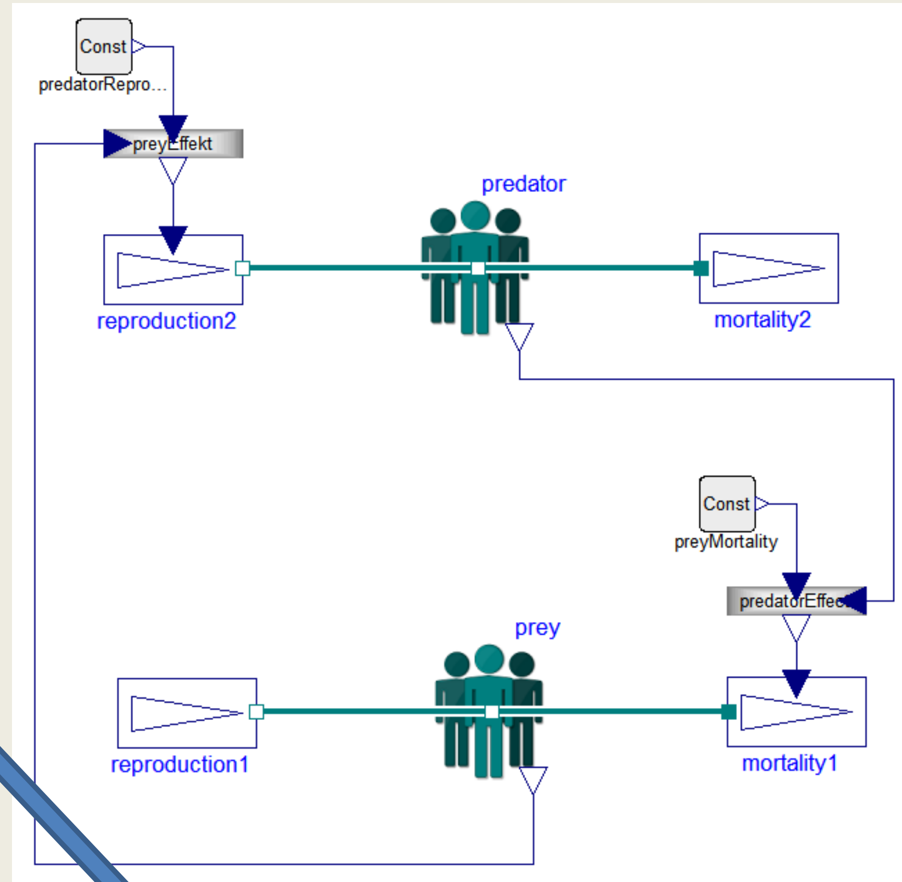
Cells in hypertonic environment




arachnoid_villi_hydr...
P
veins
V'
285 mosm/l
Osm
conductor1
P
ECF_osmotic
arteries
conductor
V'
choroid_plexus_hy...
F_hydraulic
choroidPlexusCapilaries
the same volume of CSF

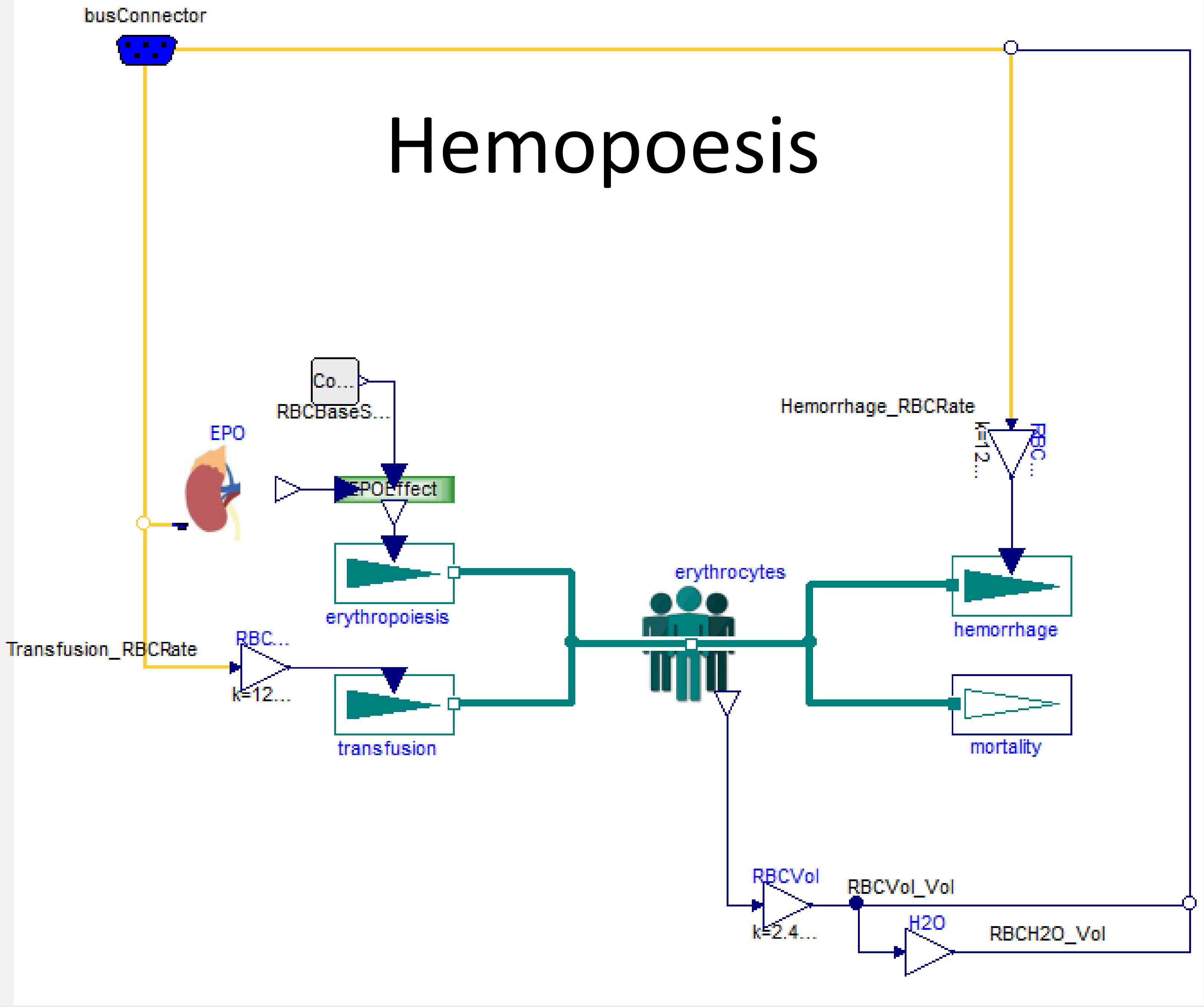
Population



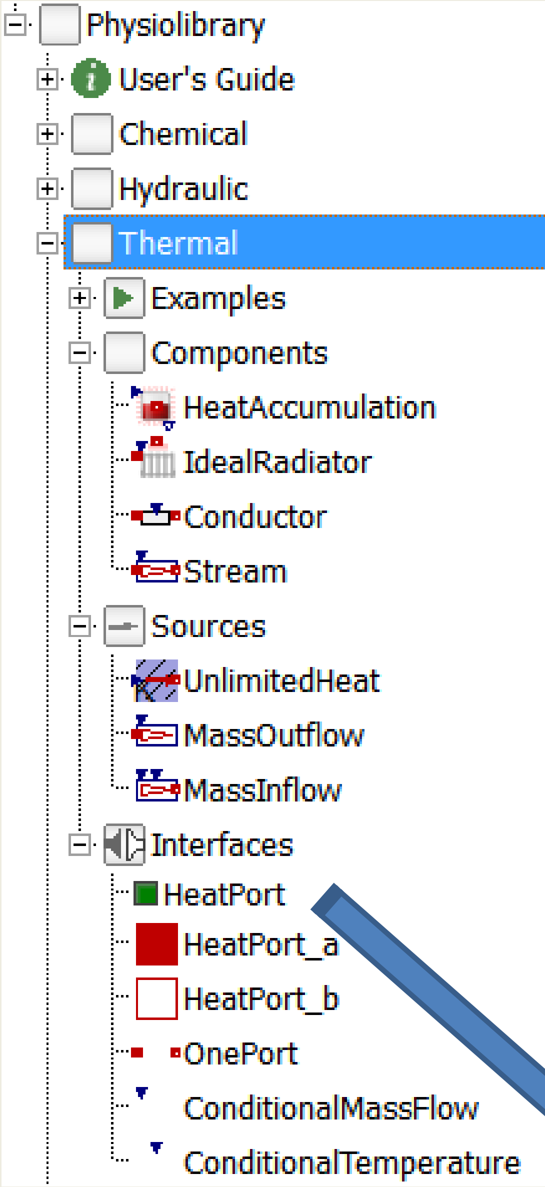


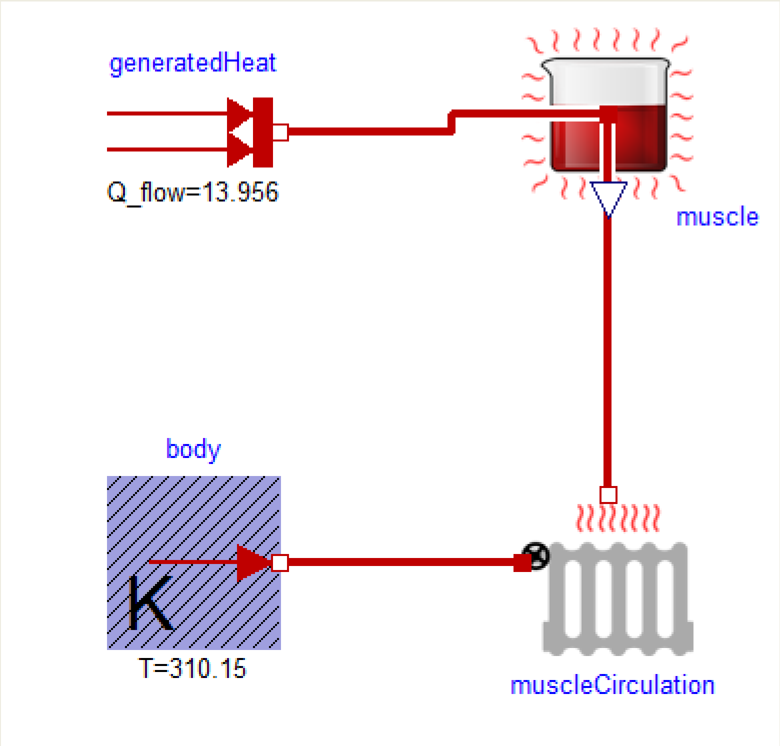

```
connector PopulationPort "Average number of population members and their change"
  Types.Population population "Average number of population individuals";
  flow Types.PopulationChange change "Average population change = change of population individuals";
  a
end PopulationPort;
```

Hemopoesis


busConnector
Co...
RBCBaseS...
EPO
EPOEffect
Hemorrhage_RBCRate
erythrocytes
erythropoiesis
hemorrhage
Transfusion_RBCRate
RBC...
k=12...
transfusion
mortality
RBCVol
RBCVol_Vol
H2O
k=2.4...
RBCH2O_Vol

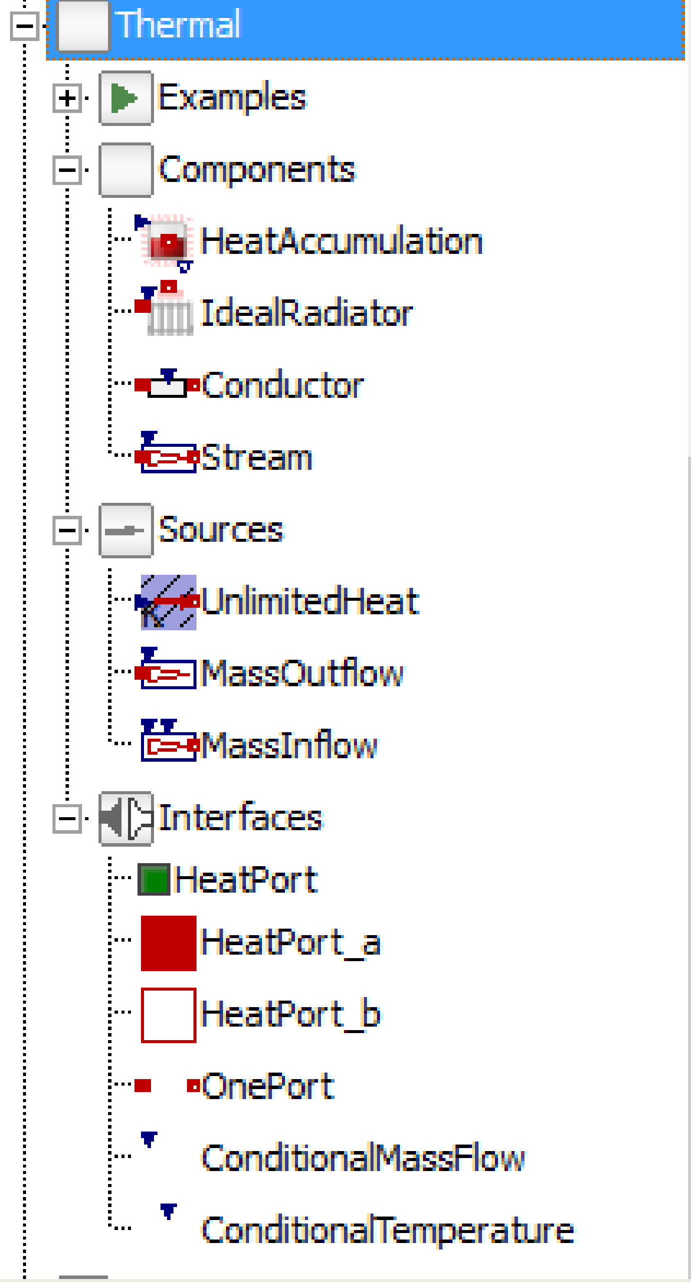
Thermal

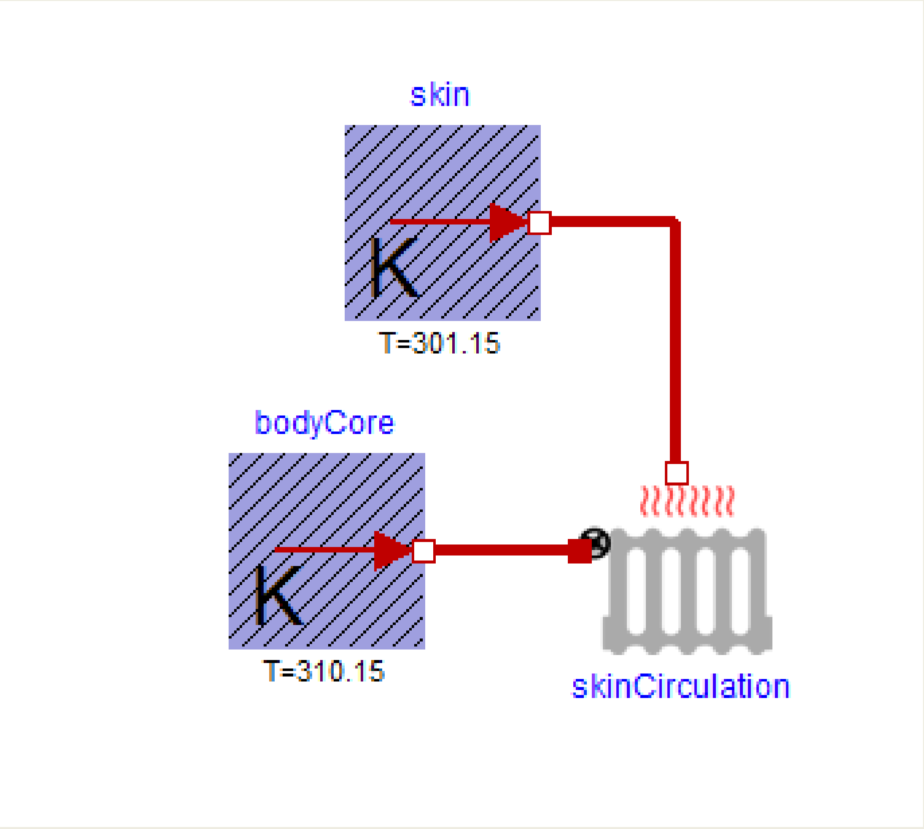




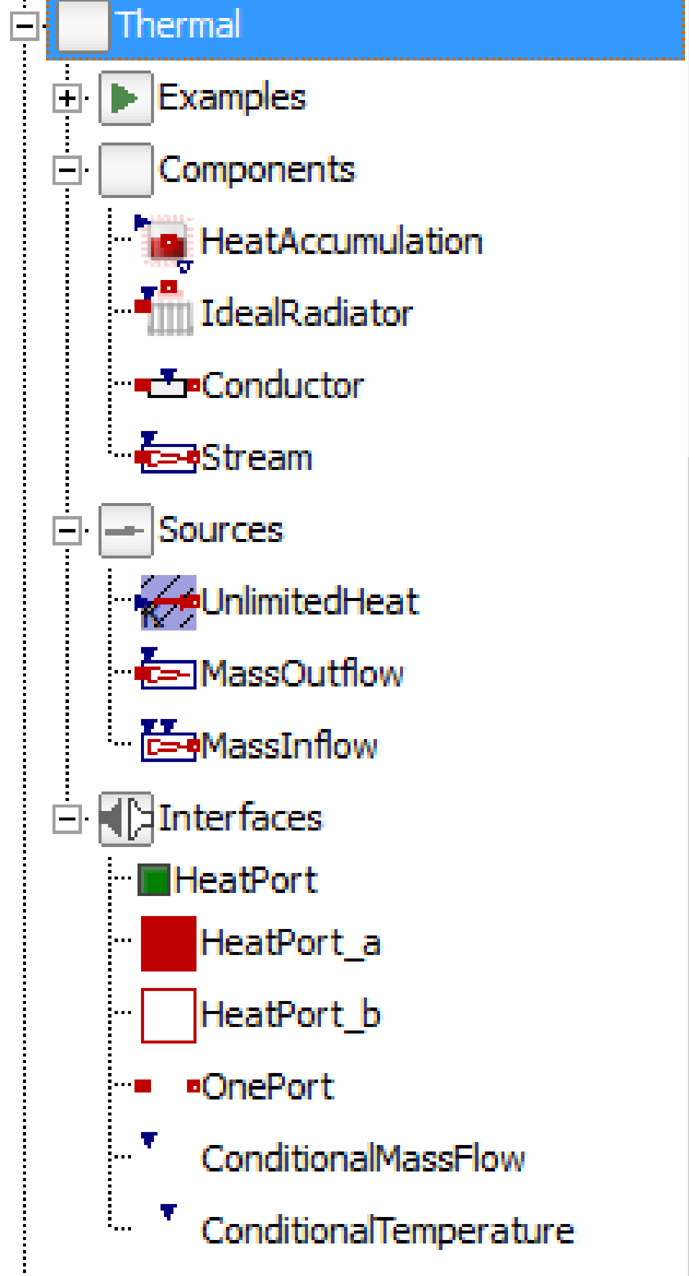

```
connector HeatPort = Modelica.Thermal.HeatTransfer.Interfaces.HeatPort
```

Skin Heat Flow

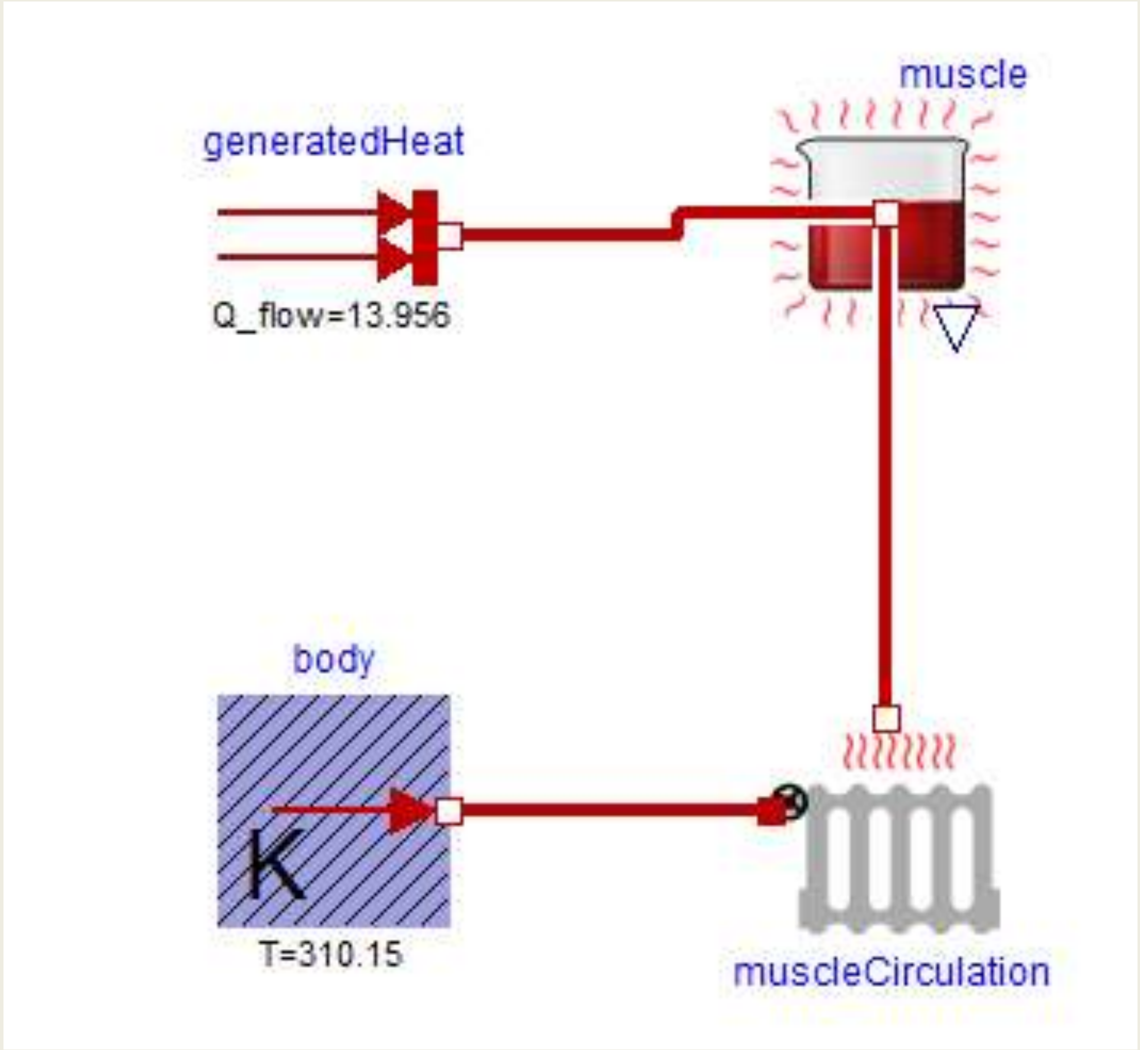




Muscle Heat

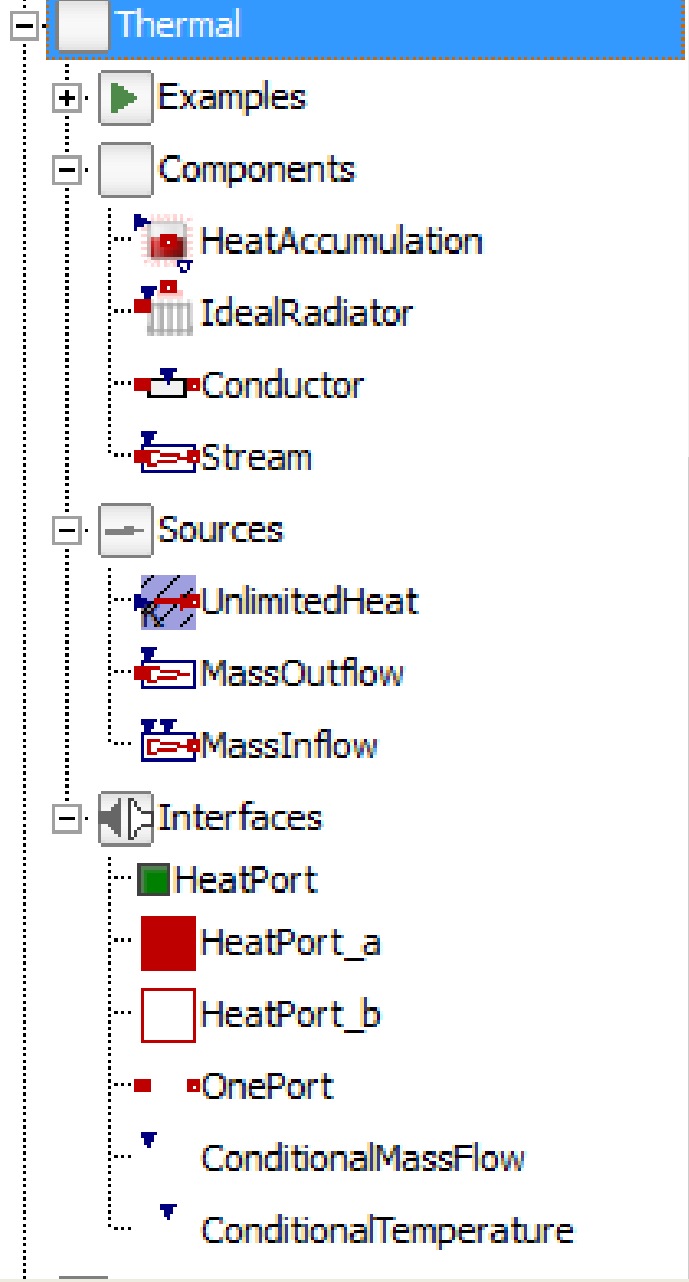


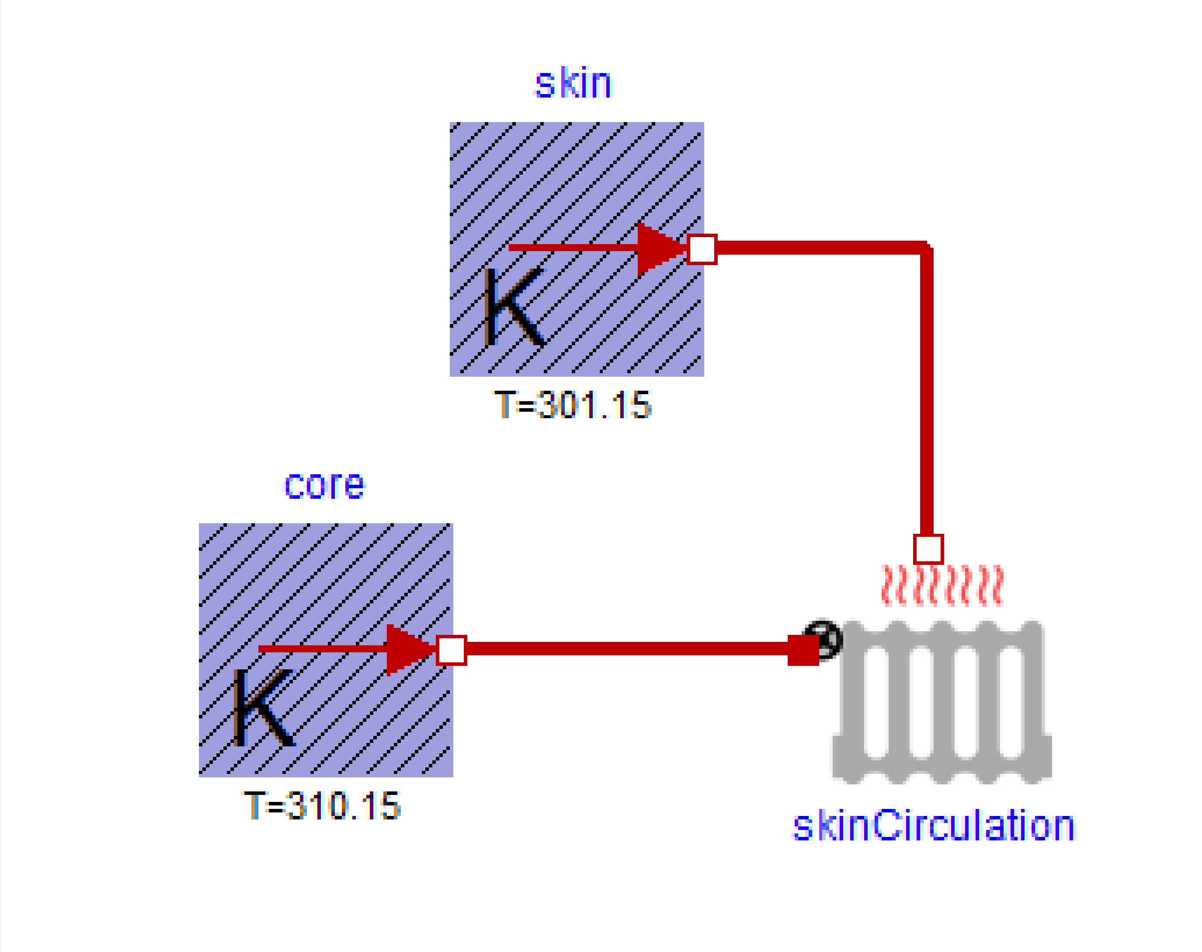
Thermal
Examples
Components
HeatAccumulation
IdealRadiator
Conductor
Stream
Sources
UnlimitedHeat
MassOutflow
MassInflow
Interfaces
HeatPort
HeatPort_a
HeatPort_b
OnePort
ConditionalMassFlow
ConditionalTemperature



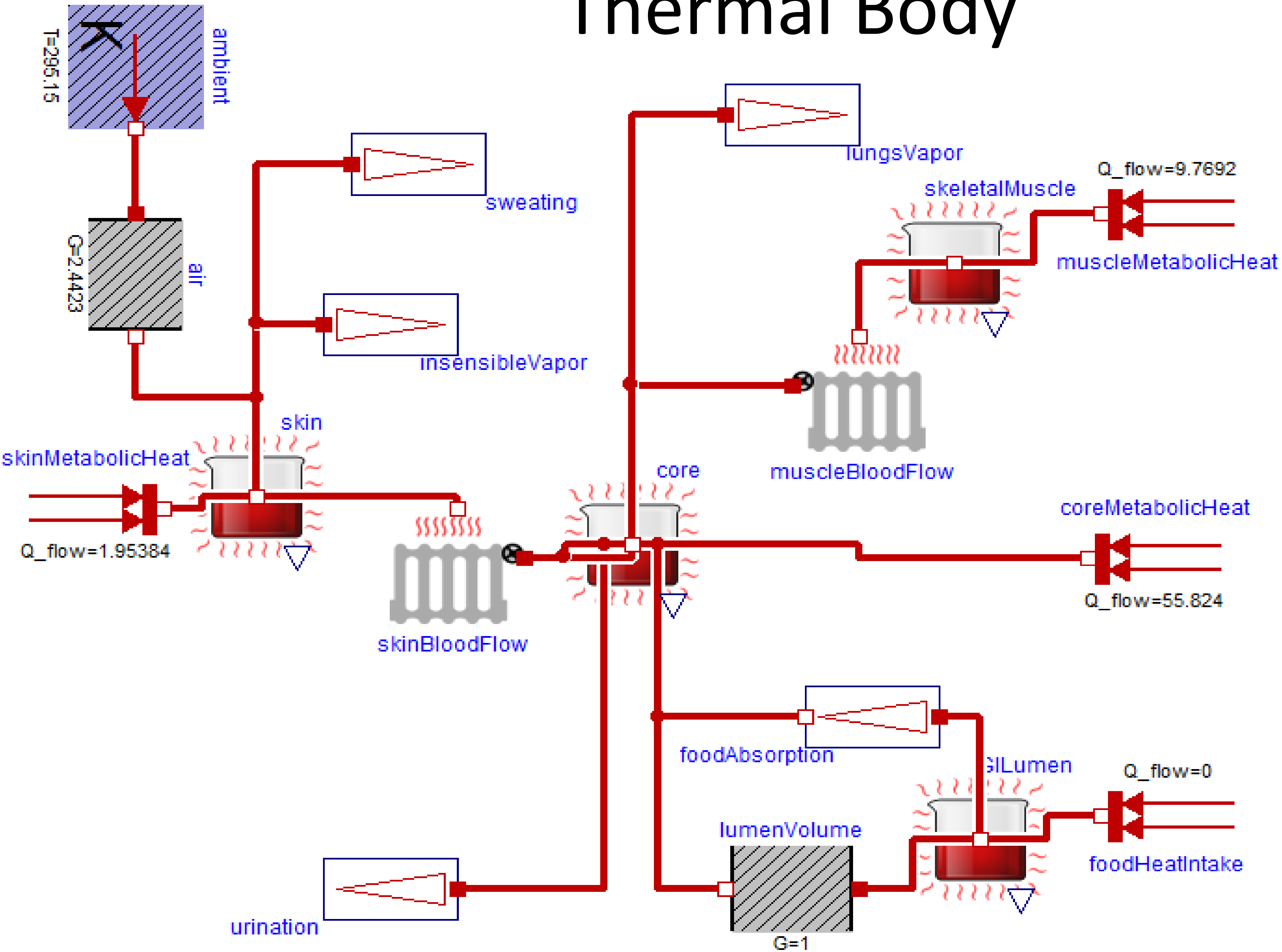
muscle
generatedHeat
Q_flow=13.956
body
K
T=310.15
muscleCirculation

Skin Heat Transfer on Blood Flow





Thermal Body



Komplexní příklad využití knihovny PHYSIOLIBRAY:

Physiomodel 1.1

viz: www.physiomodel.org