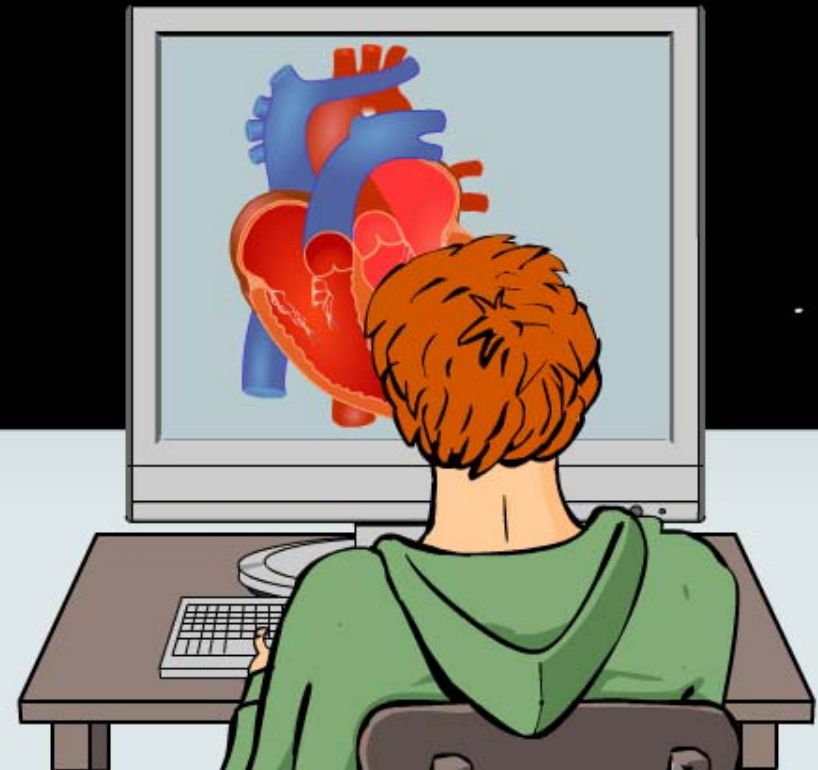


internet + interaktivní grafika + simulační hry



Tvorba modelu

Tvorba simulátoru

Nástroje pro tvorbu modelů



Formalizace fyziologických vztahů

Vytváření simulačního modelu

Ověřování chování simulačního modelu

Chování modelu je jiné než chování biologického originálu

Dostatečně dobrá shoda chování modelu s chováním biologického originálu



Nástroje pro tvorbu simulátorů

Implementace modelu do simulátoru

Vytváření uživatelského rozhraní simulátoru

Verifikace simulátoru ve výuce

Nové požadavky na simulátor – nové požadavky na simulační model



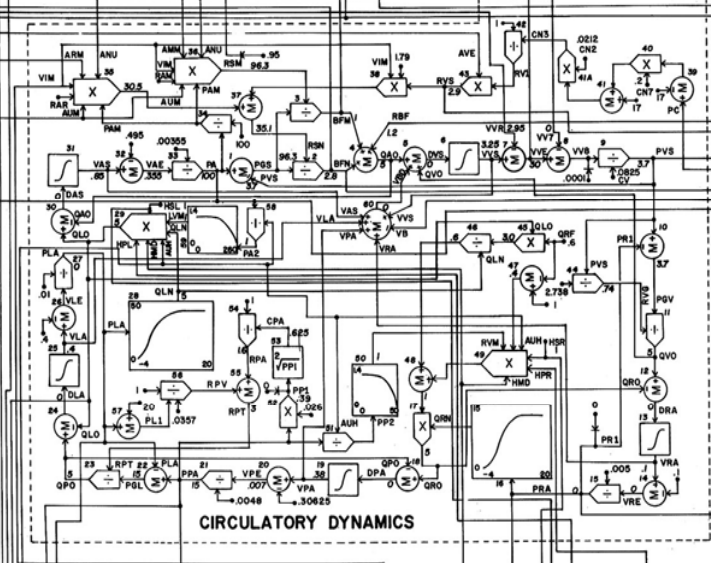
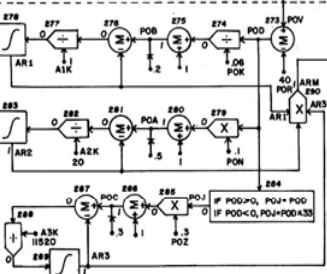
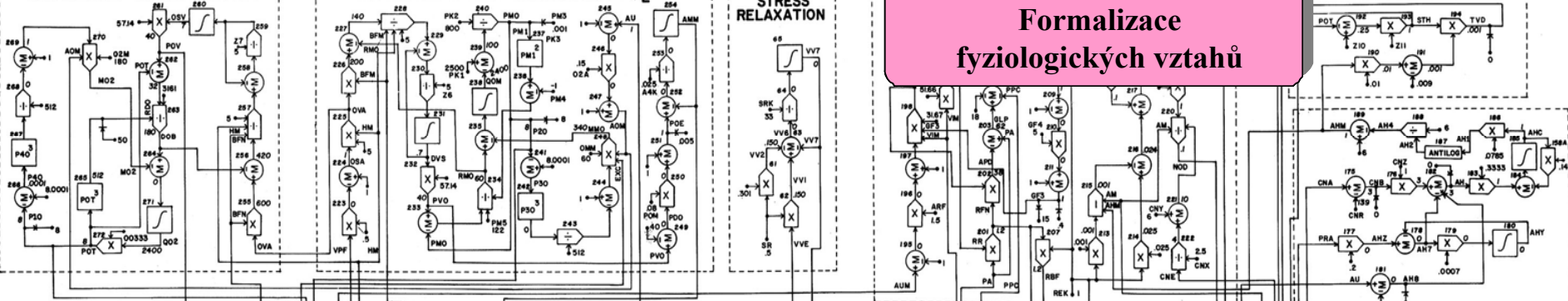
NON-MUSCLE OXYGEN DELIVERY

MUSCLE BLOOD FLOW CONTROL AND PO₂

VASCULAR STRESS RELAXATION

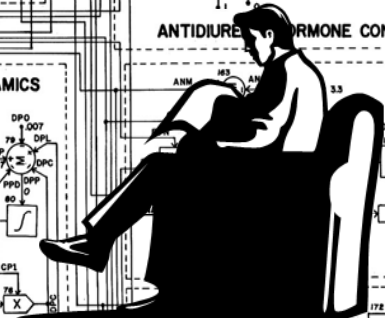
THIRST AND DRINKING

Formalizace fyziologických vztahů

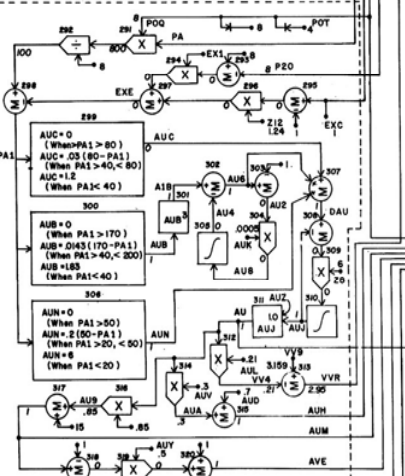


CAPILLARY MEMBRANE DYNAMICS

ANTIURETIC HORMONE CONTROL

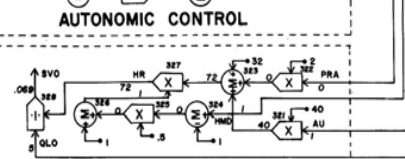


NON-MUSCLE LOCAL BLOOD FLOW CONTROL



CIRCULATORY DYNAMICS

ALDOSTERONE CONTROL



PULMONARY DYNAMICS AND FLUIDS

RED CELLS AND VISCOSITY

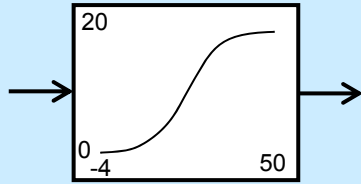
HEART HYPERTROPHY OR DETERIORATION

TISSUE FLUIDS, PRESSURES AND GEL

ELECTROLYTES AND CELL WATER

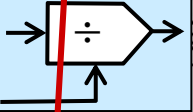


Functional block

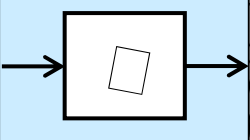


Formalizace
fyziologických vztahů

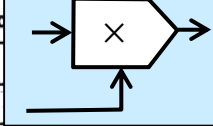
Divider



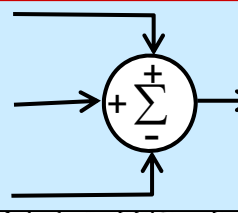
Integrator



Multiplier



Summator



$$PCP = 0.55 \text{ PLA} + 0.45 \text{ PPA}$$

PPA PLA

PCP

LOW CONTROL

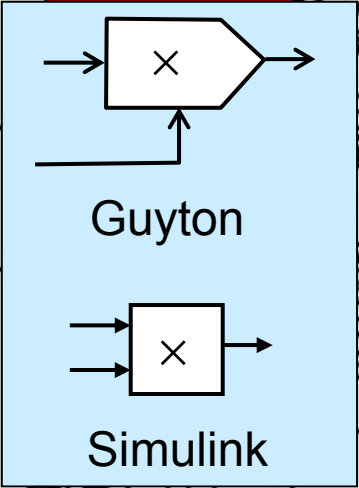
LATORY DYNAMICS



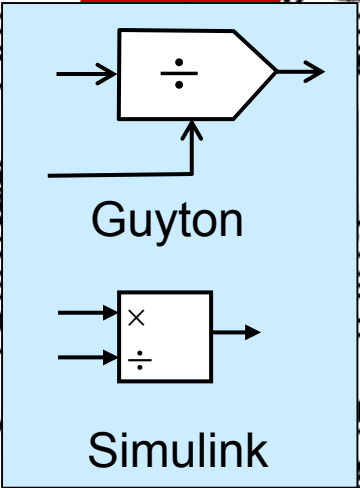
Formalizace
fyziologických vztahů



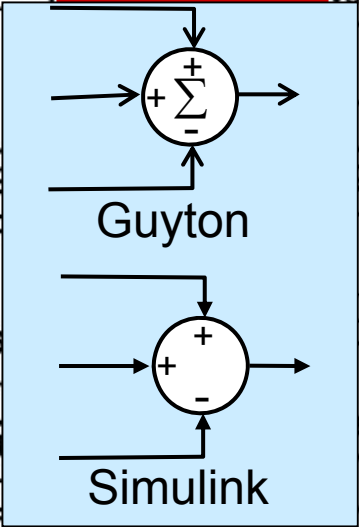
Multiplier



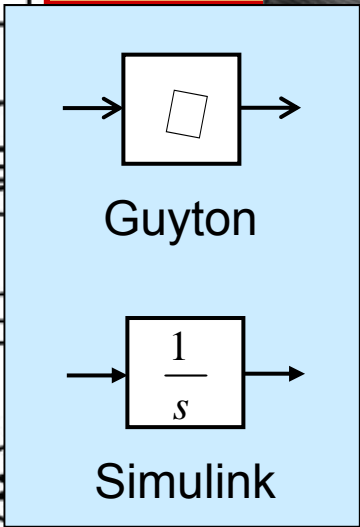
Divider



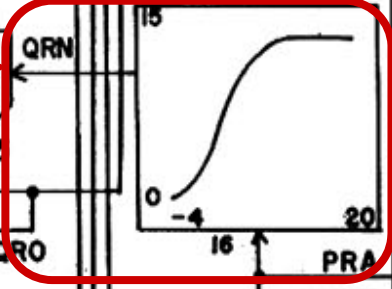
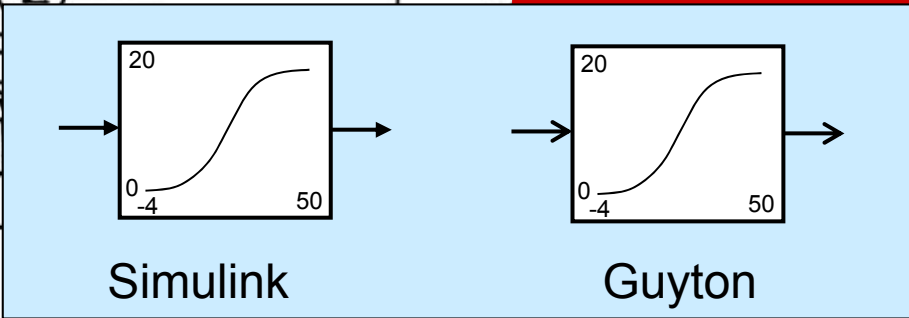
Summator



Integrator



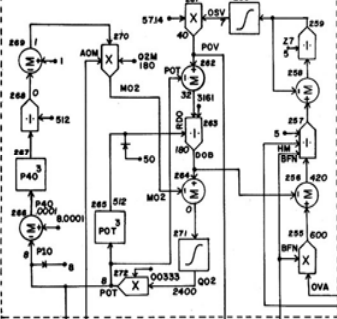
Functional block



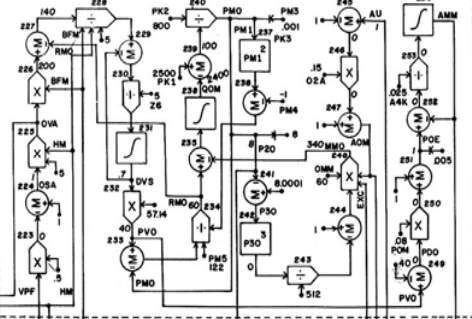
Nástroje pro tvorbu modelů

About MATLAB
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 The Language of Technical Computing
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 September 17, 2008
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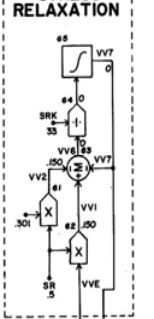
NON-MUSCLE OXYGEN DELIVERY



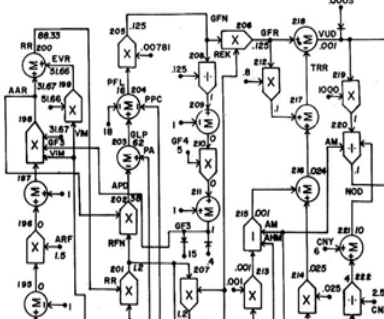
MUSCLE BLOOD FLOW CONTROL AND PO2



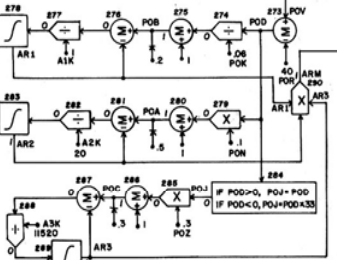
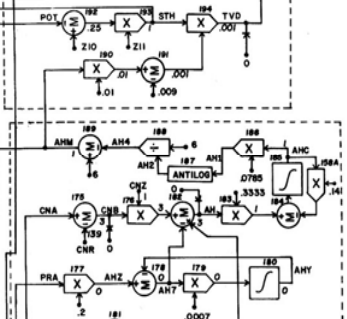
VASCULAR STRESS RELAXATION



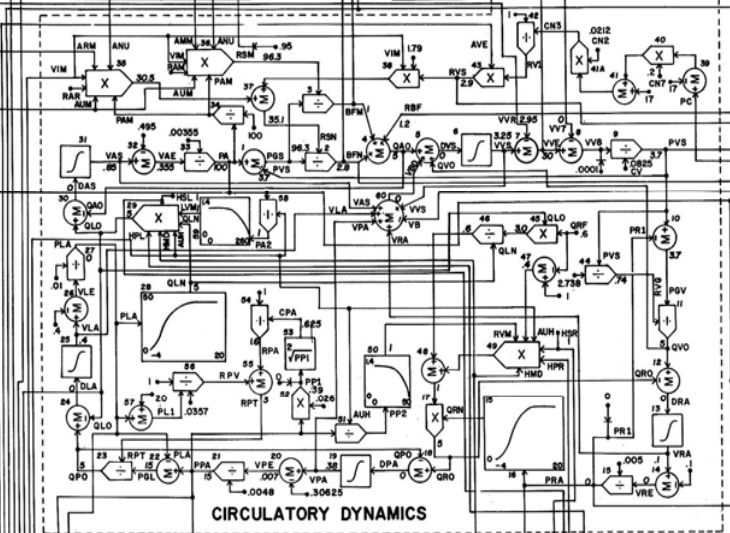
KIDNEY DYNAMICS AND EXCRETION



THIRST AND DRINKING

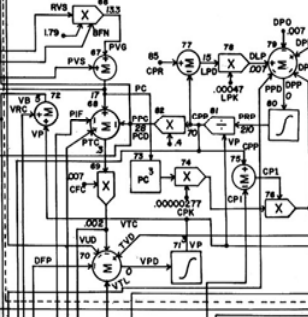


NON-MUSCLE LOCAL BLOOD FLOW CONTROL

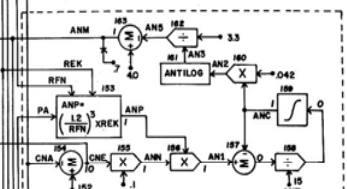


CIRCULATORY DYNAMICS

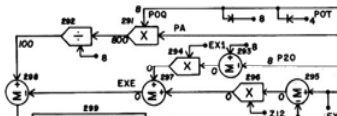
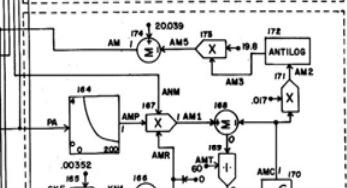
CAPILLARY MEMBRANE DYNAMICS



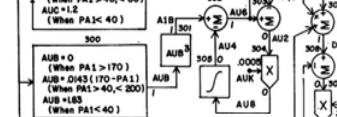
ANTIDIURETIC HORMONE CONTROL



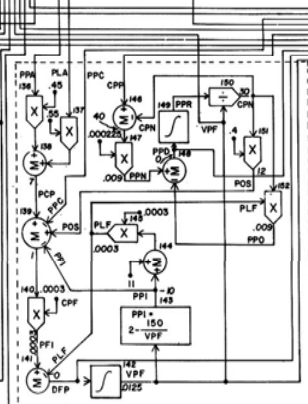
ANGIOTENSIN CONTROL



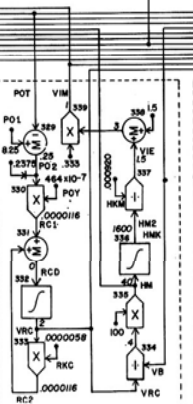
AUTONOMIC CONTROL



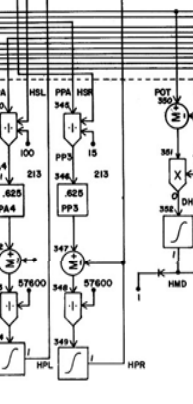
HEART RATE AND STROKE VOLUME



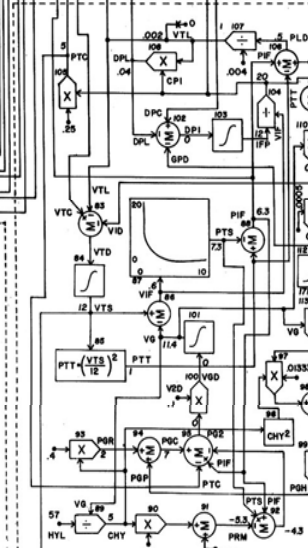
PULMONARY DYNAMICS AND FLUIDS



RED CELLS AND VISCOSITY

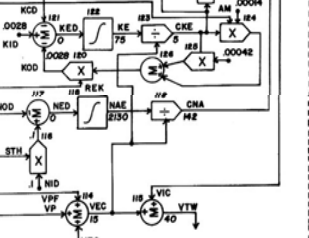
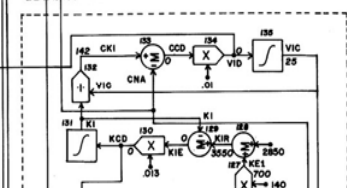


HEART HYPERTROPHY OR DETERIORATION



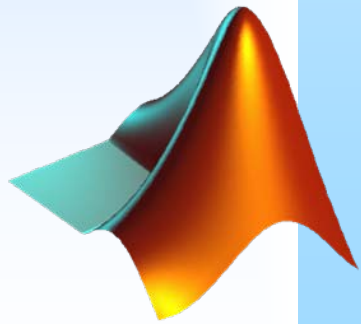
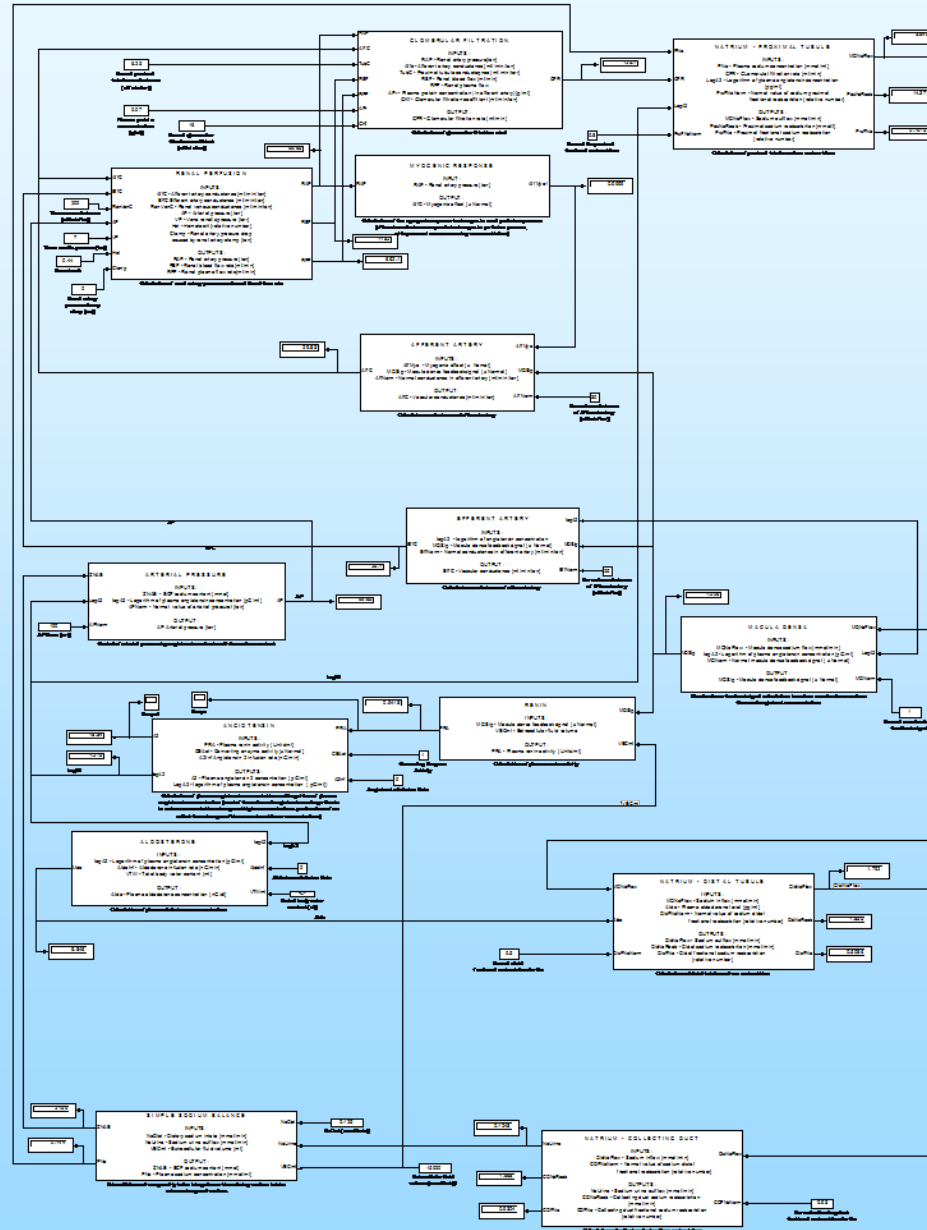
TISSUE FLUIDS, PRESSURES AND GEL

ALDOSTERONE CONTROL

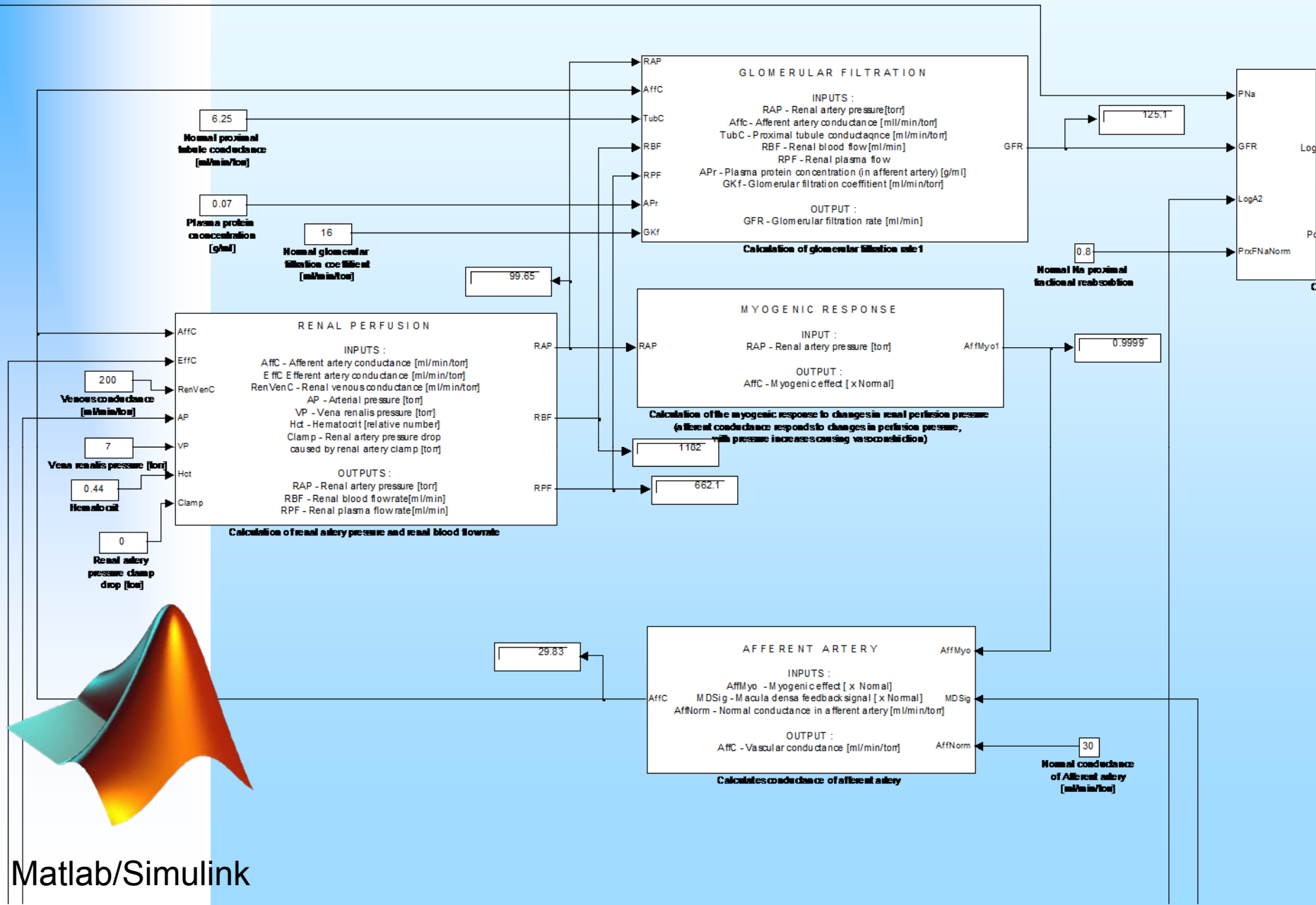


ELECTROLYTES AND CELL WATER

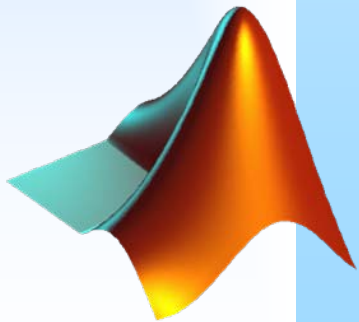
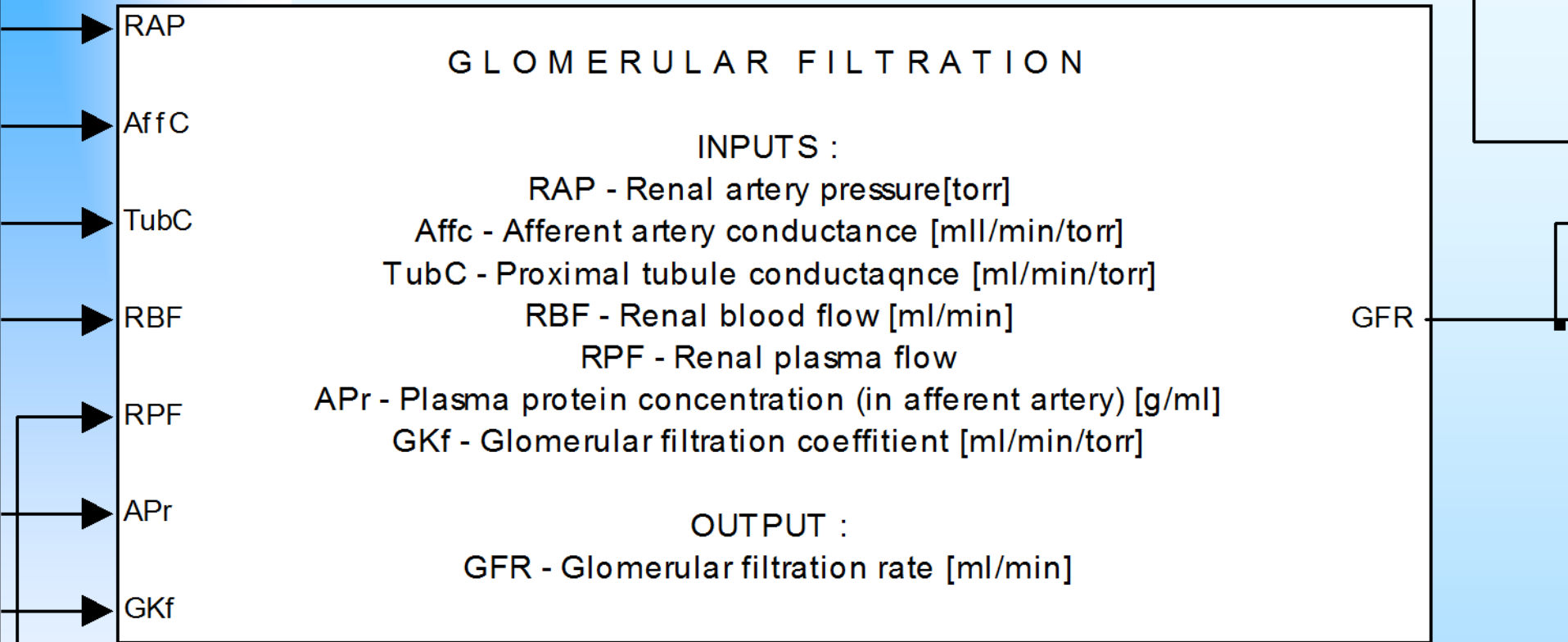
Softwarové nástroje pro tvorbu modelů



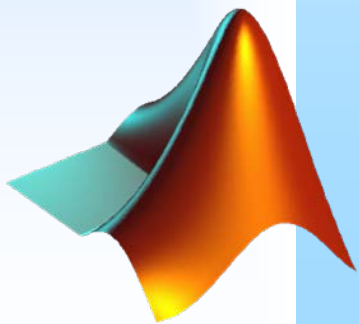
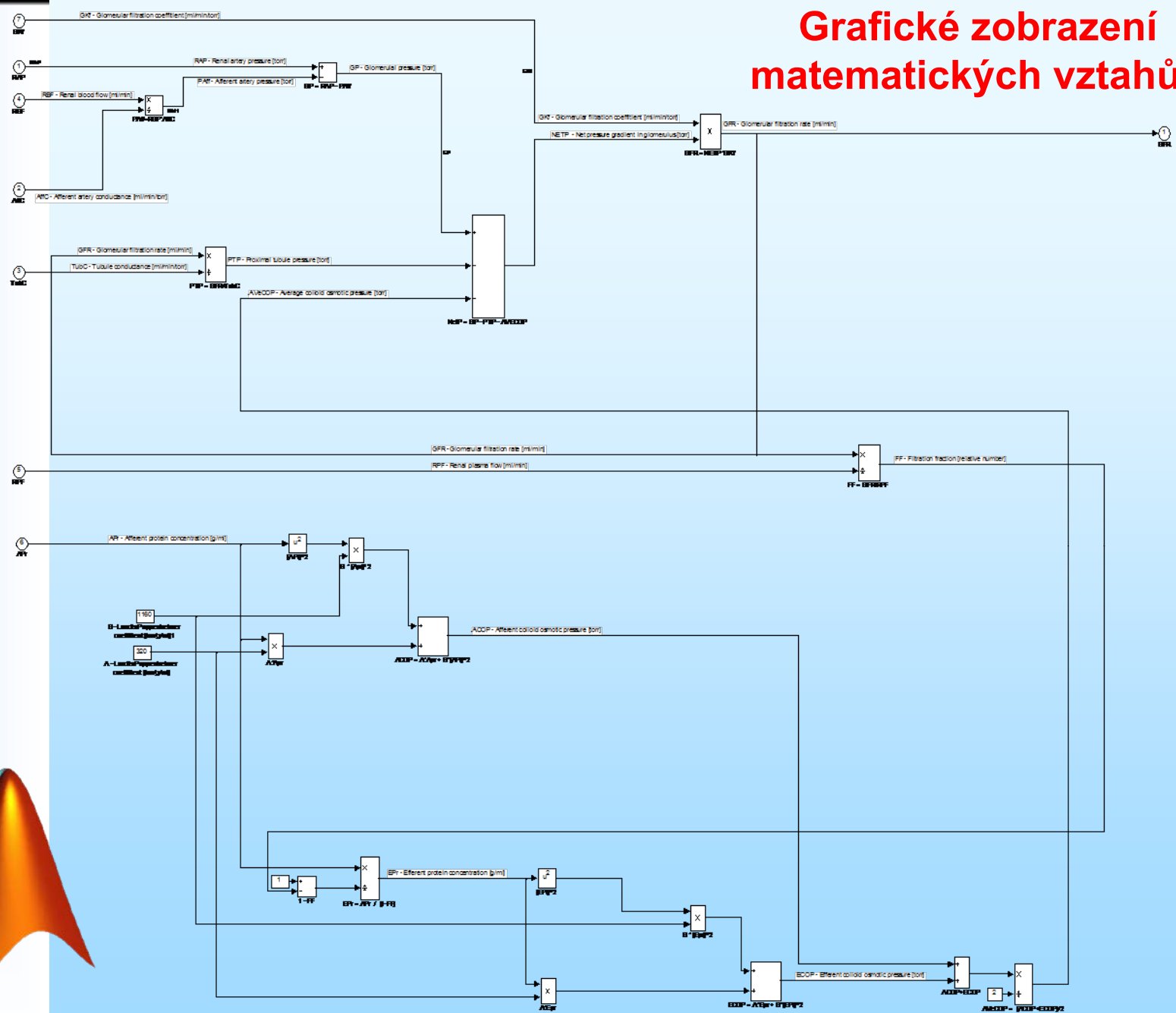
Softwarové nástroje pro tvorbu modelů



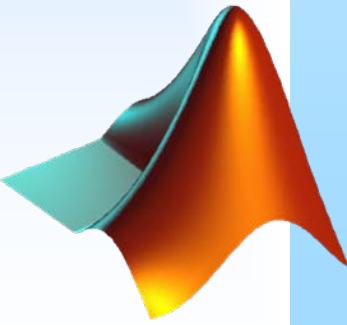
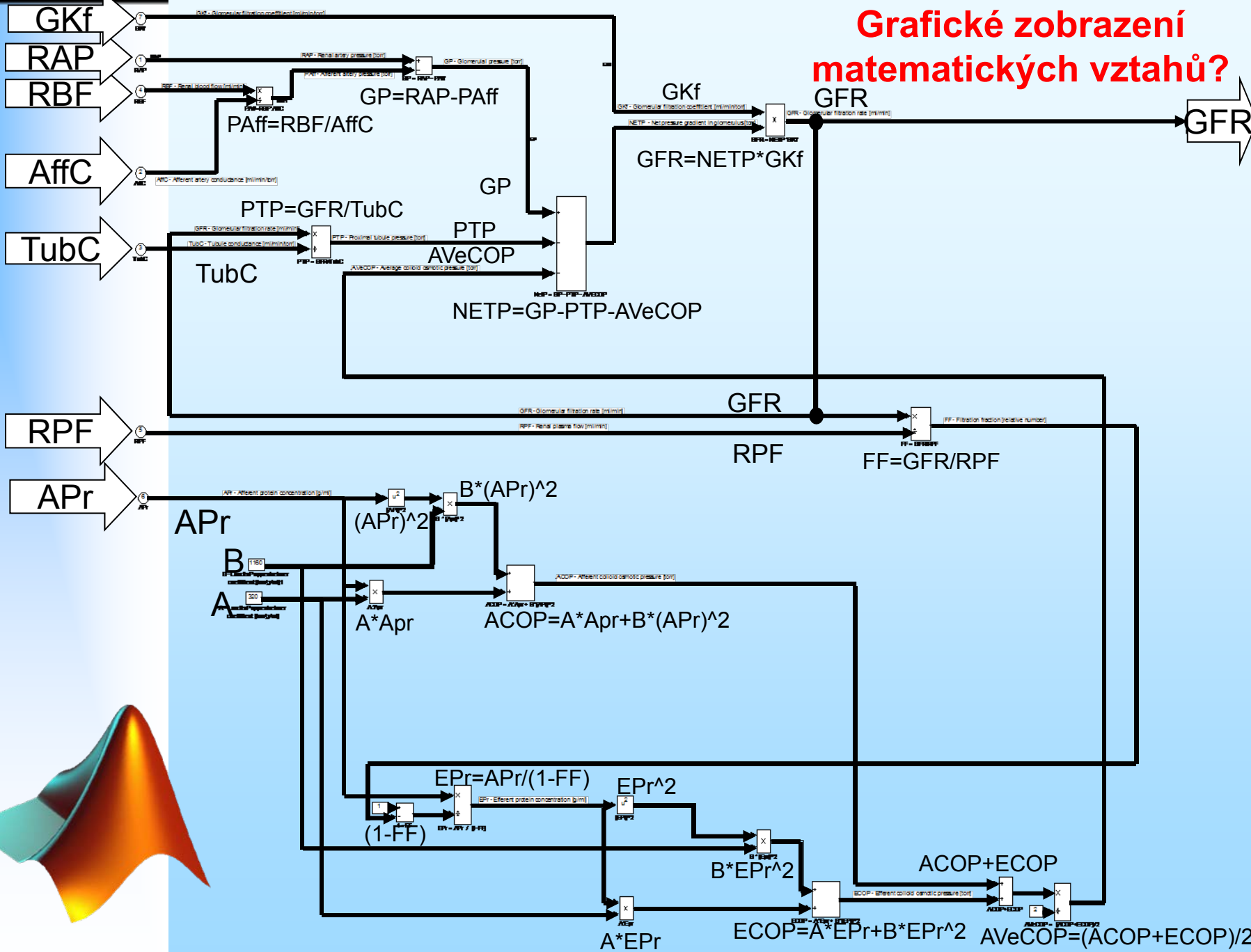
Softwarové nástroje pro tvorbu modelů



Grafické zobrazení matematických vztahů?

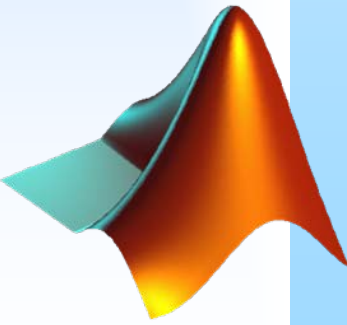
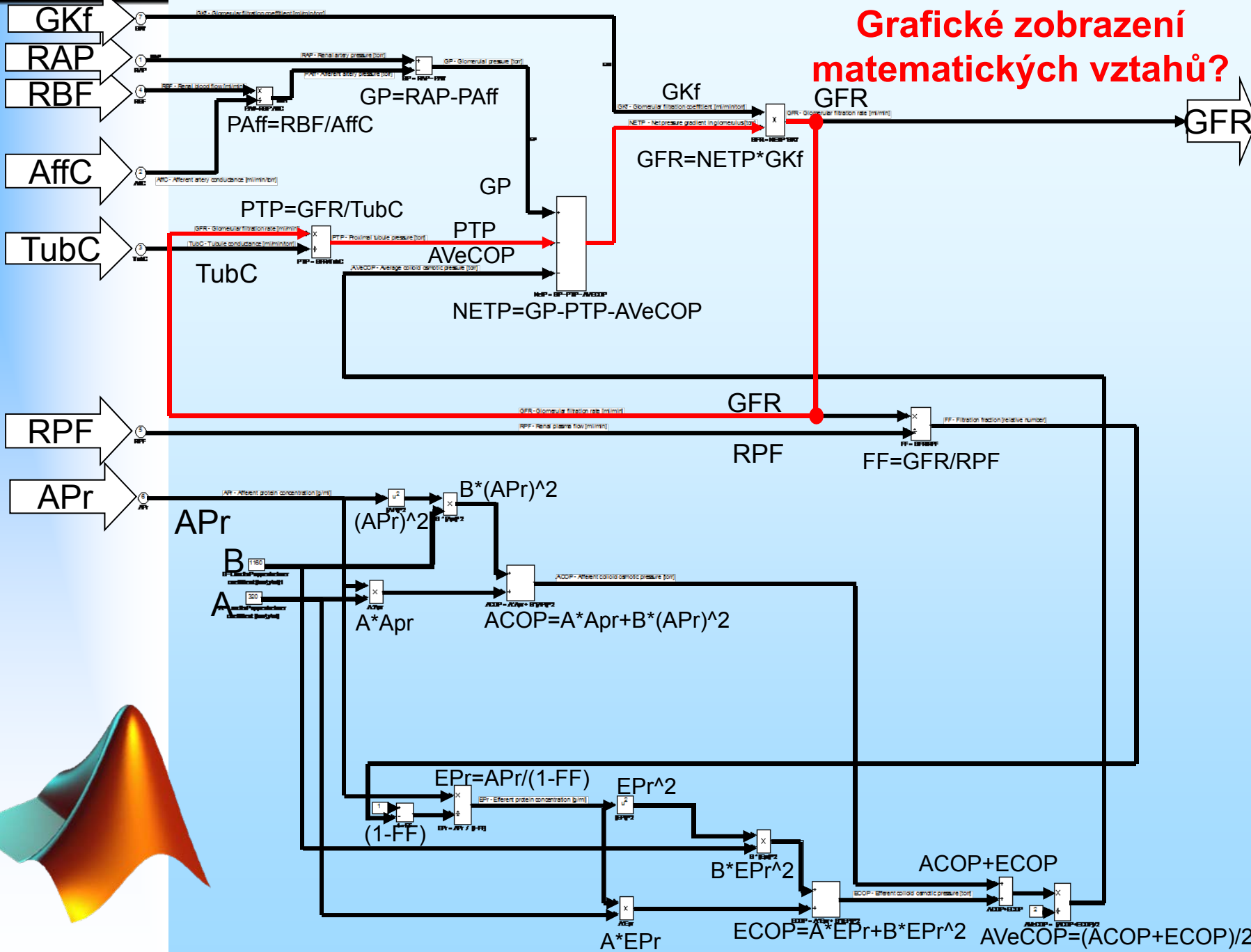


Grafické zobrazení matematických vztahů?



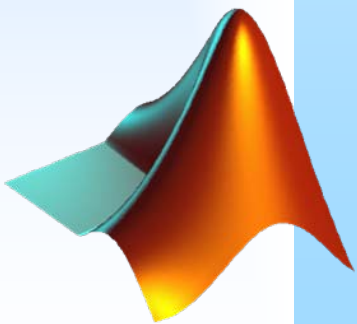
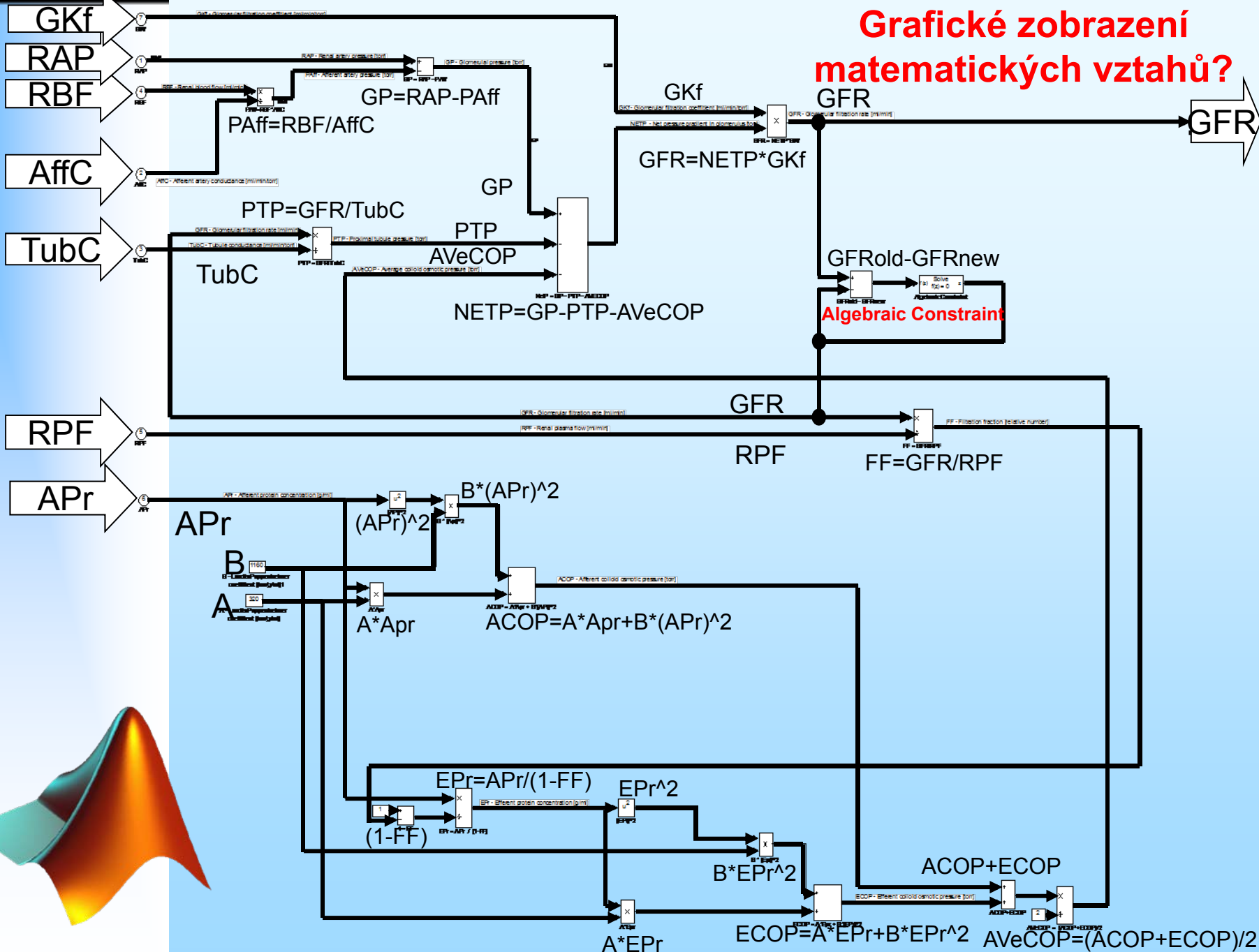
Matlab/Simulink

Grafické zobrazení matematických vztahů?



Matlab/Simulink

Grafické zobrazení matematických vztahů?

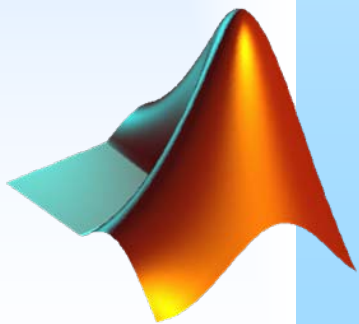


Matlab/Simulink

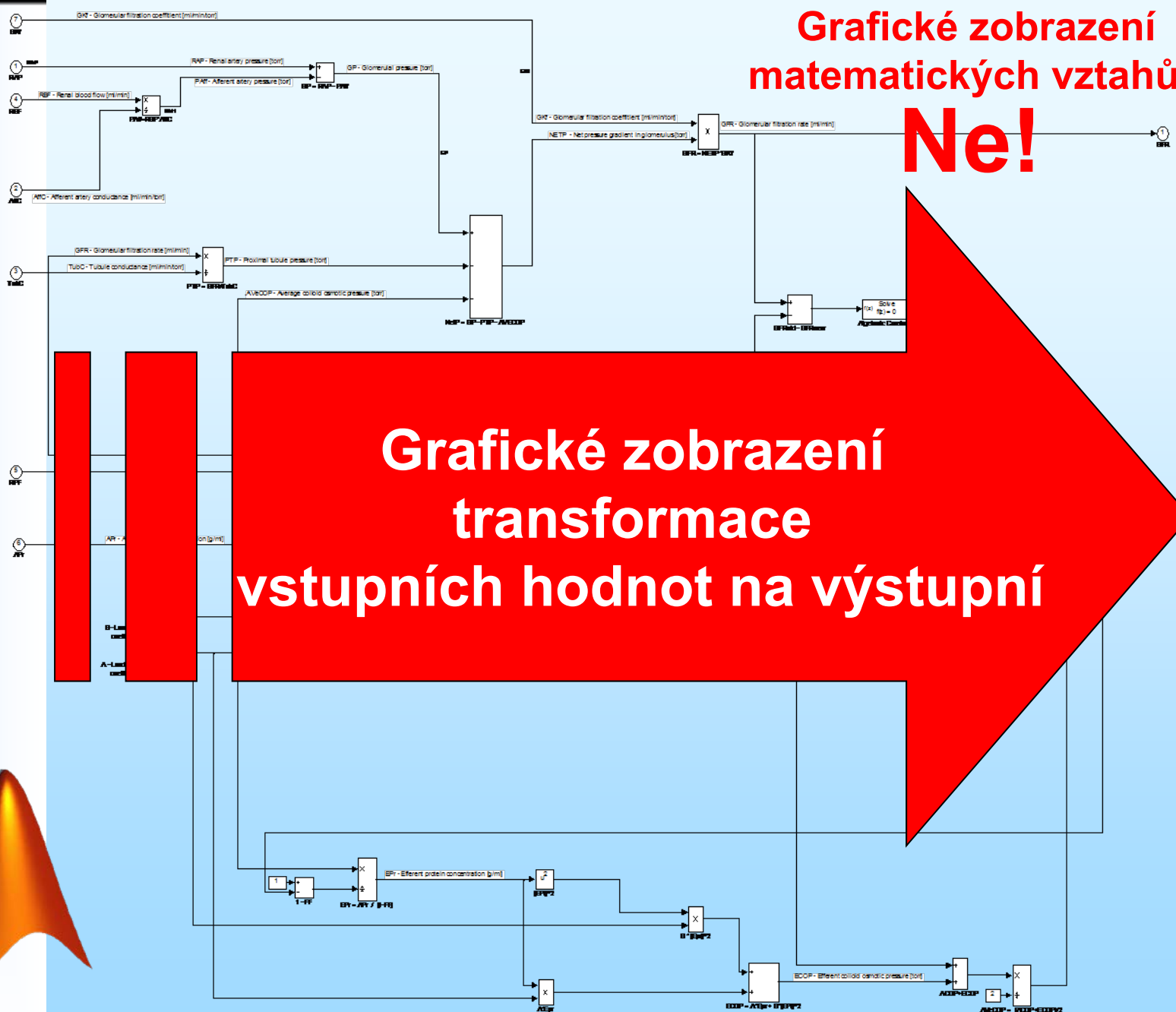
Grafické zobrazení matematických vztahů?

Ne!

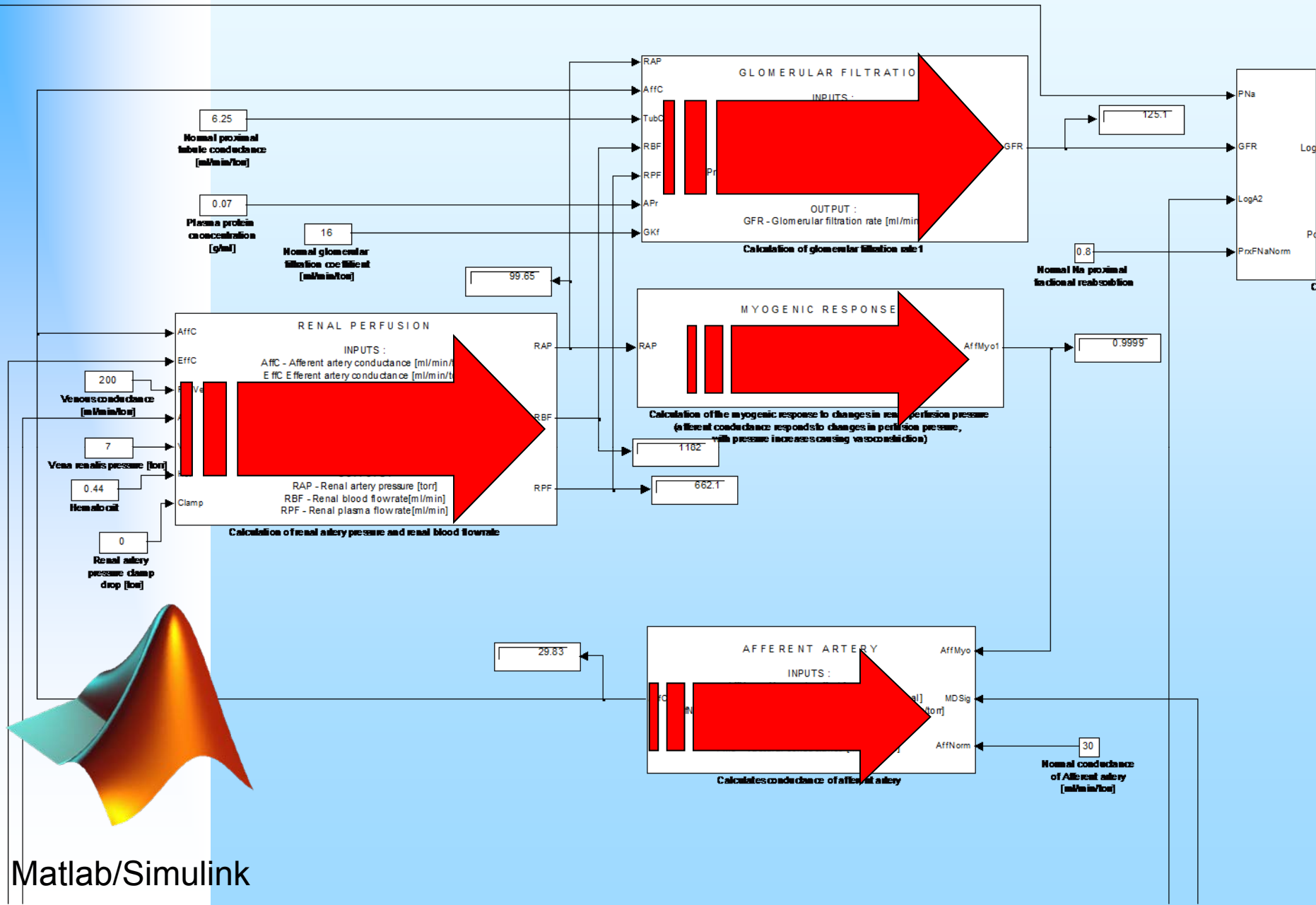
Grafické zobrazení
transformace
vstupních hodnot na výstupní



Matlab/Simulink



Softwarové nástroje pro tvorbu modelů

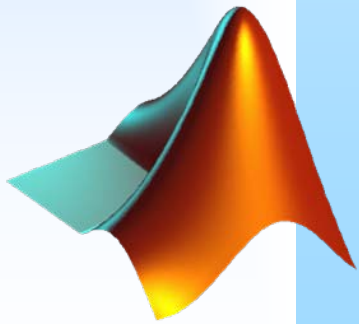


Kauzální modelovací nástroje

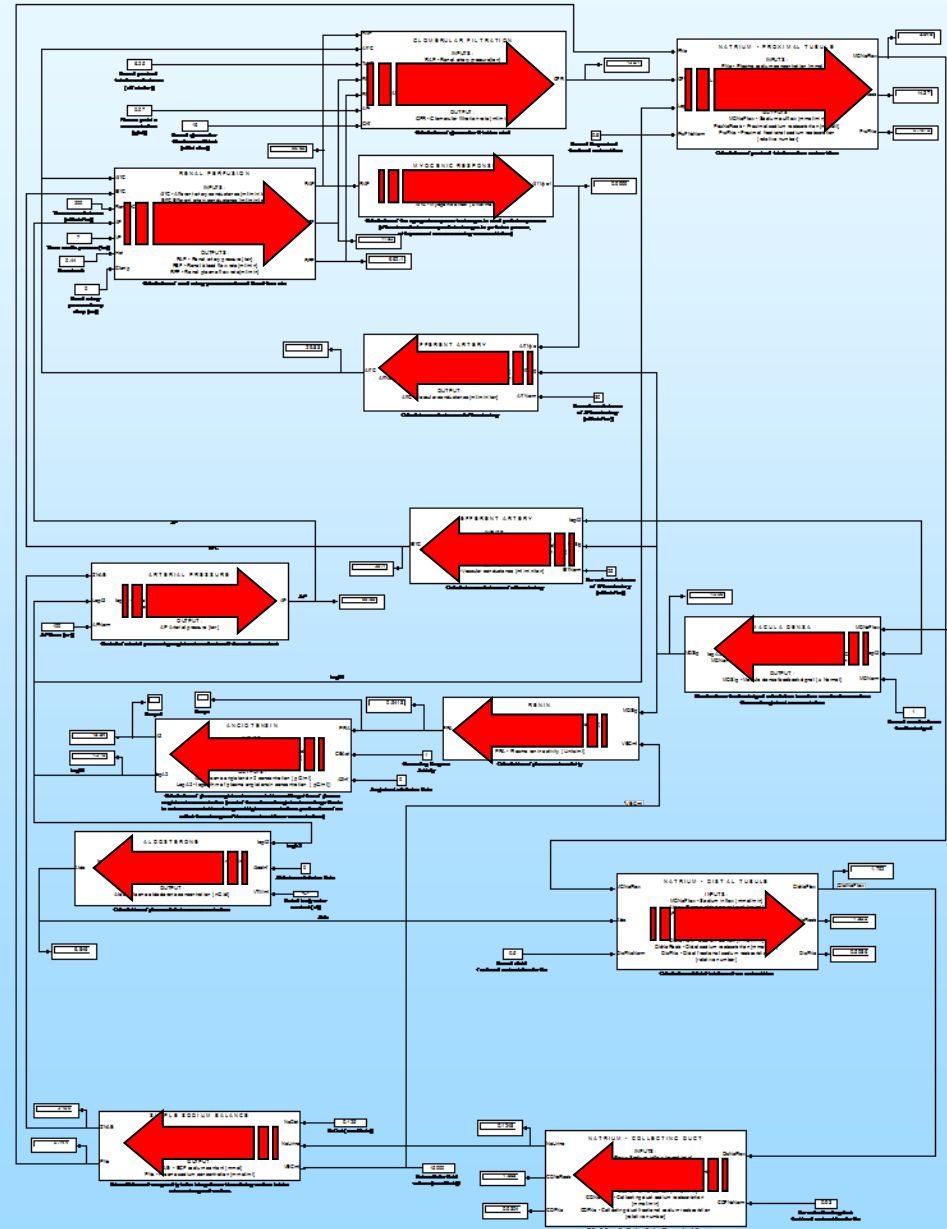
Je jednoznačně
definován
postup výpočtu

Kauzální modelování

Model v Simulinku
vyjadřuje spíše
způsob výpočtu než
strukturu modelované
reality



Matlab/Simulink



Akauzální modelovací nástroje

MODELICA

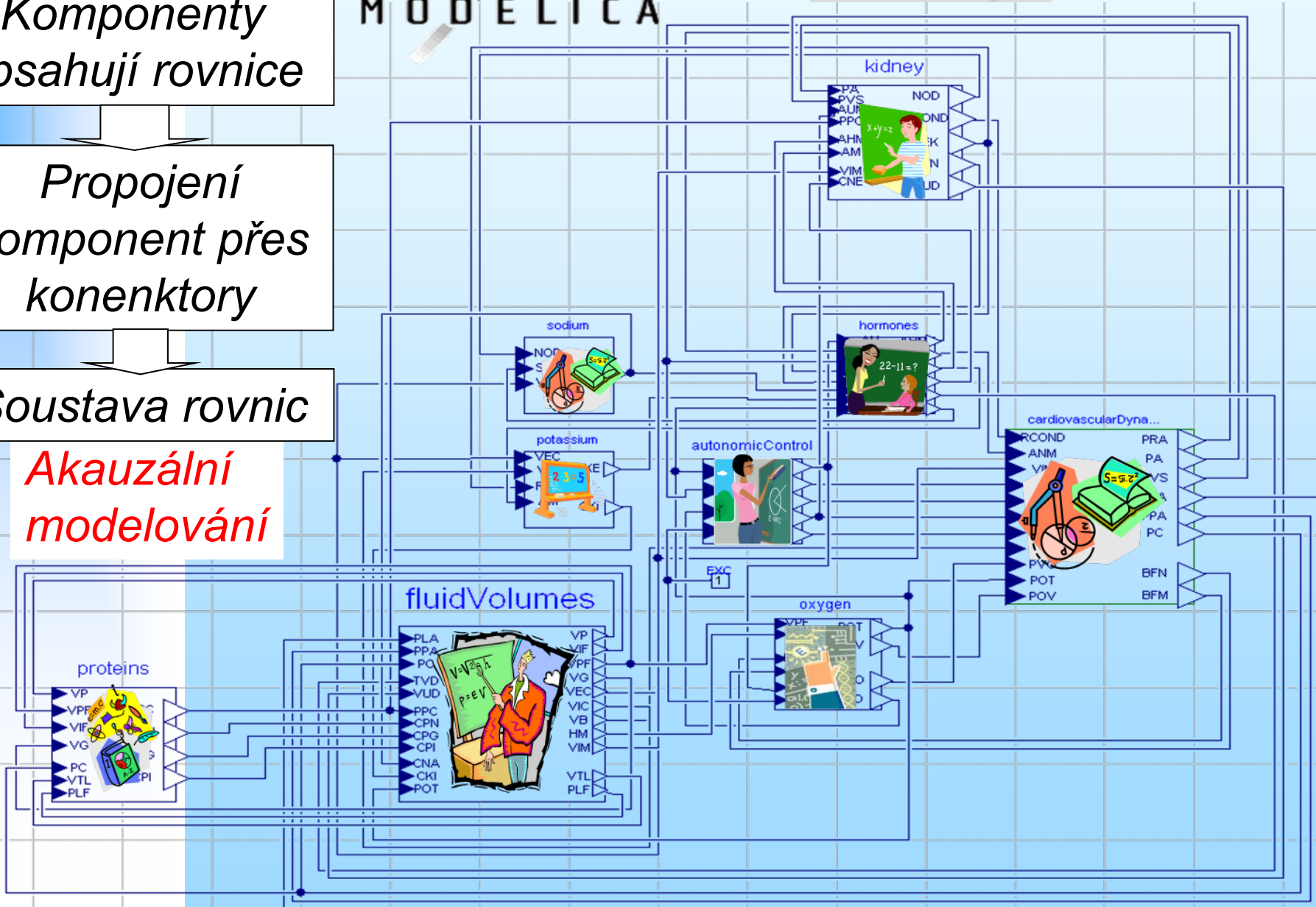
SimScape

Komponenty obsahují rovnice

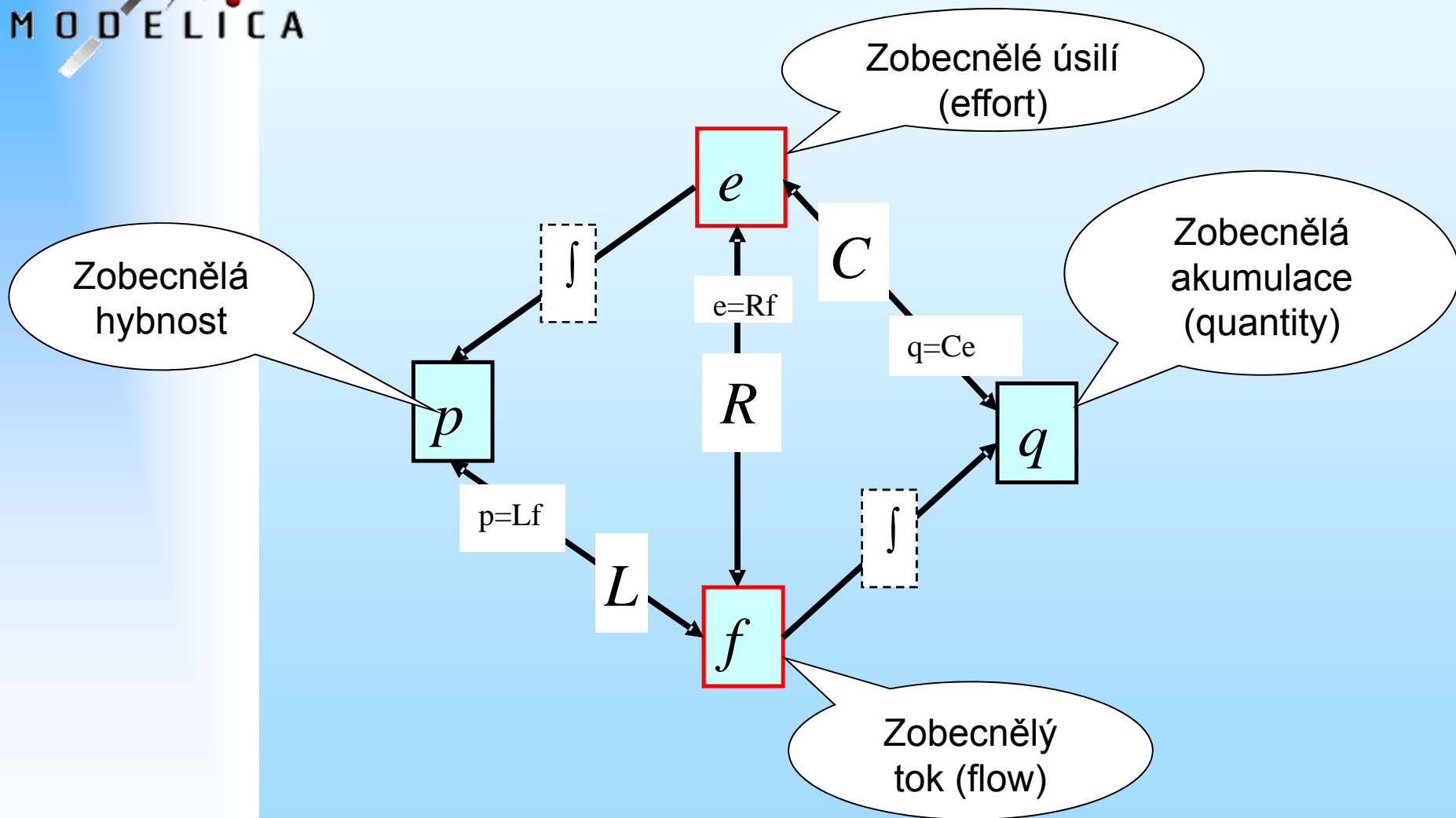
Propojení komponent přes konektory

Soustava rovnic

Akauzální modelování

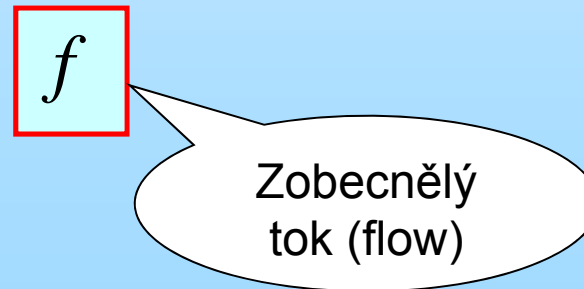
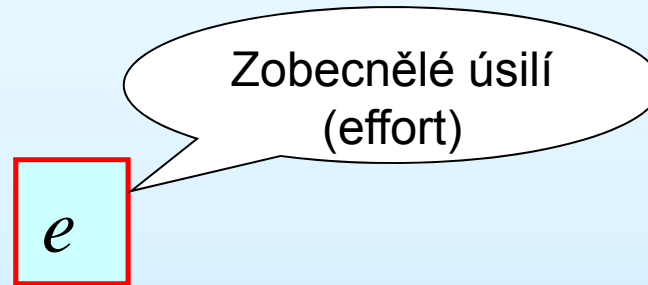


Akauzální přístup



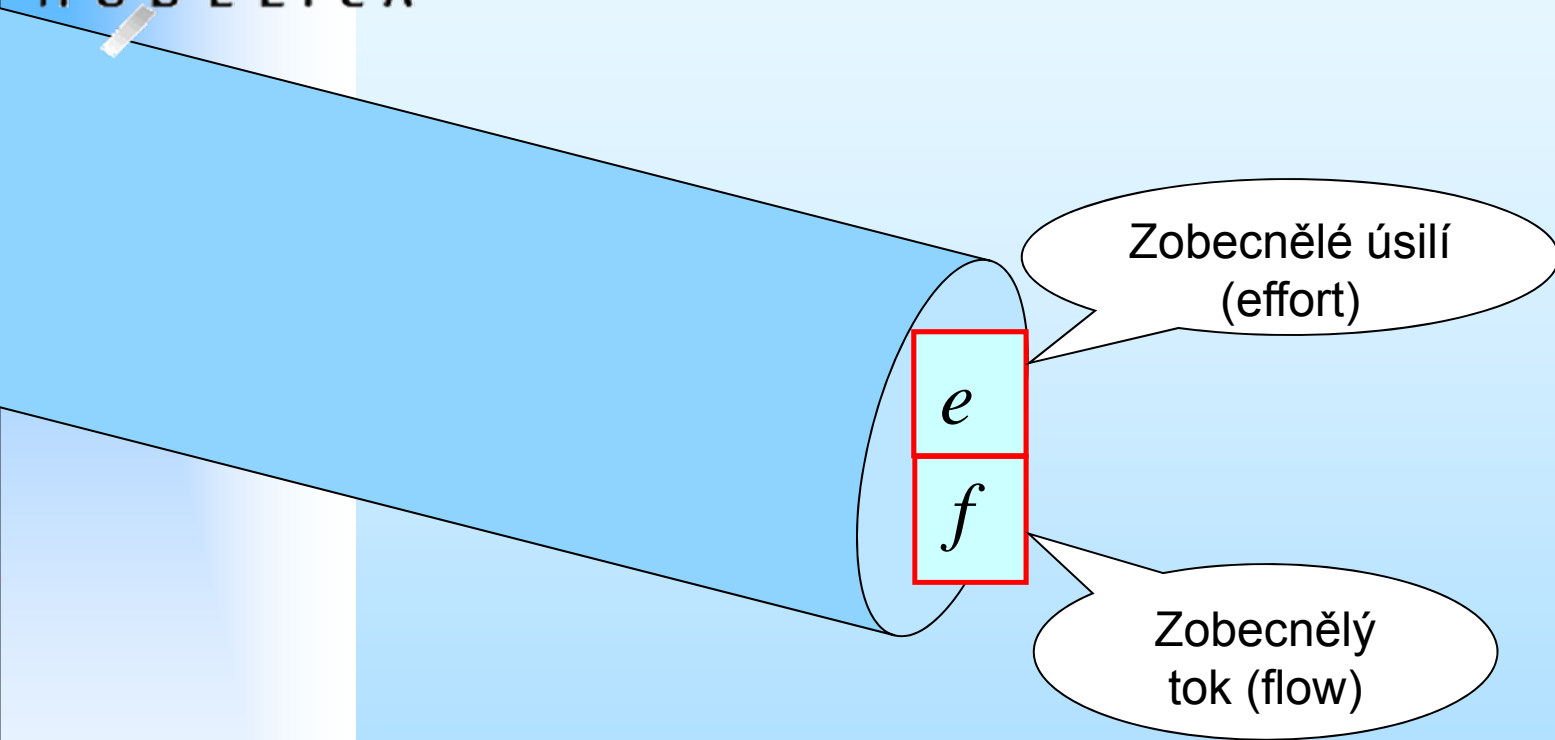
Obecné systémové vlastnosti

Akauzální přístup



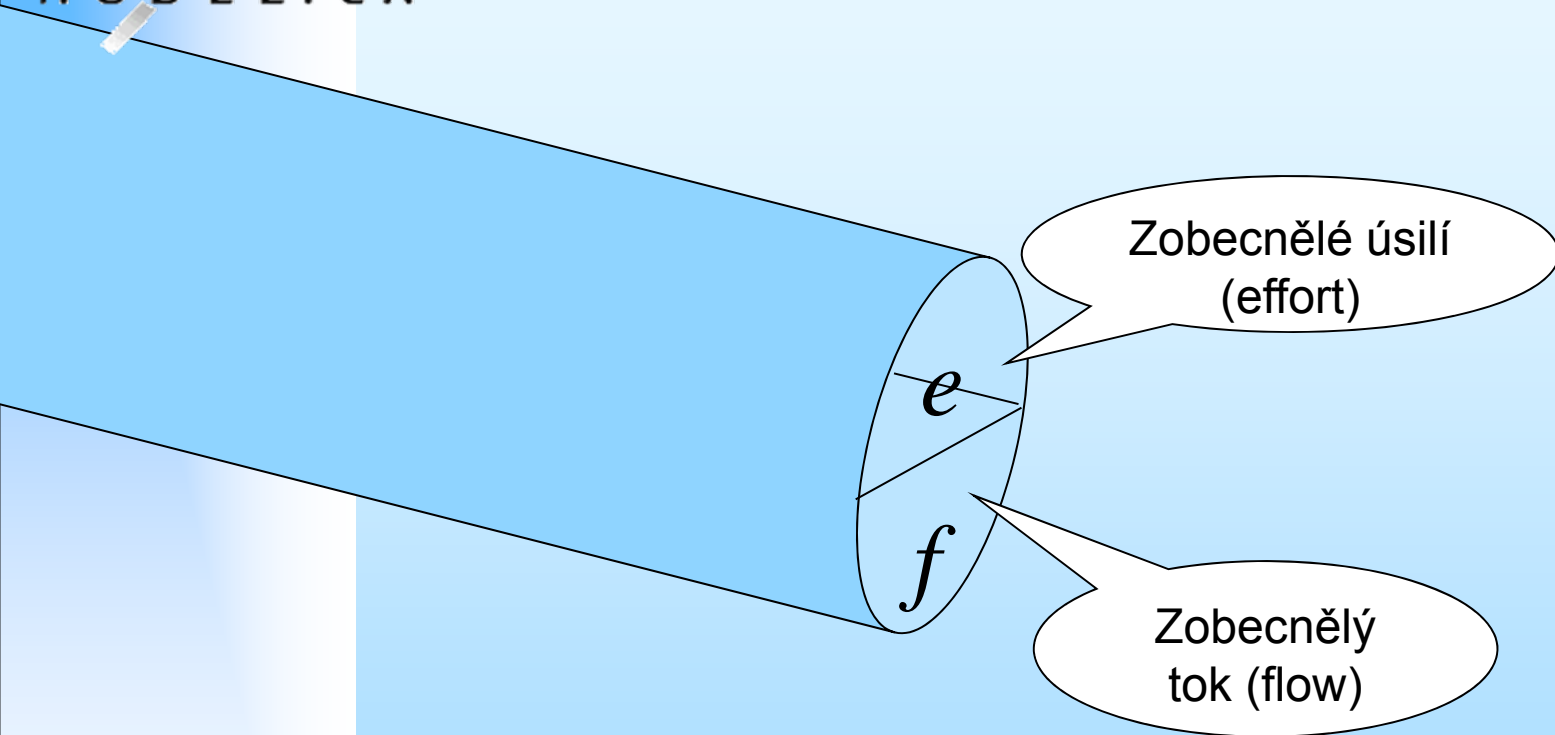
Obecné systémové vlastnosti

Akauzální přístup

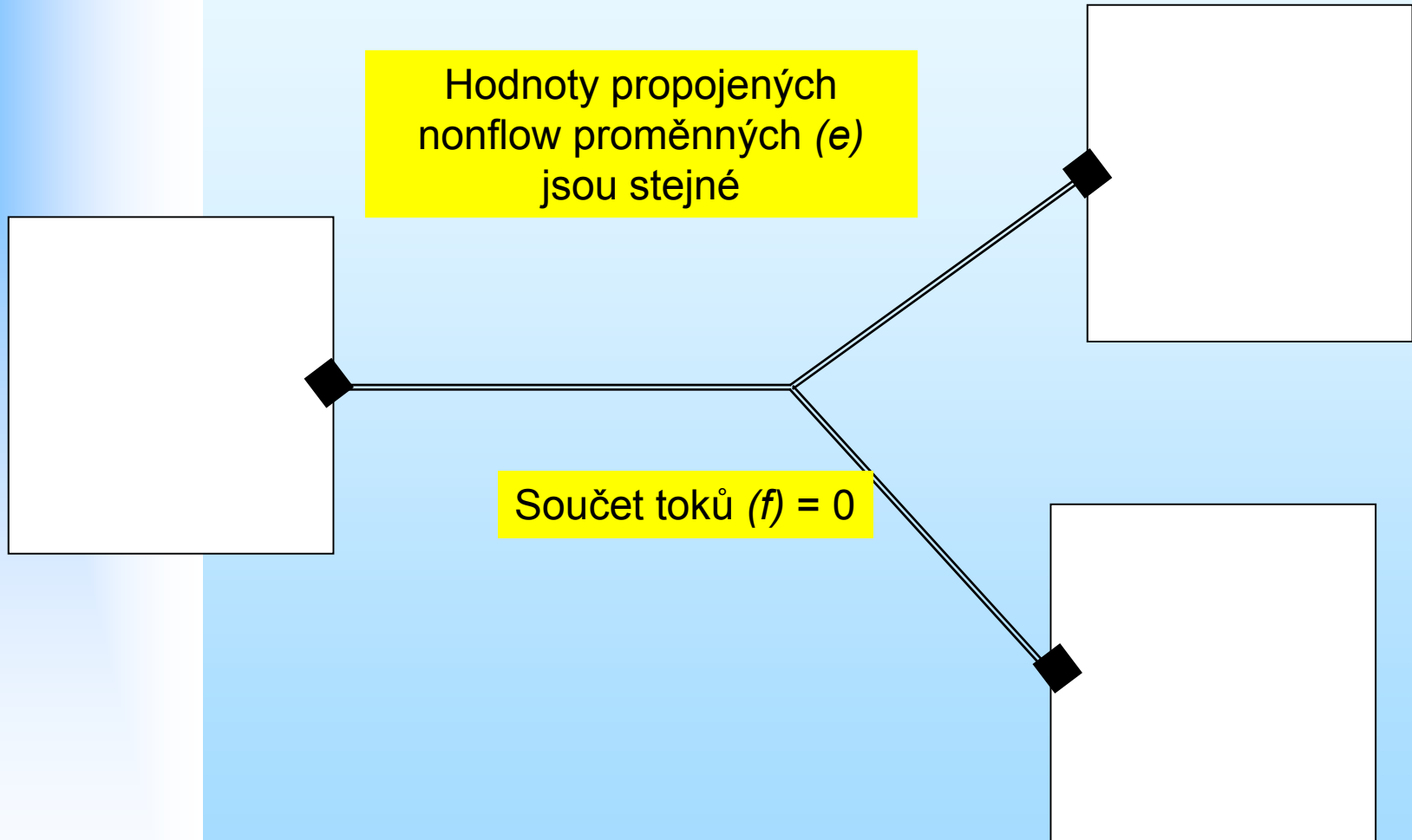


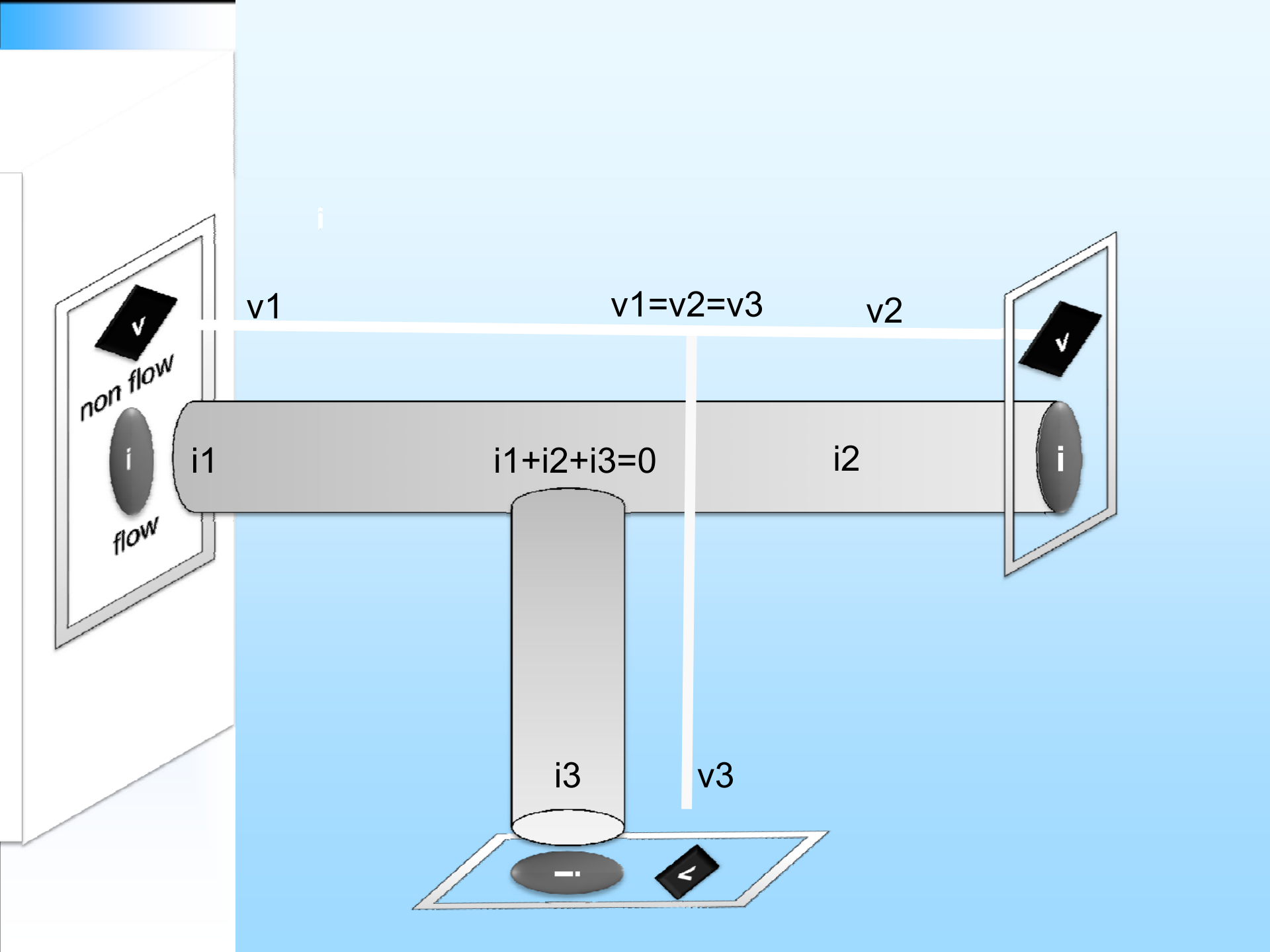
Obecné systémové vlastnosti

Akauzální konektory



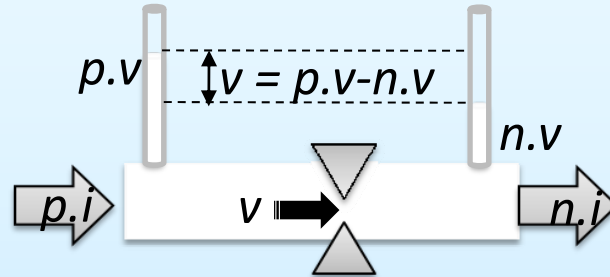
Akauzální propojení





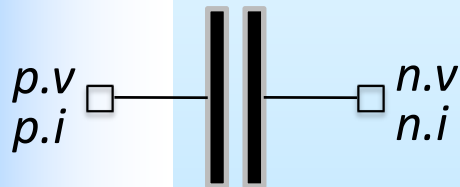


$$R \cdot i = v$$

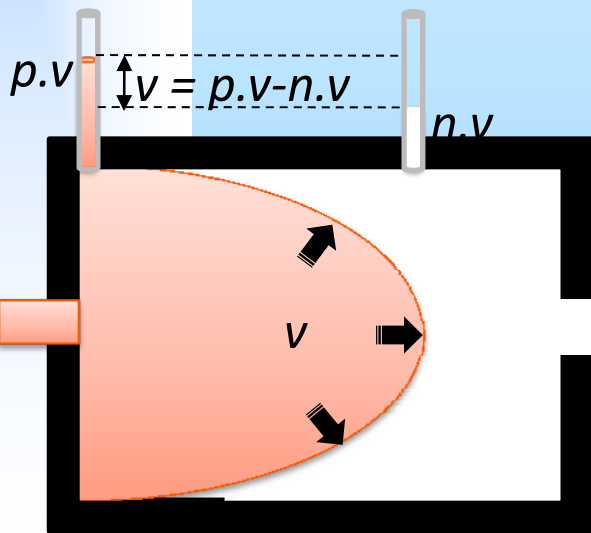


$$i = p.i = n.i$$

Capacitor



$$i = C \cdot \text{der}(v)$$

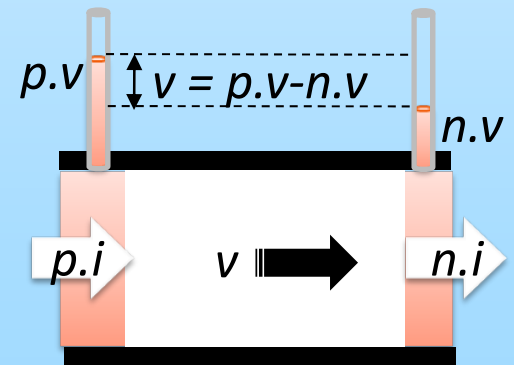


$$i = p.i = n.i$$

Inductor



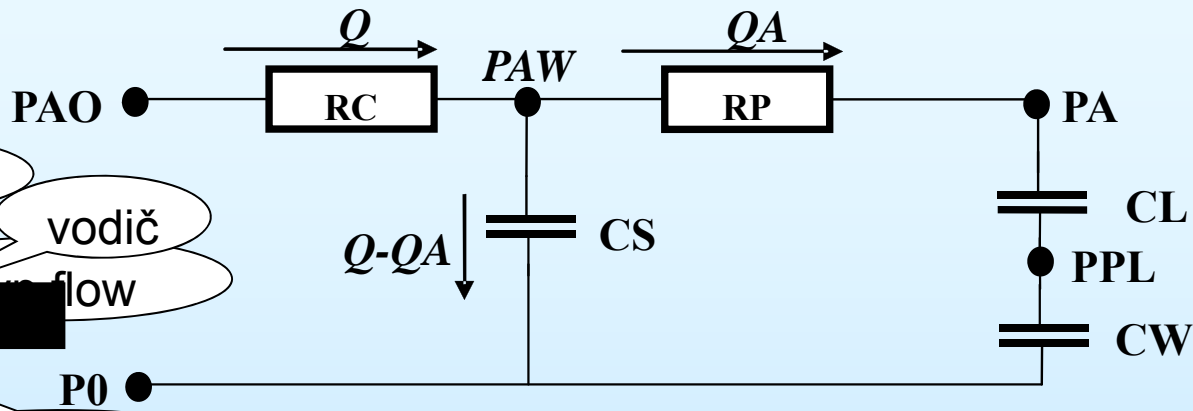
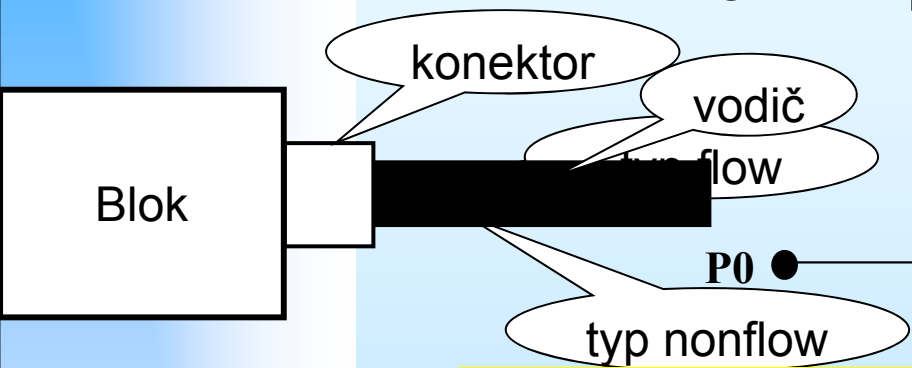
$$L \cdot \text{der}(i) = v$$



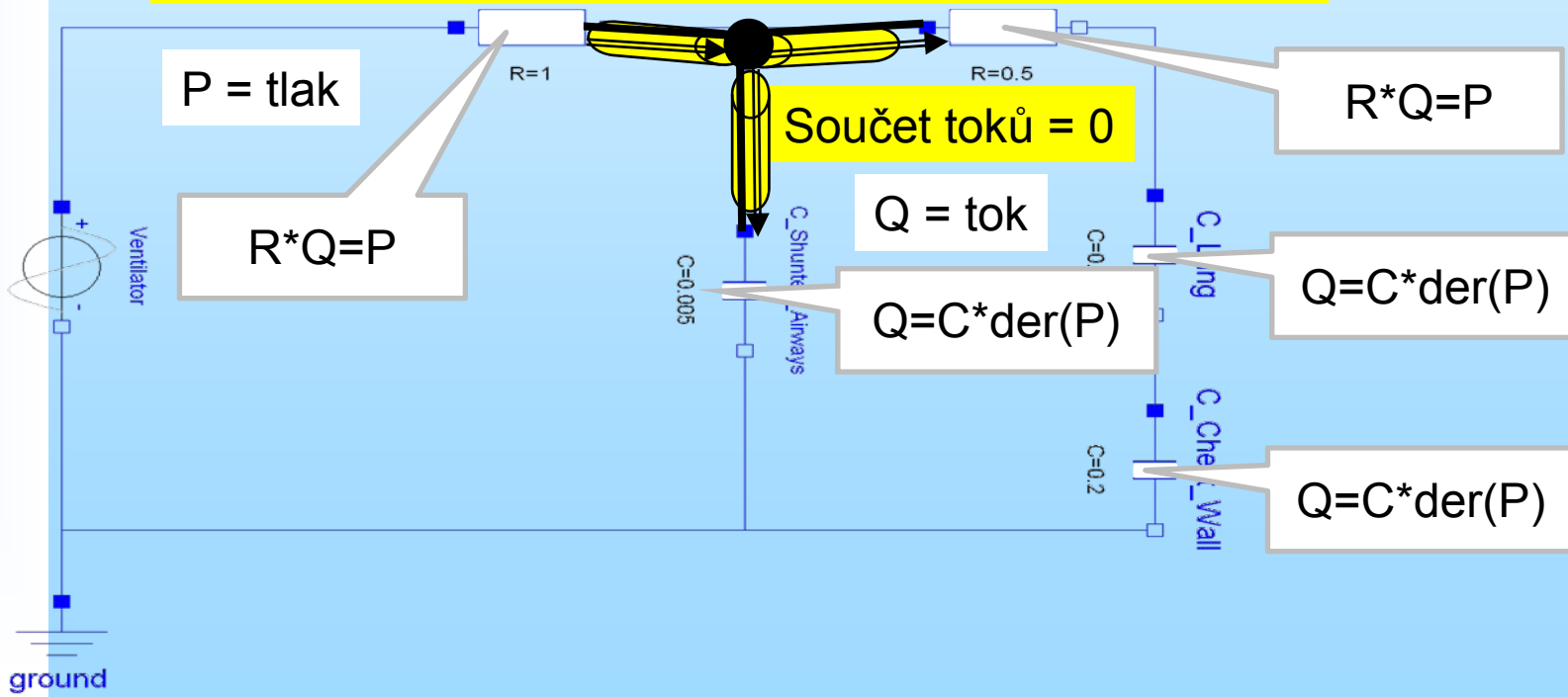
$$i = p.i = n.i$$

Modelování v Modelice

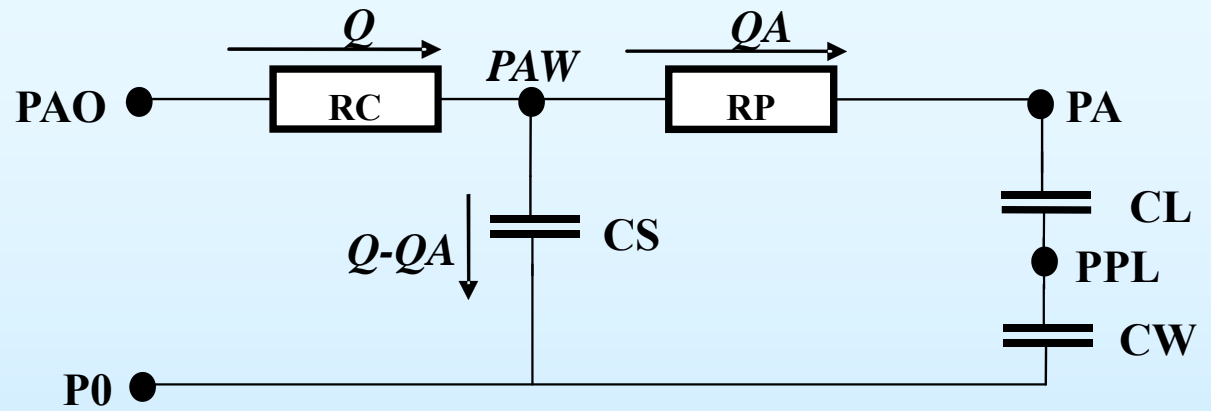
Postačí popis rovnicemi
– akauzální modelování



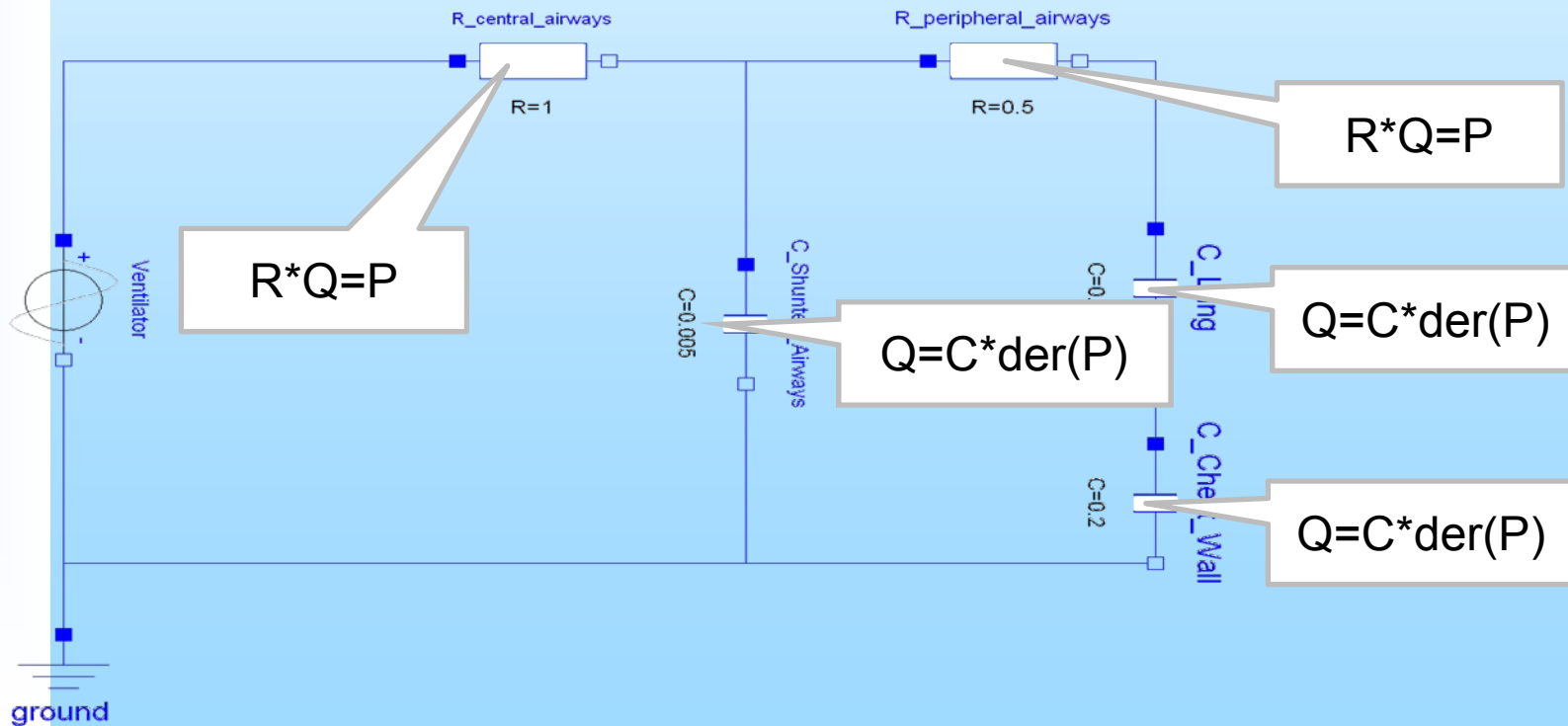
Hodnoty propojených nonflow proměnných jsou stejné

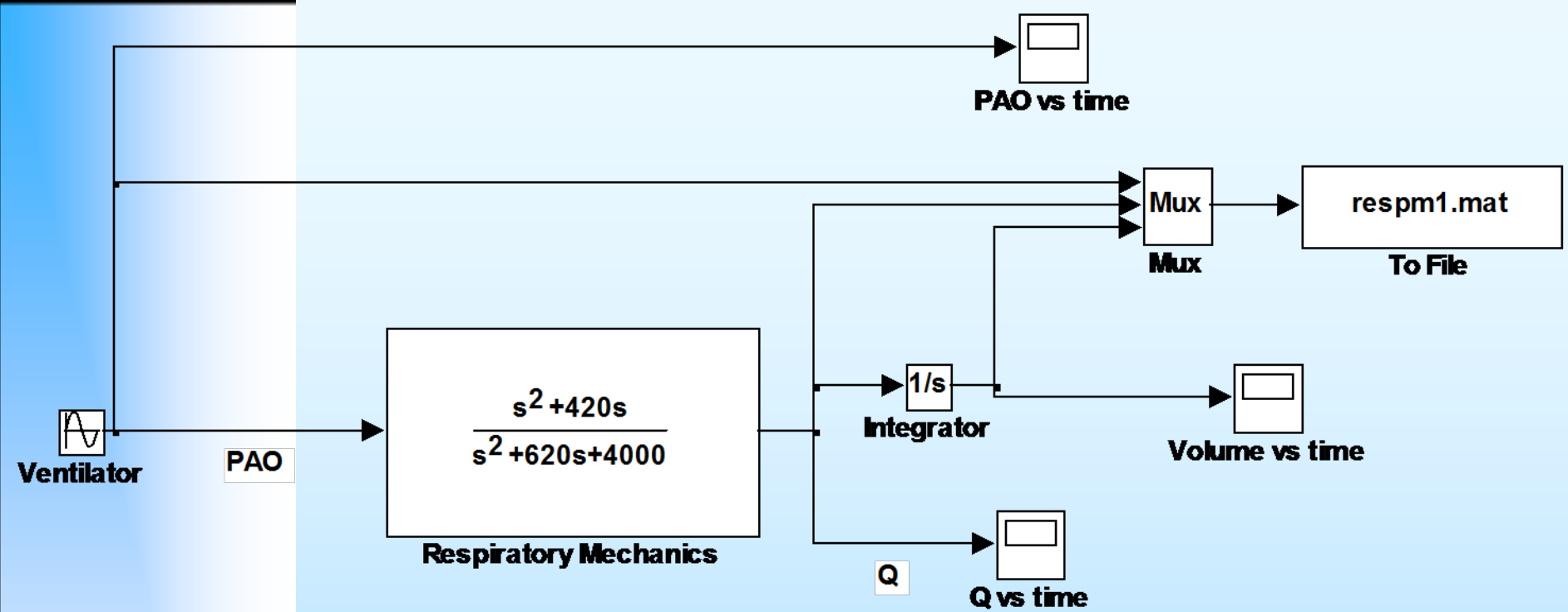


Modelování v Modelice



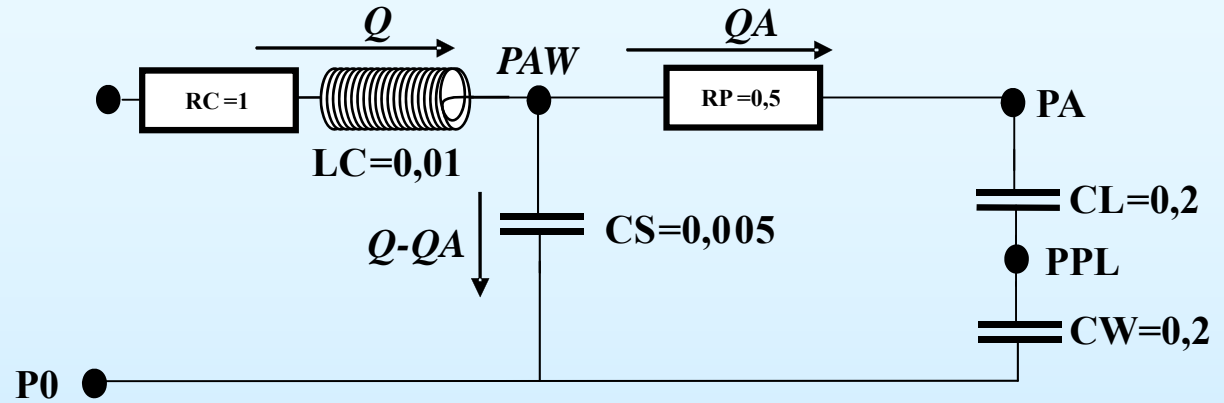
Postačí popis rovnicemi
– akauzální modelování



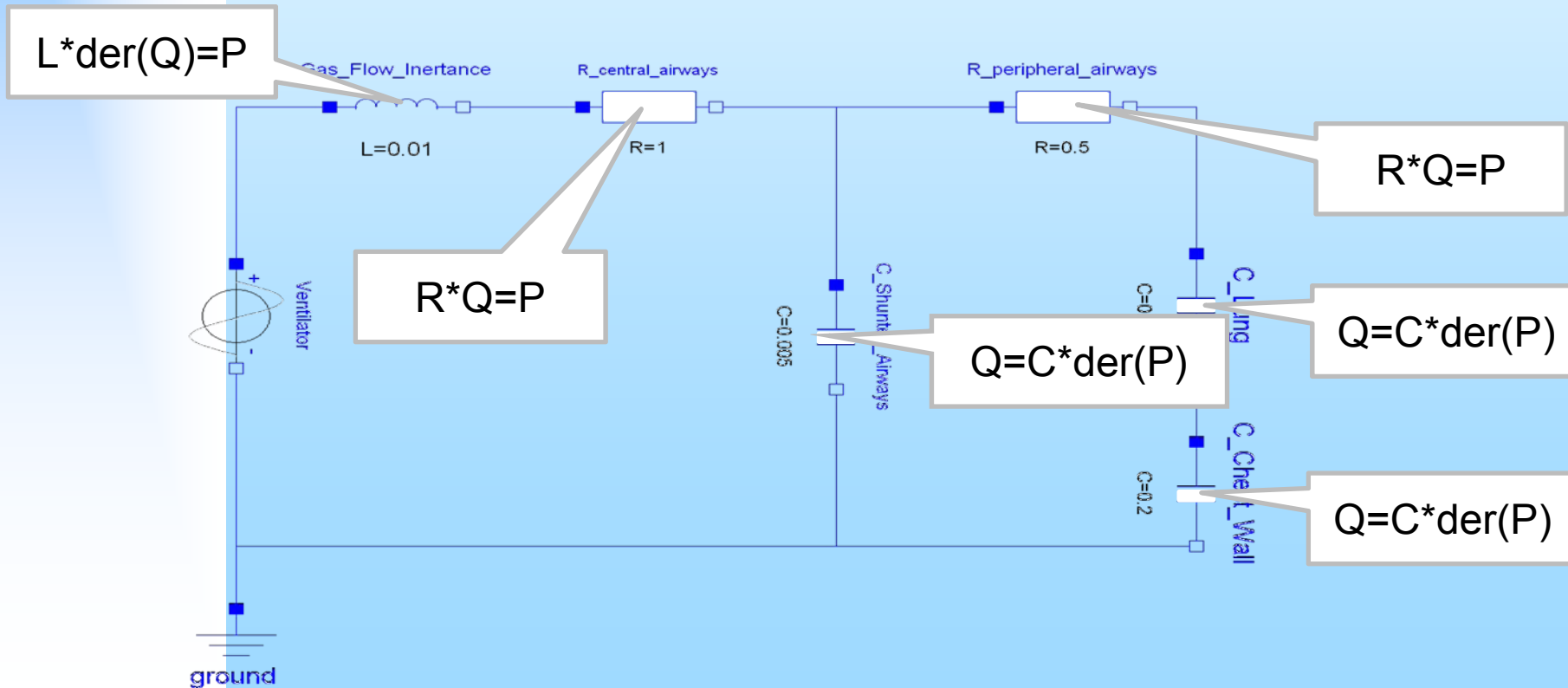


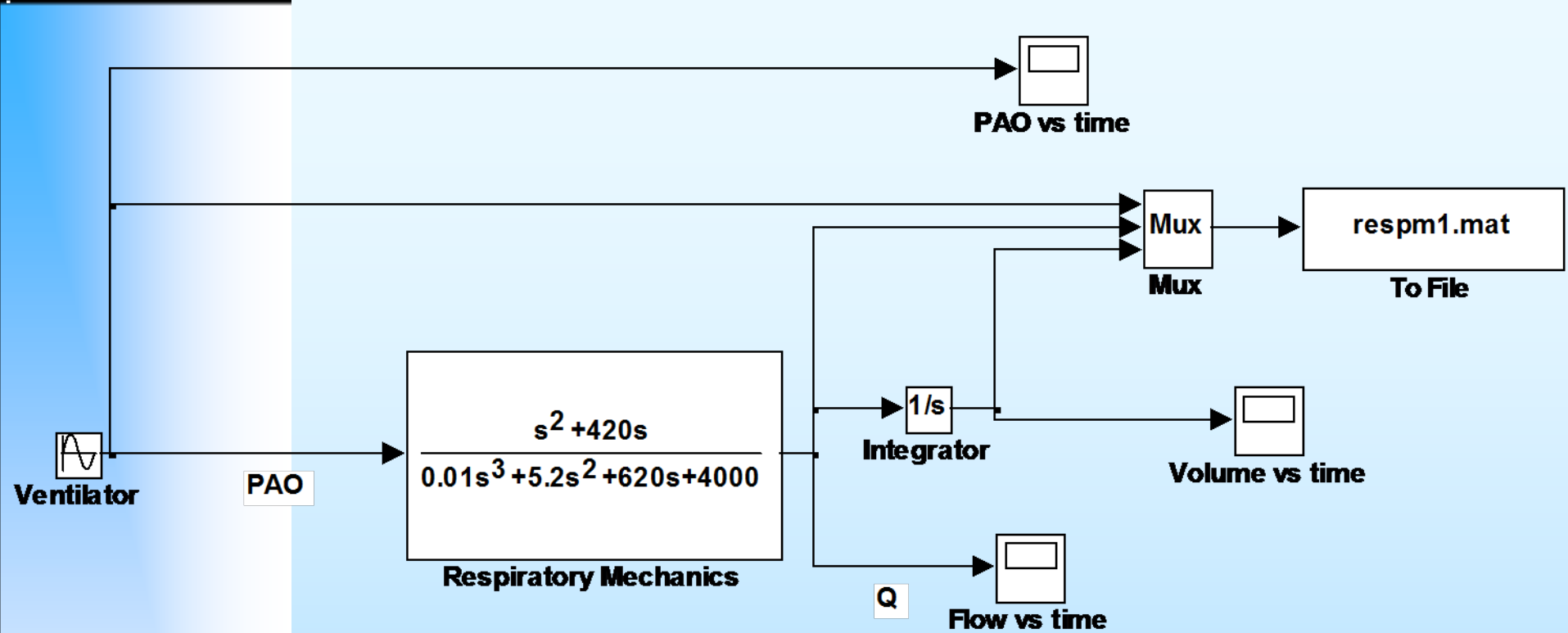
Example: Simple pulmonary mechanics model – Simulink solution

Modelování v Modelice



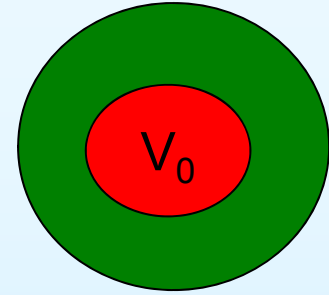
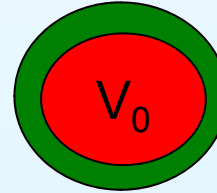
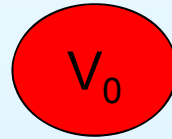
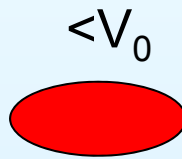
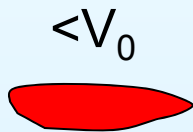
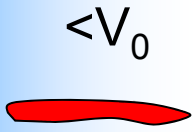
Postačí popis rovnicemi
– akauzální modelování



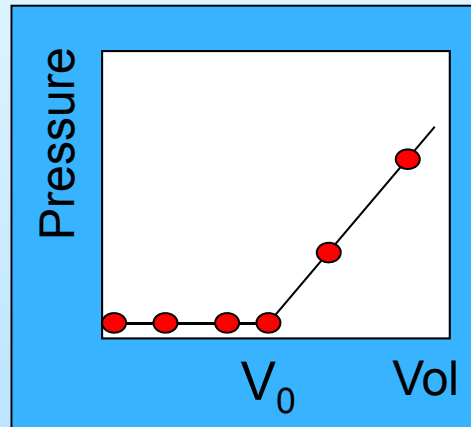


Example: Simple pulmonary mechanics model – Simulink solution

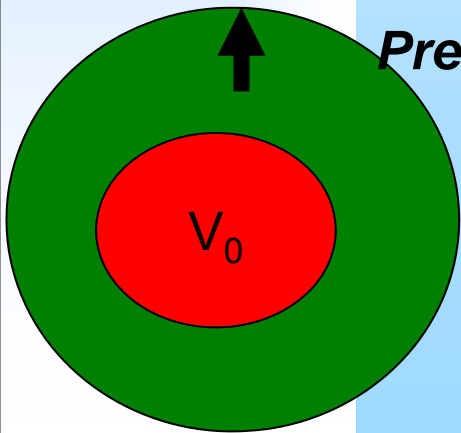
Příklad: Elastický kompartment



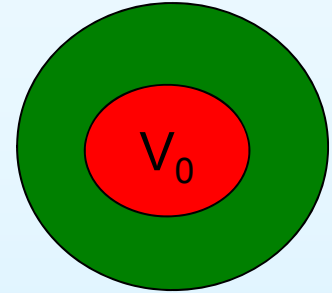
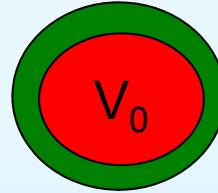
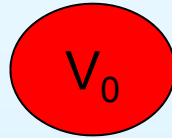
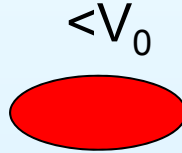
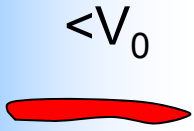
$$\text{StressedVolume} = \max(\text{Vol} - V_0, 0);$$



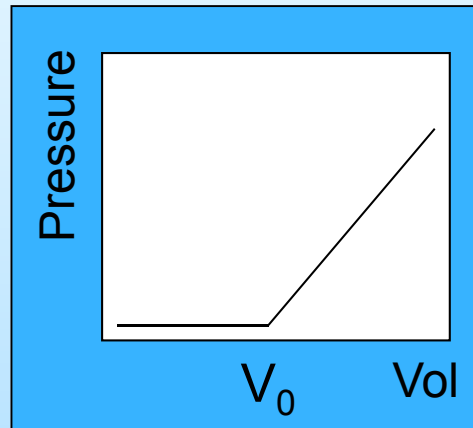
$$\text{Pressure} = (\text{StressedVolume} / \text{Compliance})$$



Příklad: Elastický kompartment



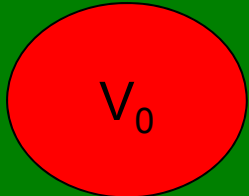
$$\text{StressedVolume} = \max(\text{Vol} - V_0, 0);$$



ExternalPressure

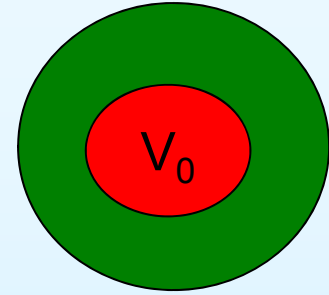
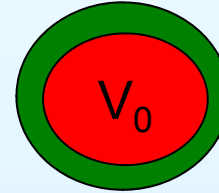
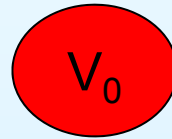
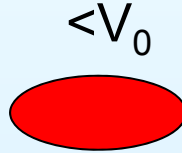
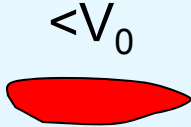
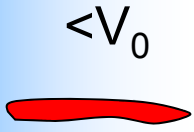


$$\text{Pressure} = (\text{StressedVolume} / \text{Compliance}) + \text{ExternalPressure};$$

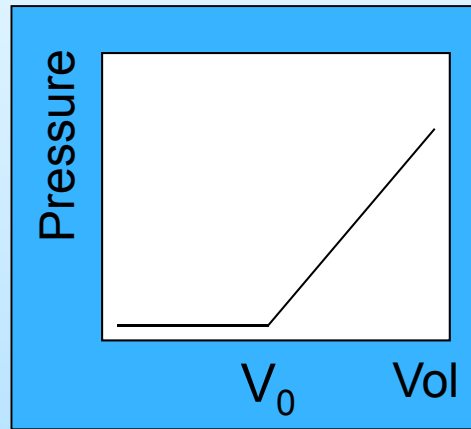


V_0

Příklad: Elastický kompartment



$$\text{StressedVolume} = \max(\text{Vol} - V_0, 0);$$



ExternalPressure

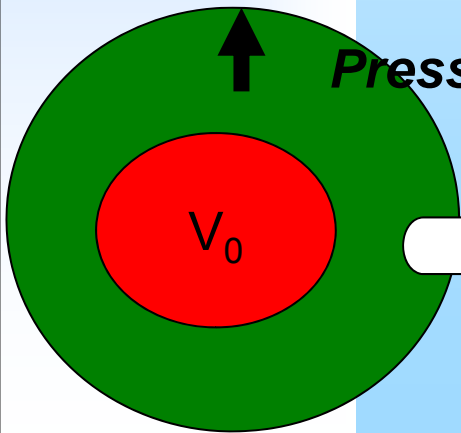


$$\text{Pressure} = (\text{StressedVolume} / \text{Compliance}) + \text{ExternalPressure};$$

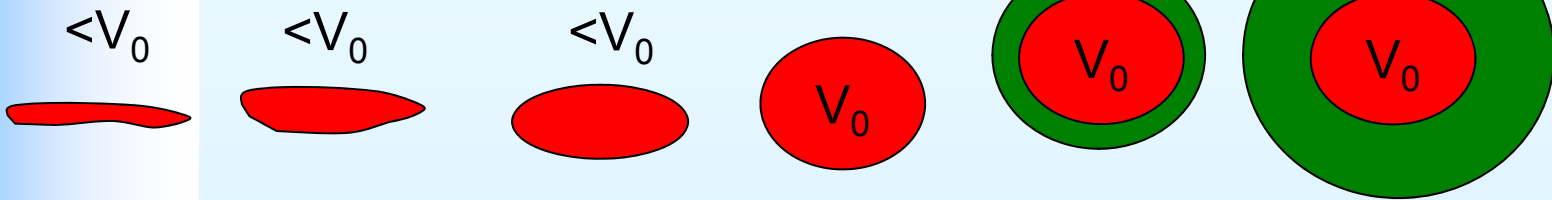
$$\text{der}(\text{Vol}) = q;$$



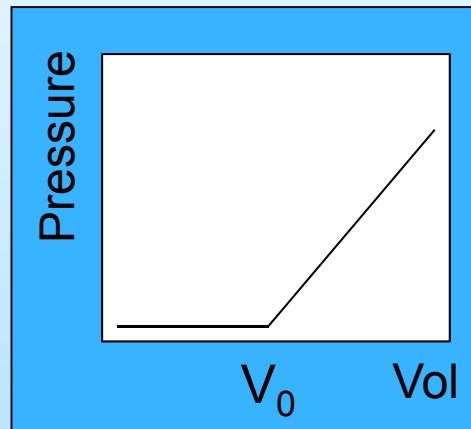
tok - q



Příklad: Elastický kompartment



StressedVolume = $\max(\text{Vol} - V_0, 0)$;



ExternalPressure

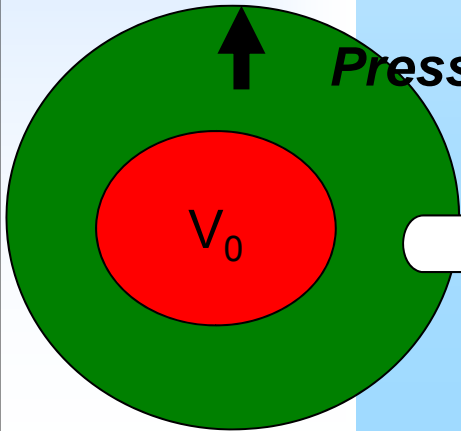


Pressure = (**StressedVolume**/Compliance) + **ExternalPressure**;

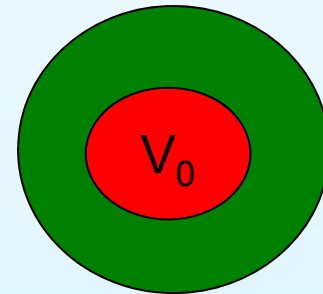
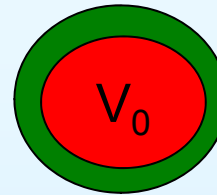
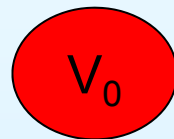
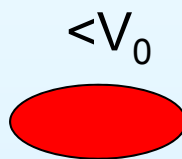
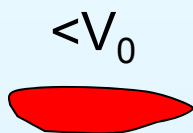
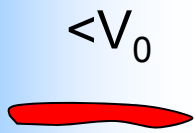
$\text{der}(\text{Vol}) = q$;

tok - q

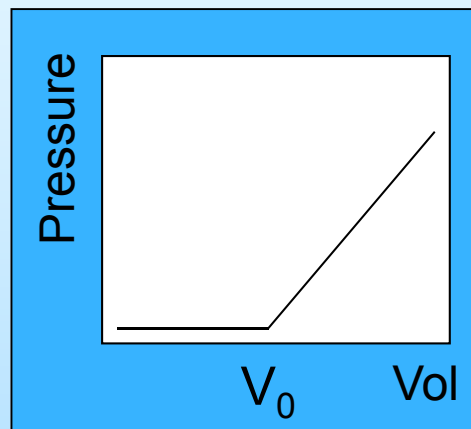
- pressure



Příklad: Elastický kompartment



StressedVolume = $\max(\text{Vol} - V_0, 0)$;



Název konektoru:
referencePoint

ExternalPressure



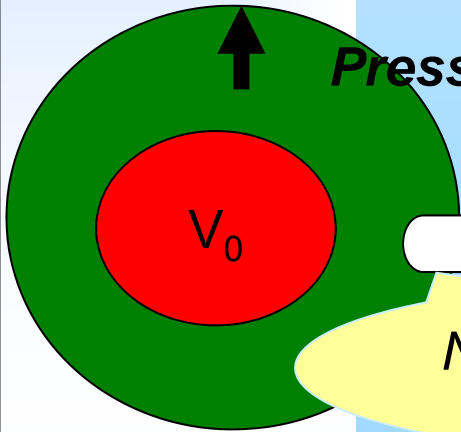
Pressure = $(\text{StressedVolume} / \text{Compliance}) + \text{ExternalPressure}$;

$\text{der}(\text{Vol}) = q$;

tok - $\text{referencePoint}.q$

$\text{referencePoint}.pressure$

Název konektoru:
referencePoint



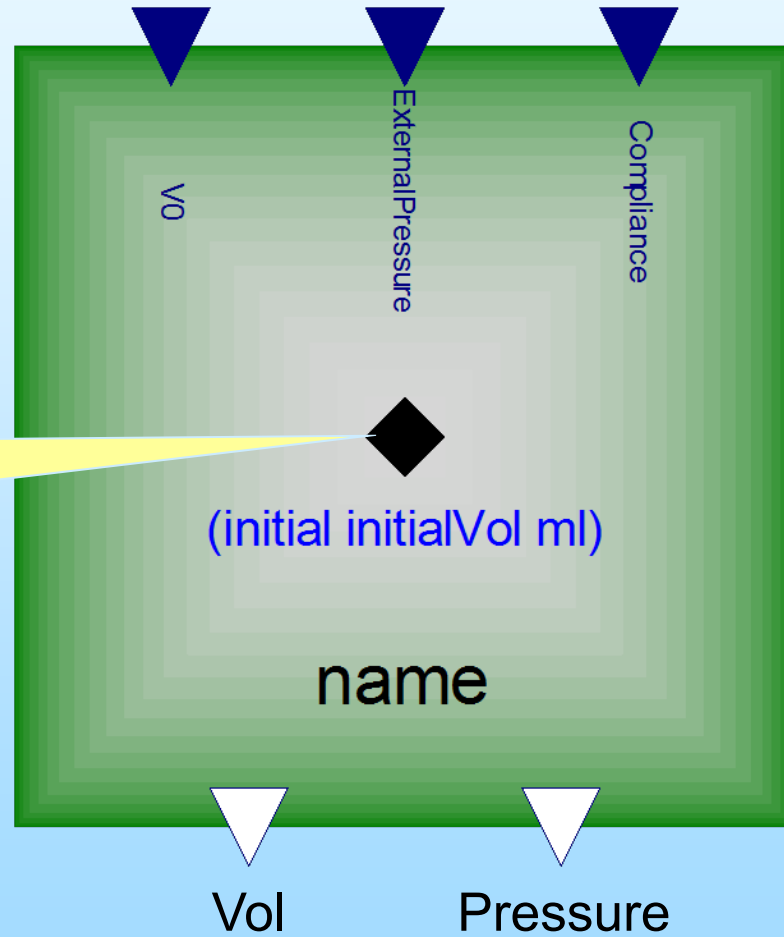
Příklad: Elastický kompartment



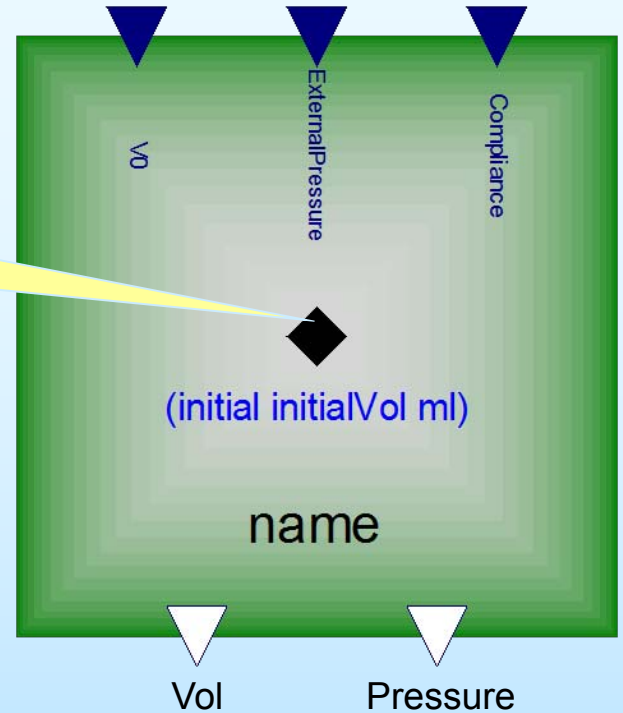
Třídy: „Vzory“

Komponenty: „Instance“

*Název akauzálního konektoru:
referencePoint*



referencePoint.pressure
referencePoint.q



initial equation

Vol = initialVol;

equation

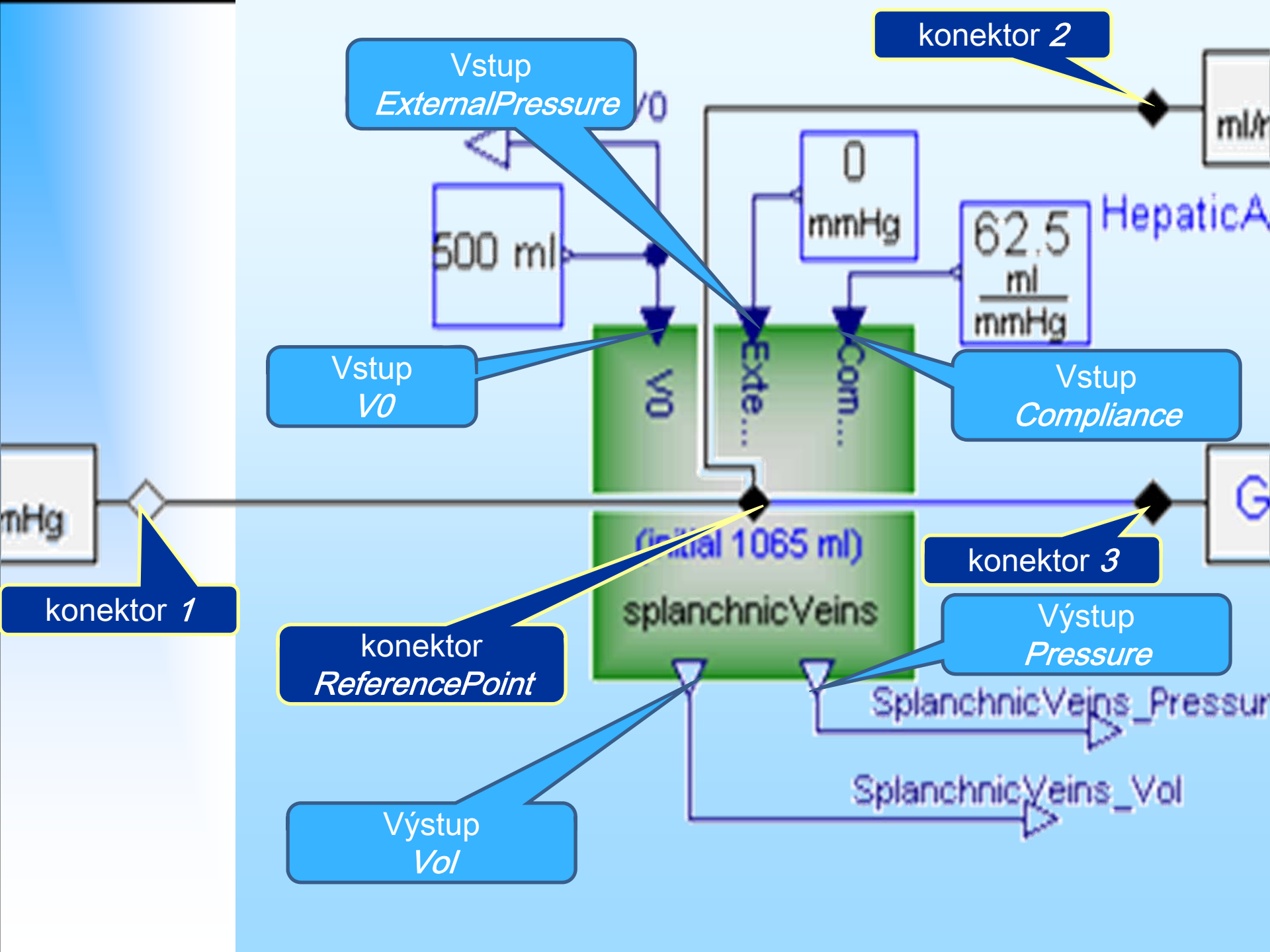
der(Vol) = referencePoint.q;

StressedVolume = max(Vol-V0,0);

Pressure = (StressedVolume/Compliance) + ExternalPressure;

referencePoint.pressure = Pressure;

end VascularElasticBloodCompartment;



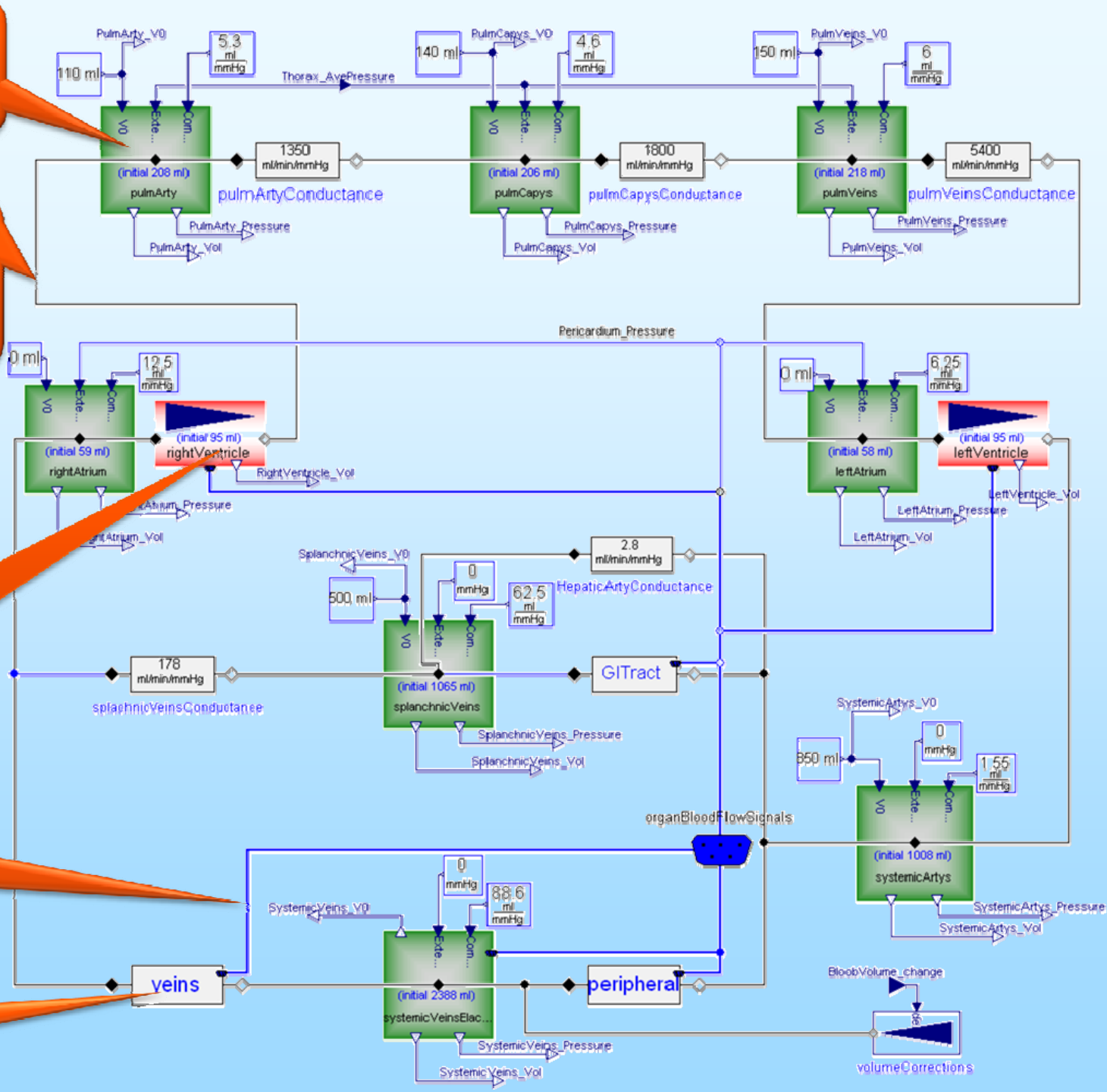
Elastické kompartmenty cév

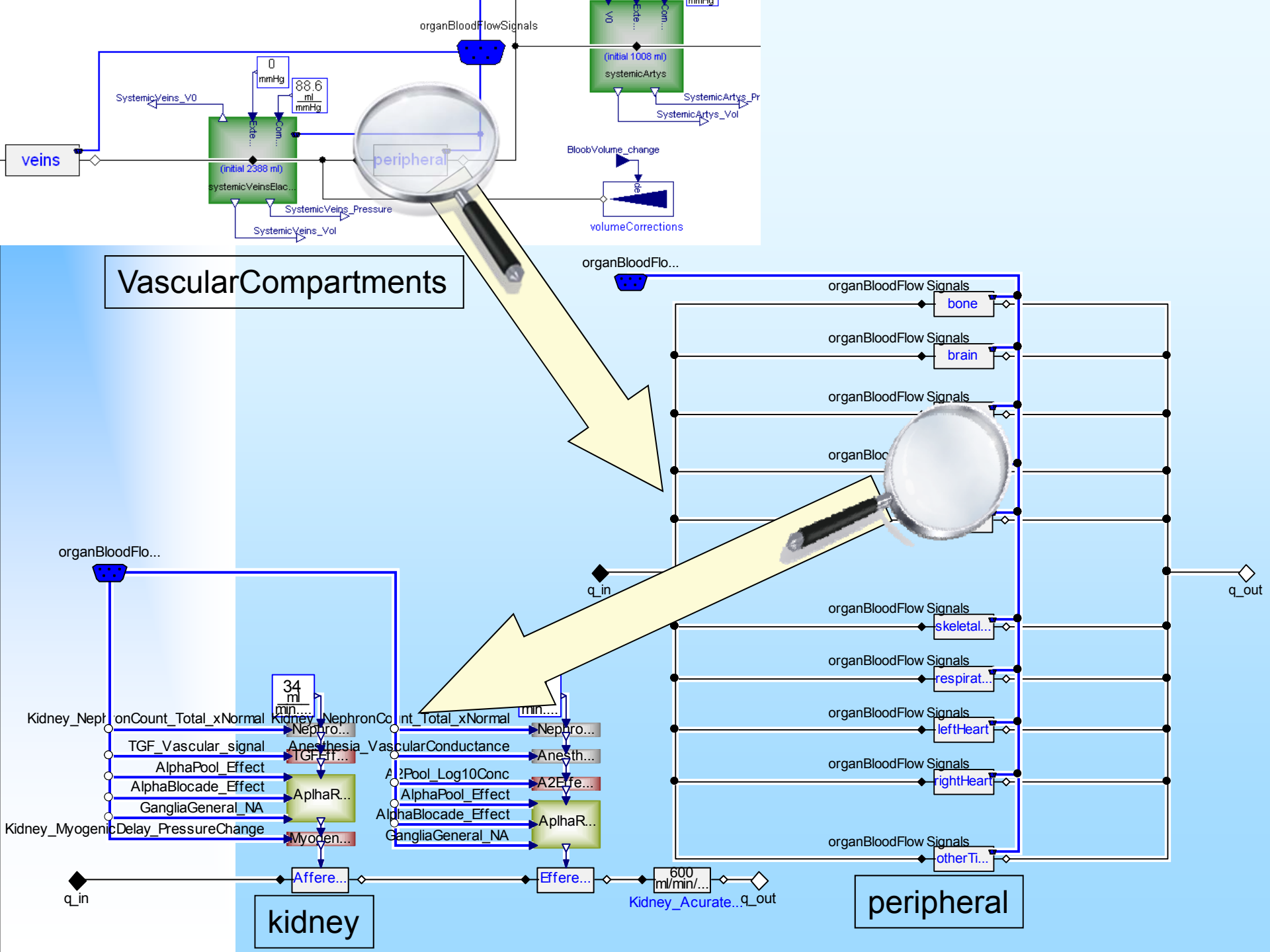
Toky krve v cévách (mají tlak a průtok)

Řízené čerpadlo (pravá komora)

Sběrnice řídicích signálů

Regulovatelné odpory





Quantitative Human Physiology (QHP)



```
Mozilla Firefox
Soubor Úpravy Zobrazit Historie Záložky Yahoo! Nástroje Nápořádá
CO2, Hemoglobin, AcidBase, ADH, AirSupply, Aldosterone, AminoAcid, if ANESTHESIA then Anesthesia,
if not ANESTHESIA then NoAnesthesia, if ANP then DetailedANP, if not ANP then BasicANP, Bladder,
BloodVolume, BloodIons, Bone, Brain, CardiacCycle, Catechols, CellProtein, Circulation, CiryProtein,
CoronarySinus, CPR, Creatine, Creatinine, DailyPlanner, Diagnosis, Diet, Drugs, Electrolytes, Environment,
EPO, Estradiol, Exercise, Fat, FattyAcid, FSH, GILumen, GITract, Glucagon, Glucose, Glycerol, GnRH,
Gravity, H2O, hCG, Heart, HeartValves, Heat, Hemodialysis, Hemorrhage, HepaticFunction, Hypothalamus,
Inhibin, Infusions, Insulin, InsulinInjection, IVDrip, IVEpinephrineInjection, Ketoacid, Kidney, Lactate,
LeftHeart, LegMusclePump, Leptin, LH, LipidDeposits, Liver, LiverMetabolism, LowerExternalPressure,
Lungs, Metabolism, Morphology, Nephrons, Nerves, O2, OralH2OGlucoseLoad, Organs, Orthostatics,
Osmoles, OtherTissue, Pericardium, Peritoneum, Posture, Progesterone, Renin, RespiratoryCenter,
RespiratoryMuscle, RightHeart, SequesteredBlood, SkeletalMuscle, Skin, SplanchnicVeins, Sweat,
Testosterone, ThyroidGland, TiltTable, TissueH2O, Transfusion, Tnglyceride, VascularCompartments
if GENDER-FEMALE then Ovaries, if GENDER-FEMALE then Uterus, Testes,
[structure: Structure ]
[definitions]
```

VascularCompartments

```
Mozilla Firefox
Soubor Úpravy Zobrazit Historie Záložky Yahoo! Nástroje Nápořádá
VascularCompartments/VascularCompartments
(ref VascularCompartments REF) (ref Ventricles REF)
LeftAtrium, PulmArty, PulmCapys, PulmVeins, RightAtrium, SplanchnicVeins,
LeftVentricle, RightVentricle,
[structure: VascularCompartments ]
[definitions]
[block: CalcPressure(1) ]
RightAtrium.CalcPressure
LeftAtrium.CalcPressure
SystemicArtyys.CalcPressure
[block: CalcPressure(2) ]
SplanchnicVeins.CalcPressure
RightAtrium.CalcPressure
PulmArty.CalcPressure
PulmCapys.CalcPressure
PulmVeins.CalcPressure
LeftVentricle-Valves LeftVentricle RightVentricle-
[block: Derivs ]
RightVentricle.Derivs
SystemicVeins.Derivs
SplanchnicVeins.Derivs
RightAtrium.Derivs
PulmArty.Derivs
PulmCapys.Derivs
PulmVeins.Derivs
LeftAtrium.Derivs
SystemicArtyys.Derivs
```

SplanchnicVeins

```
Mozilla Firefox
Soubor Úpravy Zobrazit Historie Záložky Yahoo! Nástroje Nápořádá
VascularCompartments/SplanchnicVeins.DES
VascularCompartments REF) (ref Ventricles REF)
[structure: SplanchnicVeins ]
[variables]
[var: Inflow ]
[var: Outflow ]
[parm: V0 = 500.0 ]
[var: StressedVol ]
[var: Pressure ]
[var: ExternalPressure ]
[parm: Compliance = 62.5 ]
[parm: Conductance = 178 ]
[equations]
der( Change ) = Vol
initial equation: Vol = 1007.0
errorLimit: 10.0
[definitions]
[block: CalcPressure ]
StressedVol = ( Vol - V0 ) MAX 0.0
ExternalPressure = 0.0
Pressure = ( StressedVol / Compliance ) + ExternalPressure
[block: Derivs ]
Dydfax = if Conductance > 0.0 then 0.5 * Compliance / Conductance else INFINITI
Inflow = OrganFlow.SplanchnicFlow
Outflow = Conductance * ( Pressure - RightAtrium.Pressure )
Change = Inflow - Outflow
```

Equations

Změna nástrojů pro tvorbu simulátorů

**Nástroje pro tvorbu
simulátorů**

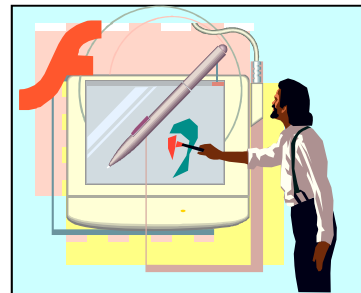


Směr – simulátory spustitelné v prohlížeči

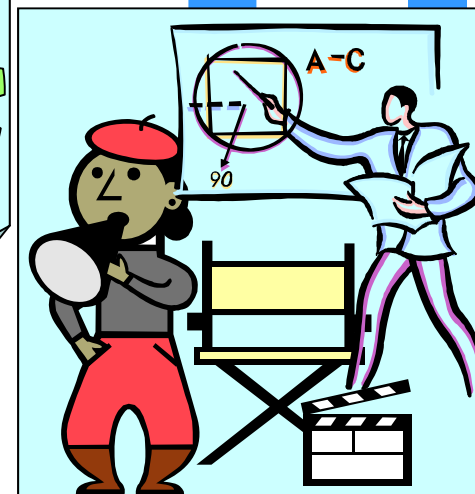
Automatické generování modelu jako virtuálního řadiče

Automatické generování modelu jako .NET assembly

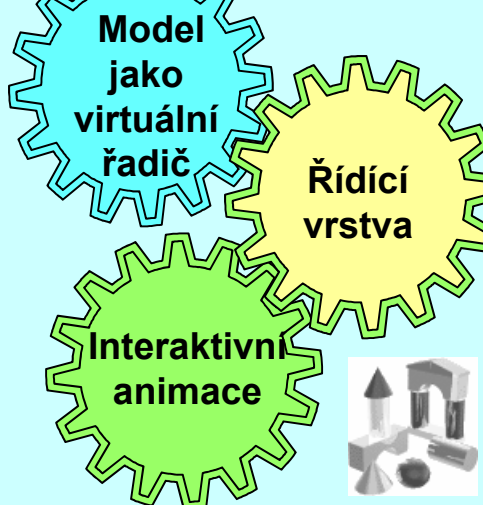
Tvorba simulačního modelu v prostředí Matlab/Simulink



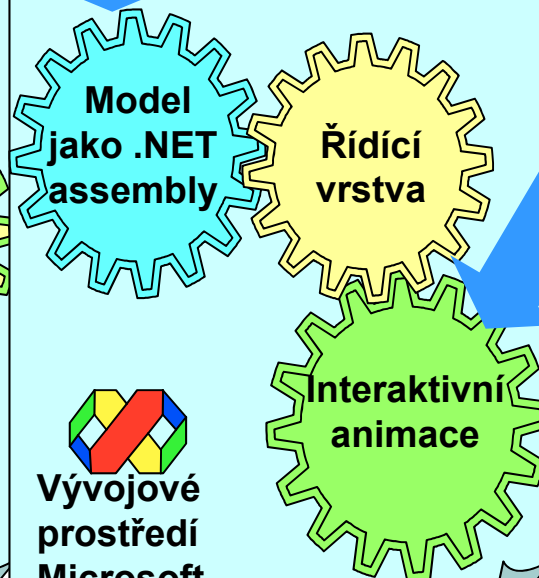
Tvorba animací (v Adobe Flash)



Tvorba scénářů výukových programů využívajících simulační hry a simulátory



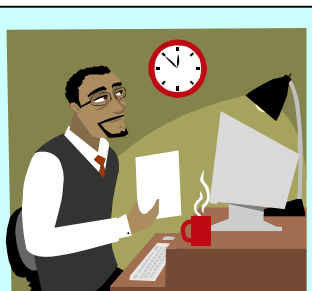
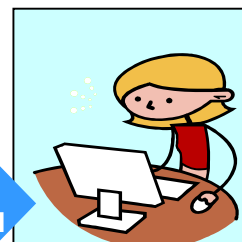
Vývojové prostředí Control Web



Vývojové prostředí Microsoft VisualStudio.NET



Distribuce simulátorů

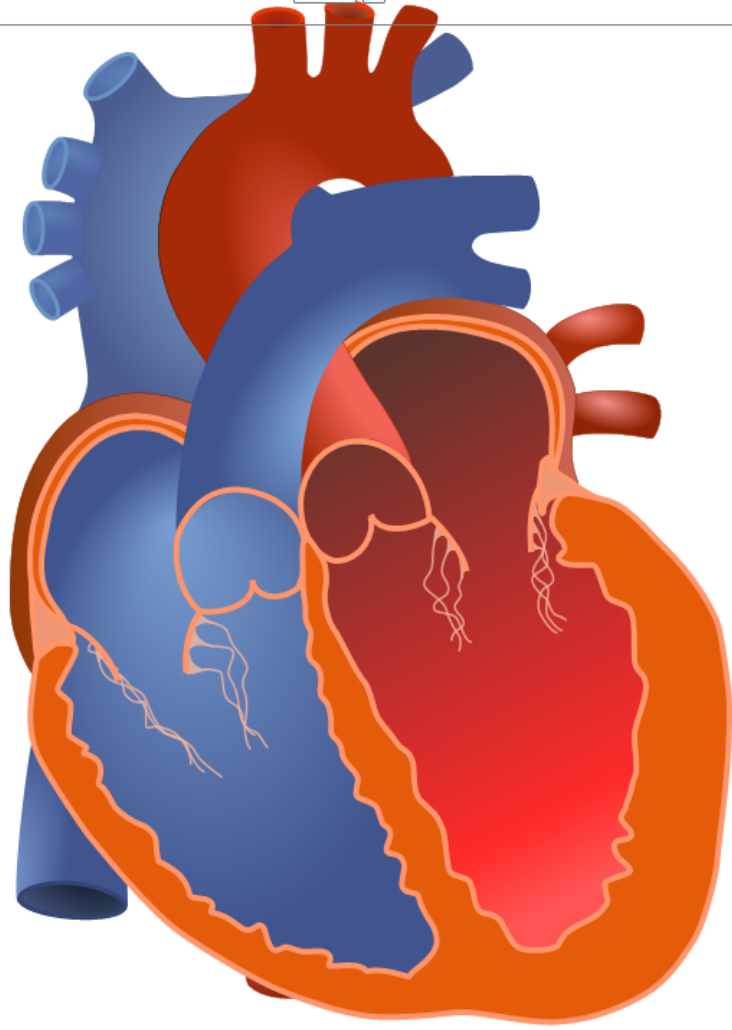


Vývoj simulátoru (programátorská práce)

Heart

All:

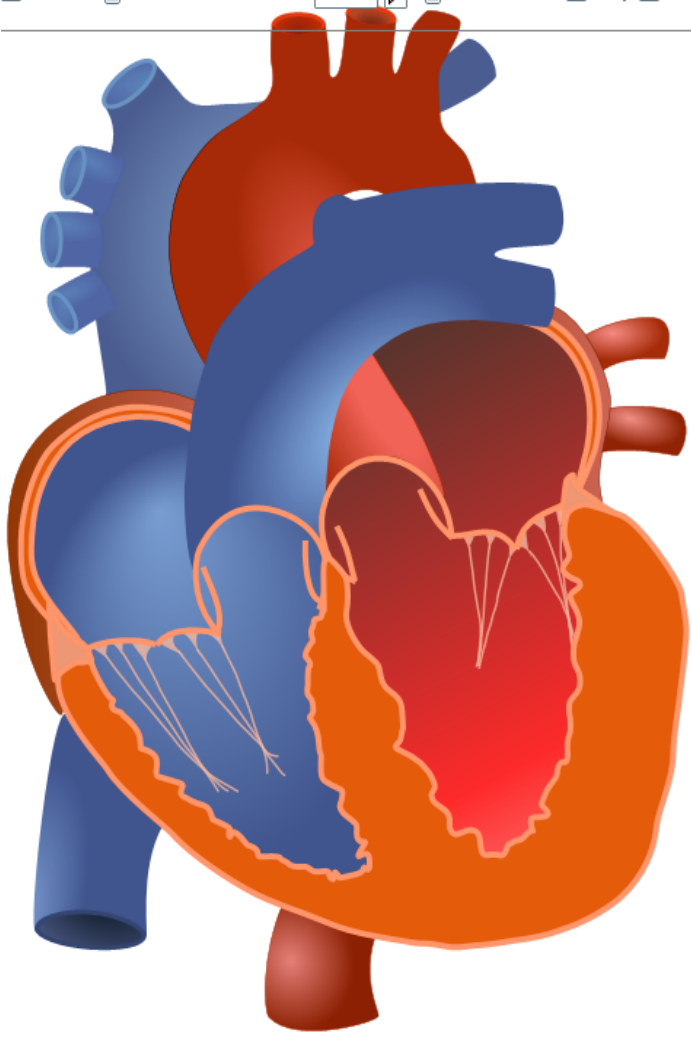
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	ventricle
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	leftAtrium
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	rightAtrium
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0.231"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	rightInValve
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	rightOutValve
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	leftInValve
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	leftOutValve



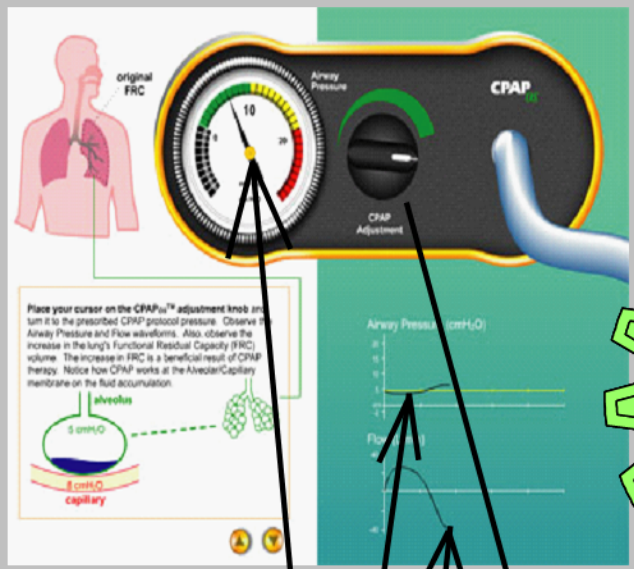
Heart

All:

<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="1"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	ventricle
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0.58"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	leftAtrium
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="0.72"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	rightAtrium
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="1"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	rightInValve
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="1"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	rightOutValve
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="1"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	leftInValve
<input checked="" type="checkbox"/> Active	<input type="range"/>	<input type="text" value="1"/>	<input type="button" value="▶"/>	<input type="button" value="◀"/>	<input checked="" type="checkbox"/> Loop	<input checked="" type="checkbox"/> AutoReverse	leftOutValve



**Vrstva
uživatelského
rozhraní**



Microsoft Expression Blend

Silverlight 2.0
.NET
komponenta

**Řídící
vrstva**

*Stavový
automat pro
určení kontextu*

výstupy

vstupy

Data Binding



Modelica .NET

Model
jako
.NET
komponenta


**Vrstva
modelu**

Simulační model



Modelica .NET


Automatické generování modelu jako .NET assembly



Tvorba simulačního modelu v prostředí Modelica

Prostředí .NET 3.5


Vývojové prostředí Microsoft VisualStudio




Model jako .NET assembly

Řídící vrstva


Interaktivní animace



Statechart editor



Animtester



Microsoft Silverlight



Tvorba animací v Expression Blend



Vývoj simulátoru (programátorská práce)



Microsoft Silverlight

Distribuce simulátorů v prohlížeči



Microsoft Silverlight



Tvorba scénářů výukových programů využívajících simulační hry a simulátory