

Physiolibrary 3.0

www.physiolibrary.org

Connectors



FluidPort

= Modelica.Fluid.Interfaces.FluidPort



ThermalPort

= Modelica.Thermal.HeatTransfer.Interfaces.HeatPort



Chemical.Interfaces.SubstancePort

= Chemical.Interfaces.SubstancePort



Medium.SubstancesPort

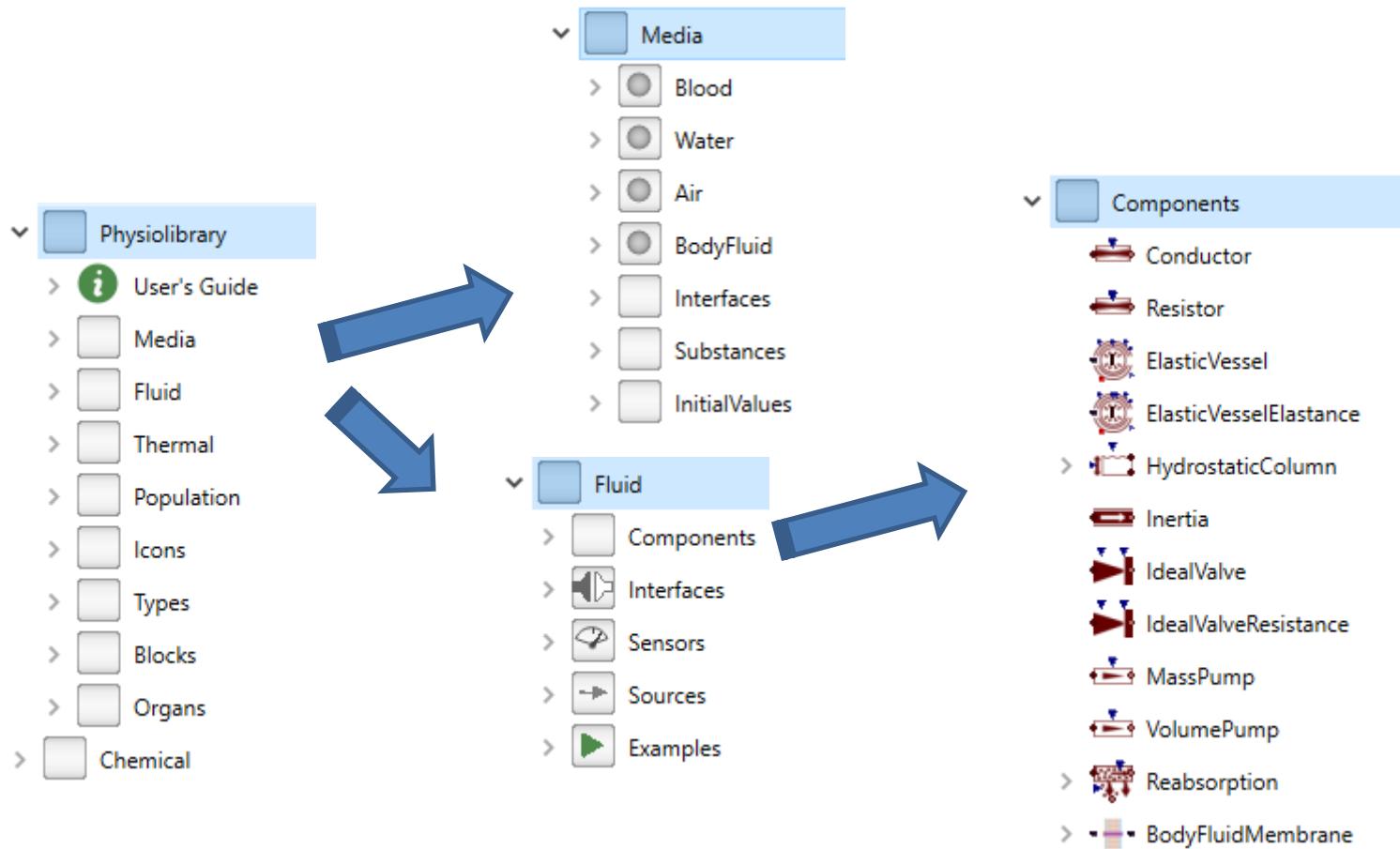
- bundle of electrochemical ports for free base medium substances



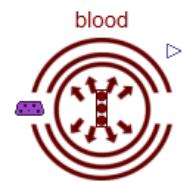
PopulationPort

- size of population, change of population

Physiolibrary Structure



Experiment – blood (de)oxygenation



General Advanced Add modifiers Attributes

Component

Name

Comment

Icon



ElasticVessel

Model

Path

Comment Elastic compartment as chemical solution envelop

Parameters

Medium	<input style="width: 100px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="Blood"/> ▾	Medium model
onElectricGround	<input type="checkbox"/>	=true, if electric potencial is zero
Compliance	<input style="width: 50px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="1"/> ▾	ml/mmHg Compliance e.g. TidalVolume/TidalPressureGradient if useComplianceInput=false
ZeroPressureVolume	<input style="width: 100px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="1e-05"/> ▾	ml Functional Residual Capacity. Maximal fluid volume, that does not generate pressure if useV0Input=false
ExternalPressure	<input style="width: 300px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="if isExternalPressureAbsolute then system.p_ambien"/> ▾	mmHg External pressure if useExternalPressureInput=false.

Initialization of medium composition

massFractions_start	<input style="width: 150px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="Blood.ArterialDefault"/> ▾	1	* Masses of all base molecules. If size is nS-1 then last value is 1-sum(others). If size is nS then all values are scaled to sum==1.
extraConcentration_start	<input style="width: 150px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="Medium.C_default"/> ▾		Extra substance amounts per kilogram of solution

Initialization

temperature_start	<input style="width: 150px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="system.T_ambient"/> ▾	°C	Initial temperature
use_mass_start	<input checked="" type="checkbox"/>		Use mass_start, otherwise volume_start
volume_start	<input style="width: 100px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="1000"/> ▾	ml	Total volume of solution start value
mass_start	<input style="width: 50px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 5px;" type="text" value="1"/> ▾	kg	Total mass of solution start value

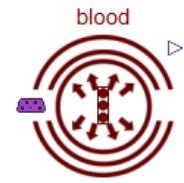
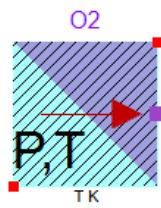
Conditional inputs

useSubstances	<input checked="" type="checkbox"/>	▶ =true, if substance ports are used
useThermalPort	<input type="checkbox"/>	▶ Is thermal port present?
useV0Input	<input type="checkbox"/>	▶ =true, if zero-pressure-fluid_volume input is used
useComplianceInput	<input type="checkbox"/>	▶ =true, if compliance input is used
useExternalPressureInput	<input type="checkbox"/>	▶ =true, if external pressure input is used
isExternalPressureAbsolute	<input type="checkbox"/>	▶ external pressure as absolute pressure? Relative to ambient otherwise.
useInternalSpaceInput	<input type="checkbox"/>	▶ =true, if internal space input is used

OK

Cancel

Info



O2 in Physiolibrary.Fluid.Examples.BloodGasesEquilibrium2

General Add modifiers Attributes

Component

Name O2

Comment

Model

Path Chemical.Sources.ExternalidealGasSubstance

Comment Ideal gas substance with defined partial pressure

Icon

Externalideal...

P T K

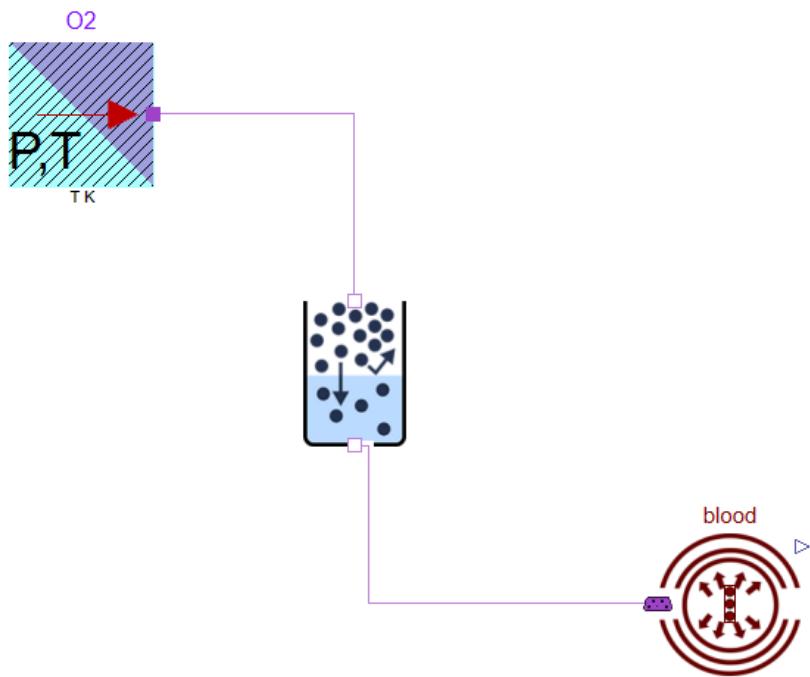
Parameters

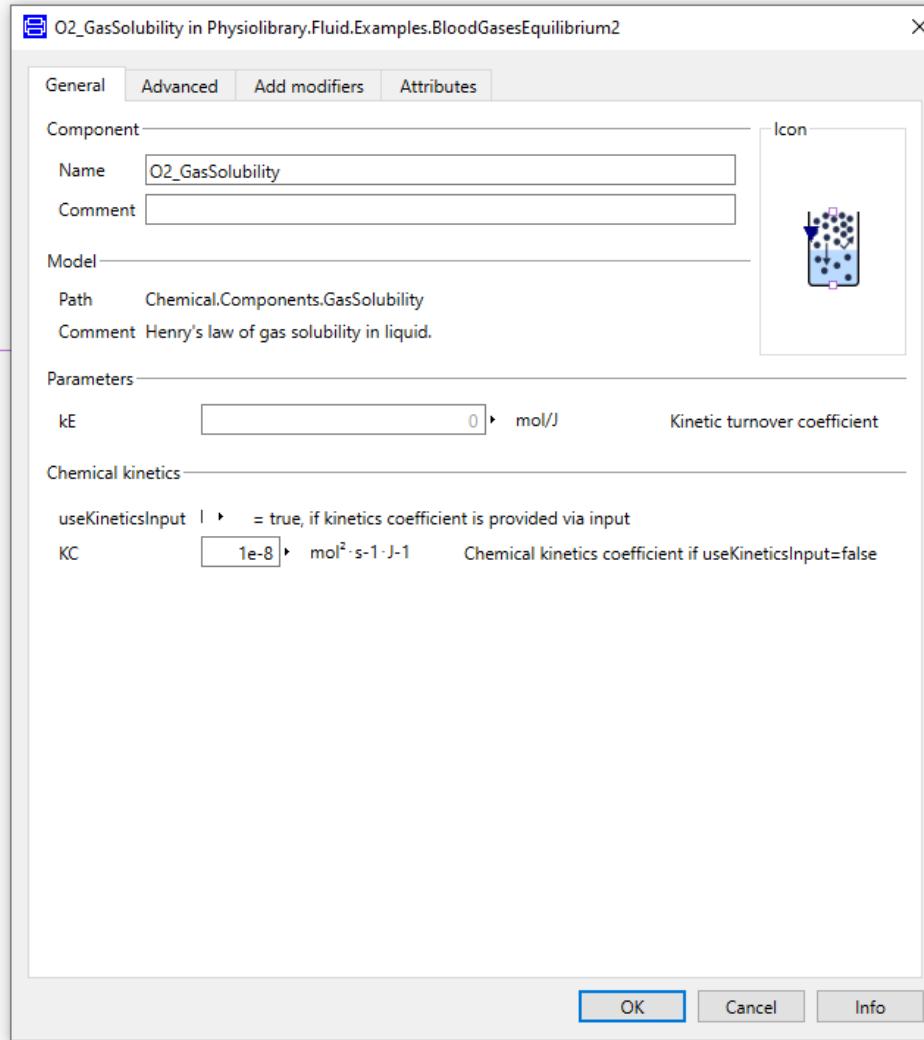
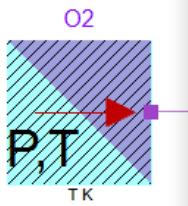
substanceData	Chemical.Substances.Oxygen_gas()	Definition of the substance
PartialPressure	1 mmHg	Fixed partial pressure if usePartialPressureInput=false
TotalPressure	system.p_ambient bar	Total pressure of the whole gaseous solution
Temperature	system.T_ambient °C	Temperature
MoleFractionBasedIonicStrength	0 %	Ionic strength
ElectricPotential	0 V	Electric potential
Volume	0.001 m³	Volume of gaseous solution

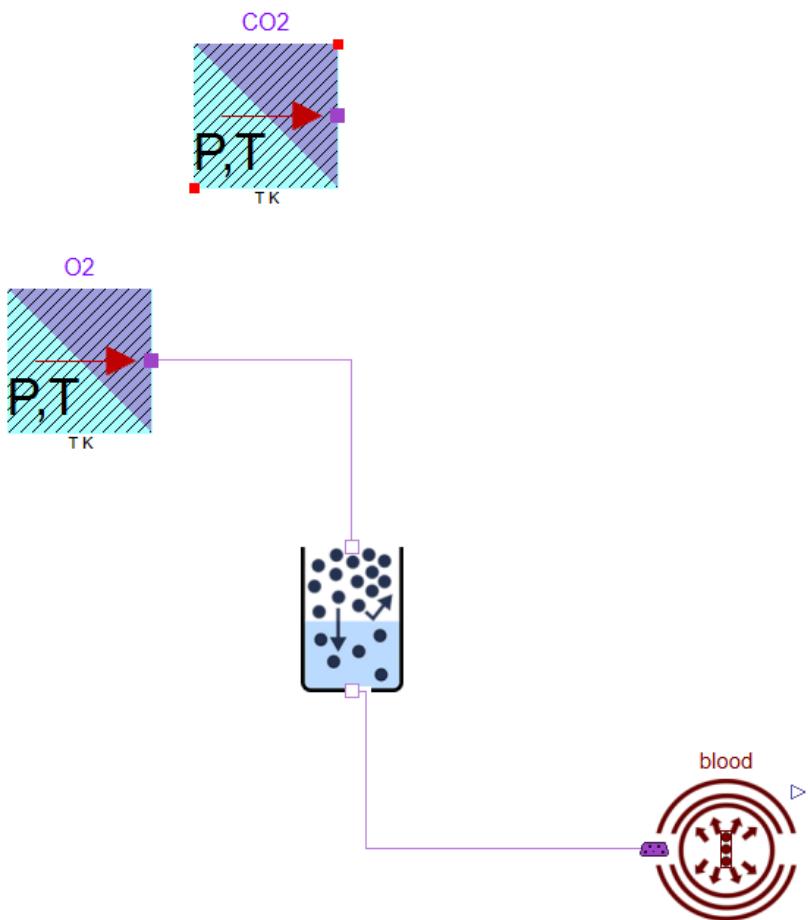
Conditional inputs

usePartialPressureInput =true, if fixed partial pressure is from input instead of parameter

OK Cancel Info







CO₂ in Physilibrary.Fluid.Examples.BloodGasesEquilibrium2

General Add modifiers Attributes

Component

Name CO₂

Comment

Model

Path Chemical.Sources.ExternalidealGasSubstance

Comment Ideal gas substance with defined partial pressure

Icon

ExternalidealGasSubstance

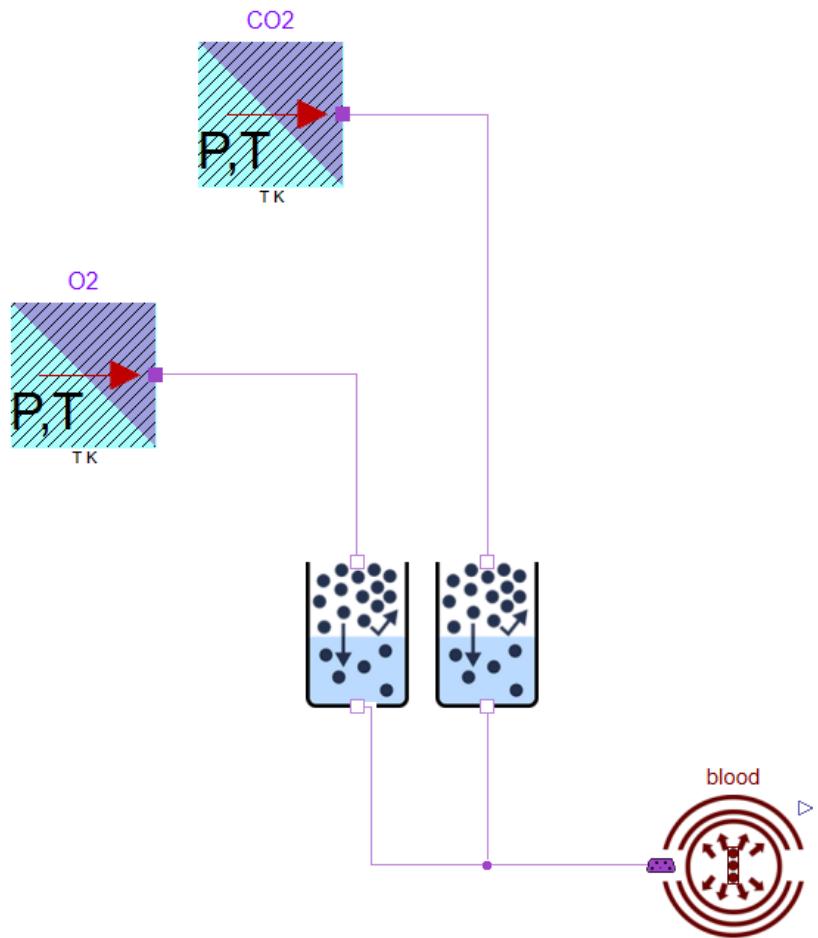
Parameters

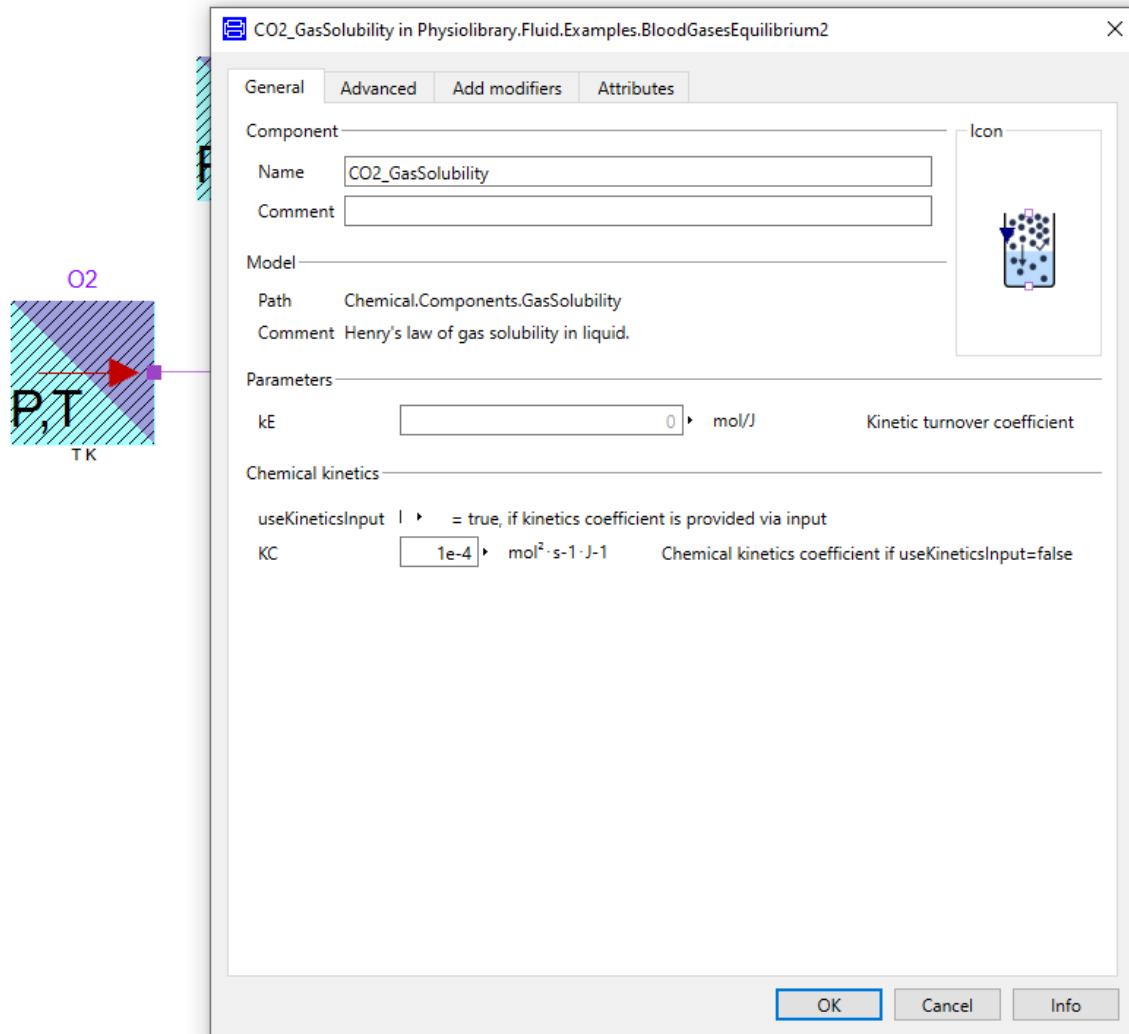
substanceData	Chemical.Substances.CarbonDioxide_gas()	Definition of the substance
PartialPressure	40	mmHg Fixed partial pressure if usePartialPressureInput=false
TotalPressure	system.p_ambient	bar Total pressure of the whole gaseous solution
Temperature	system.T_ambient	°C Temperature
MoleFractionBasedIonicStrength	0	% Ionic strength
ElectricPotential	0	V Electric potential
Volume	0.001	m ³ Volume of gaseous solution

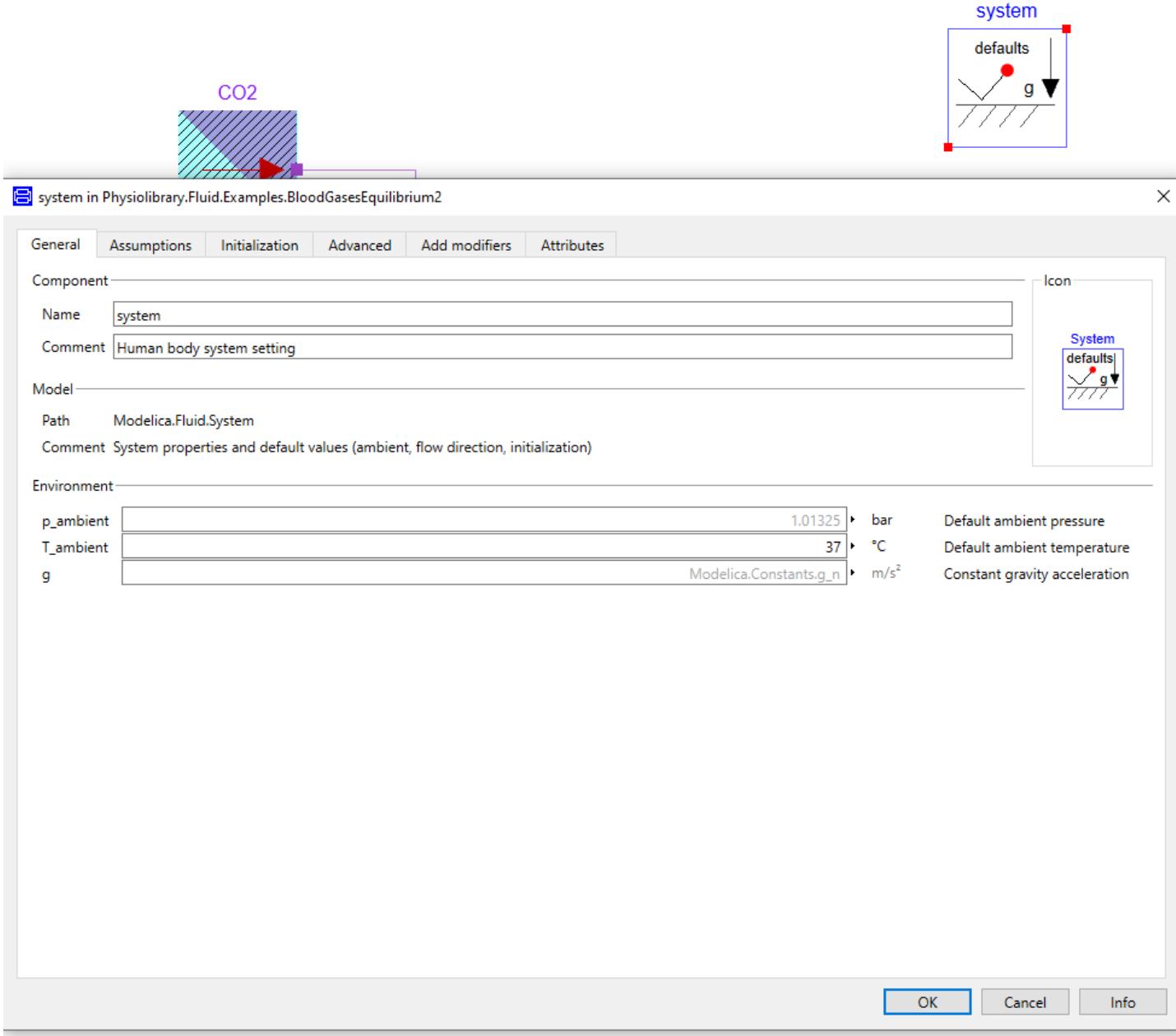
Conditional inputs

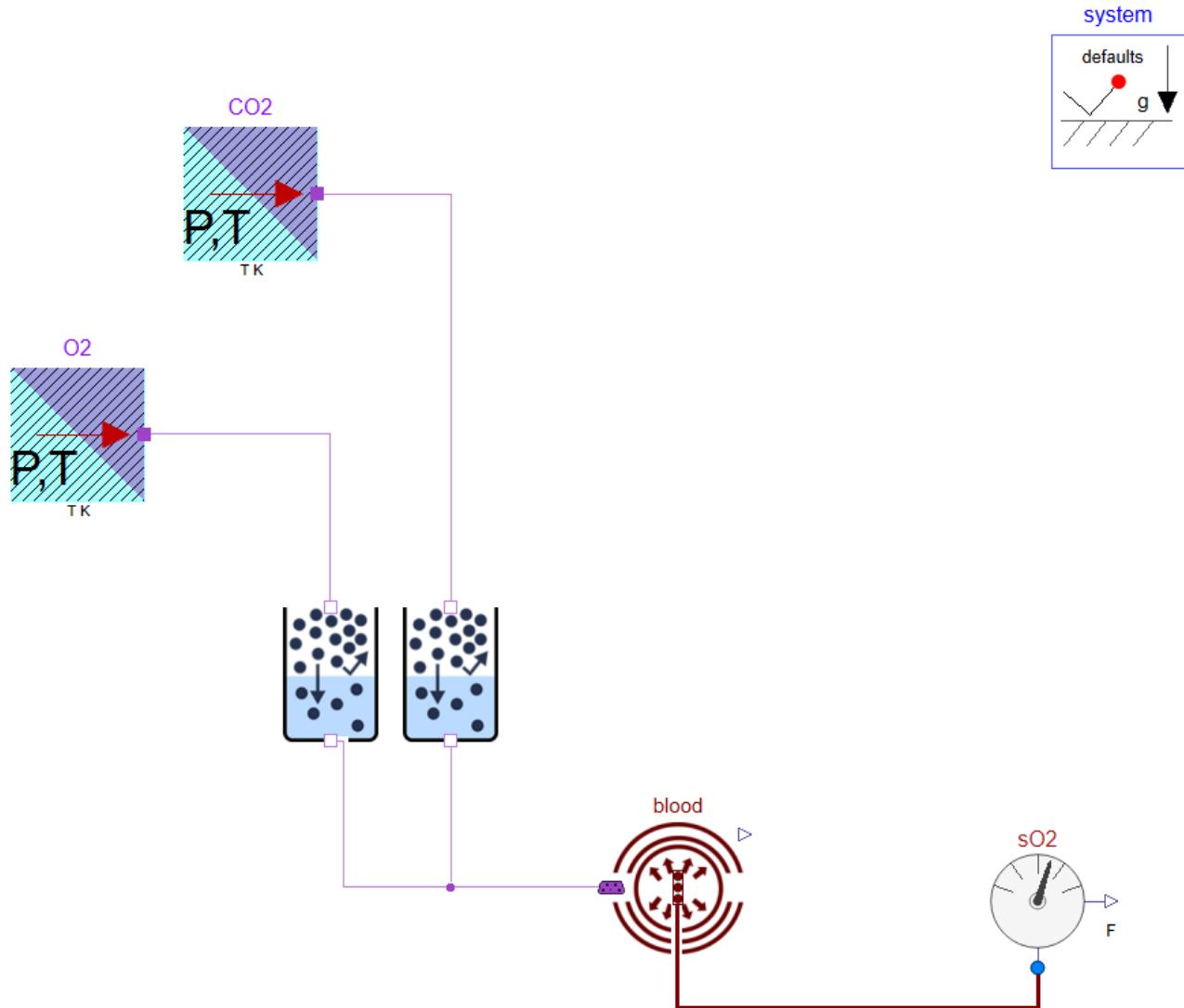
usePartialPressureInput =true, if fixed partial pressure is from input instead of parameter

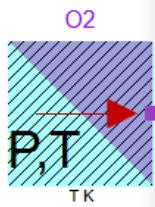
OK Cancel Info











CO₂

sO2 in Physilibrary.Fluid.Examples.BloodGasesEquilibrium2

General Add modifiers Attributes

Component

Name sO2

Comment

Model

Path Physilibrary.Fluid.Sensors.Fraction

Comment Ideal one port fraction sensor

Icon

Fraction

Parameters

Medium Physilibrary.Media.Blood ▾ ▶ Medium in the sensor

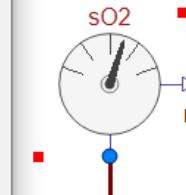
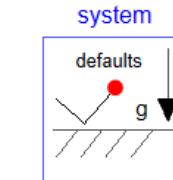
GetFraction Oxygen saturation ▾ ▶ Get fraction from medium state

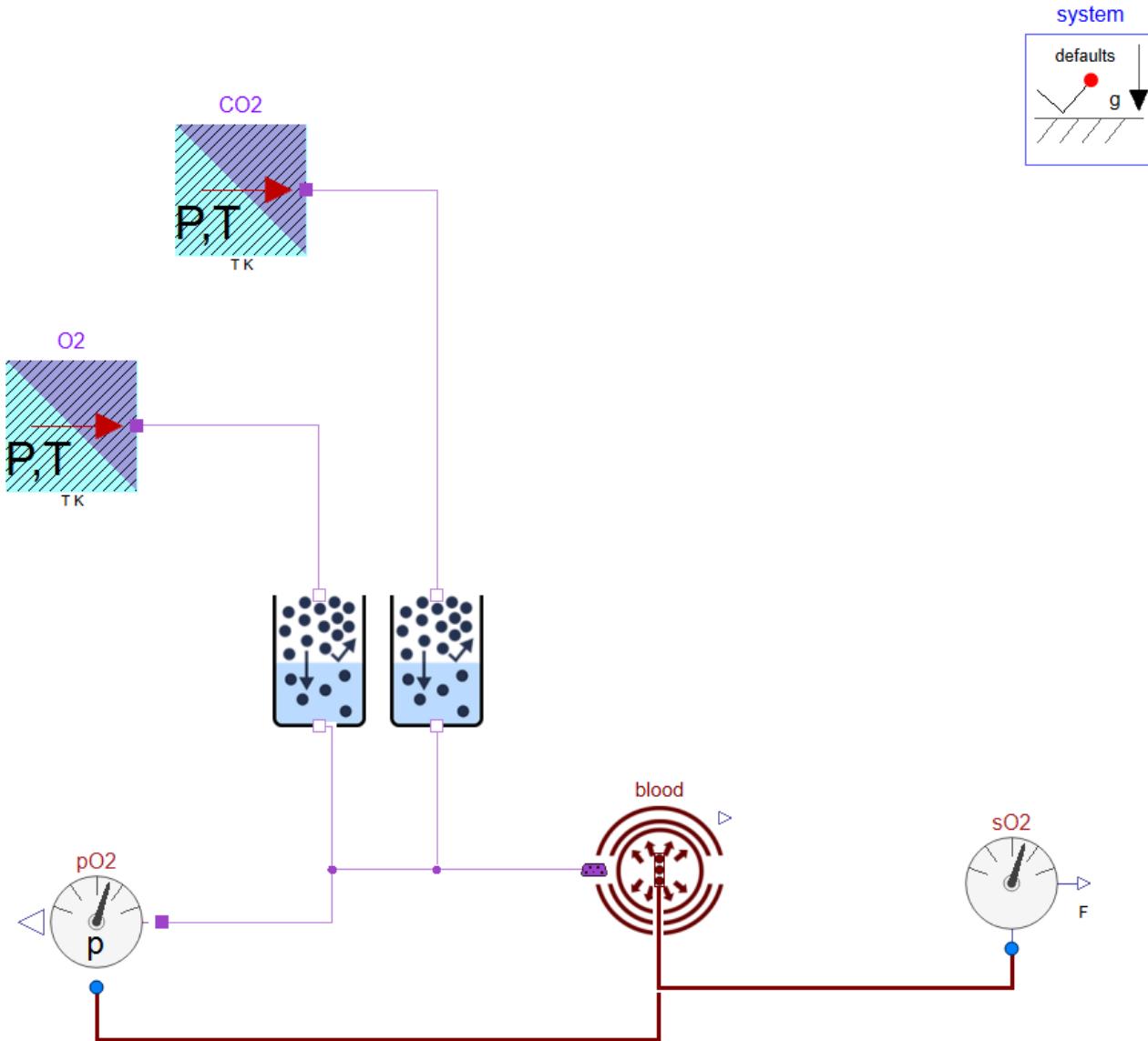
Oxygen saturation

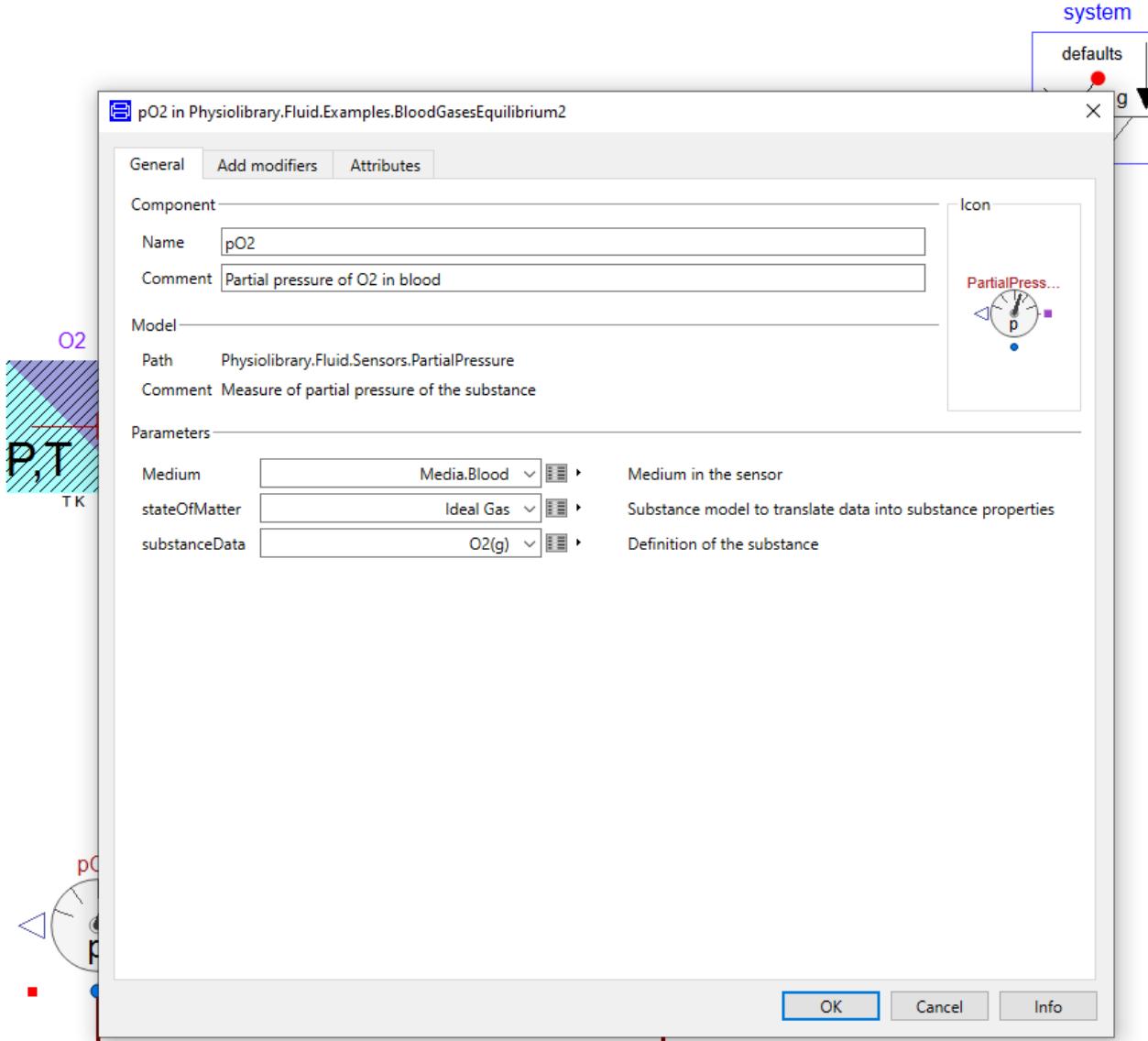
<Remove modifier>

- Oxygen saturation
- Methemoglobin fraction
- Foetalhemoglobin fraction
- Alpha blockers effect in blood plasma
- Beta blockers effect in blood plasma
- Anesthesia vascular cond...e effect in blood plasma
- Blood plasmacrit [mL/mL]
- Blood plasmacrit [kg/kg]
- Blood hematocrit [mL/mL]

OK Cancel Info

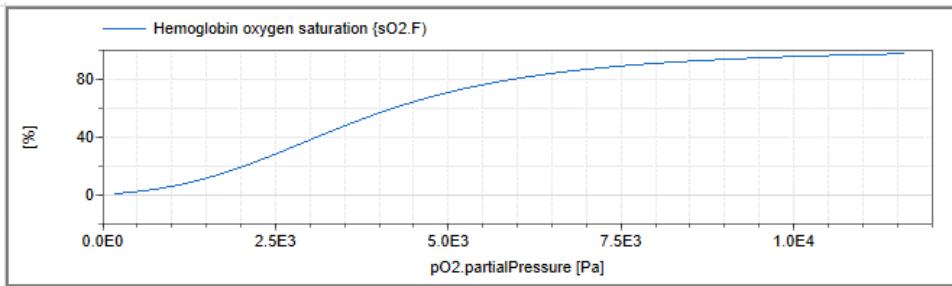




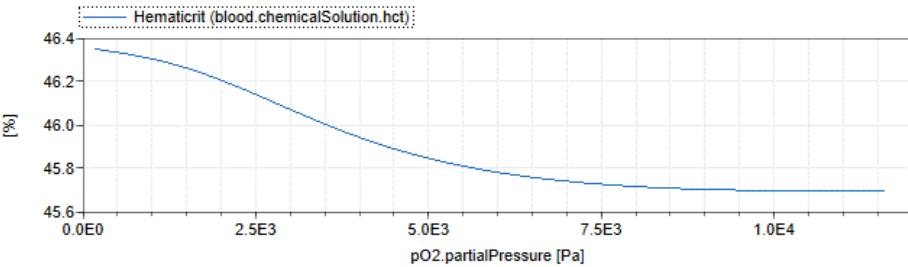
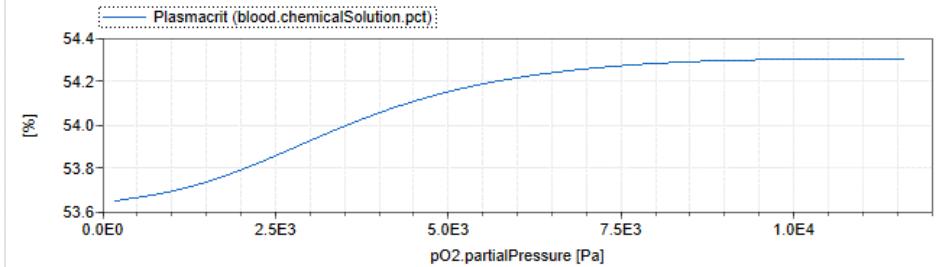
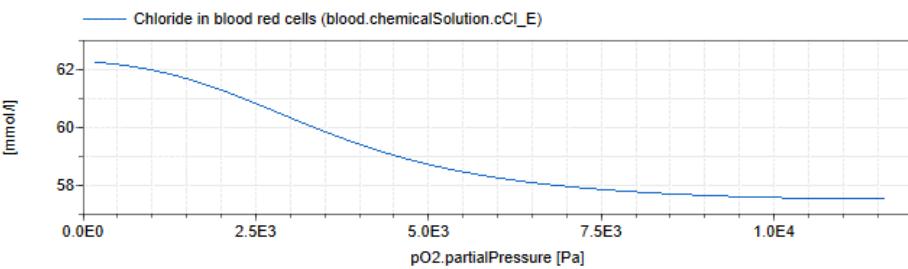
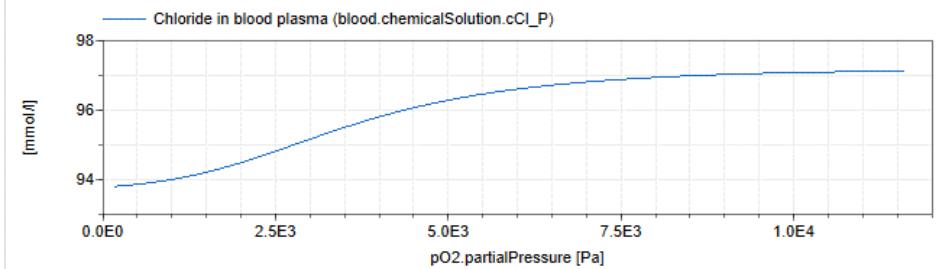
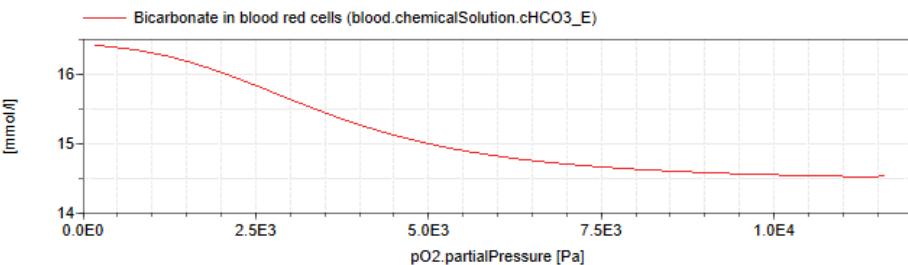
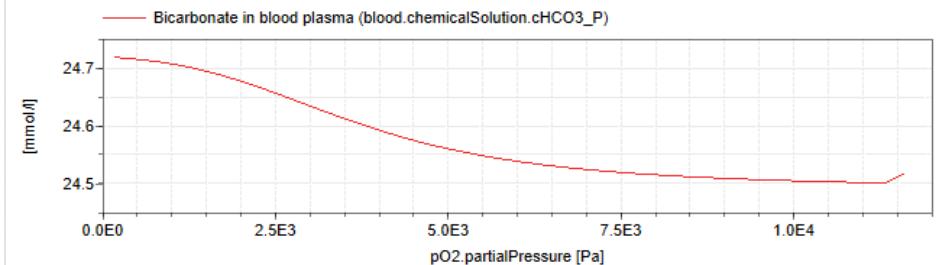
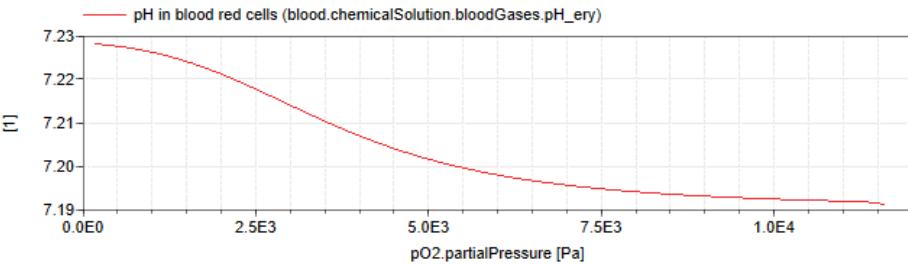
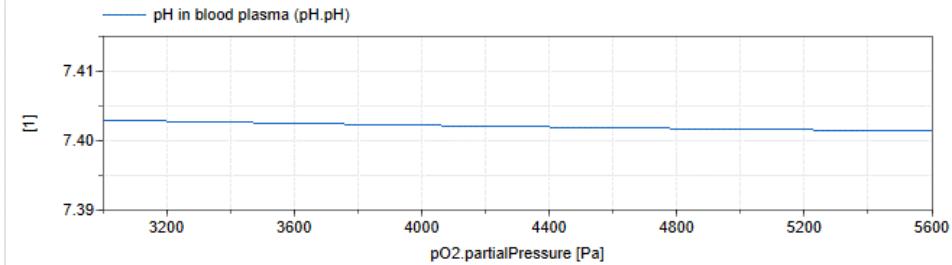


Behind

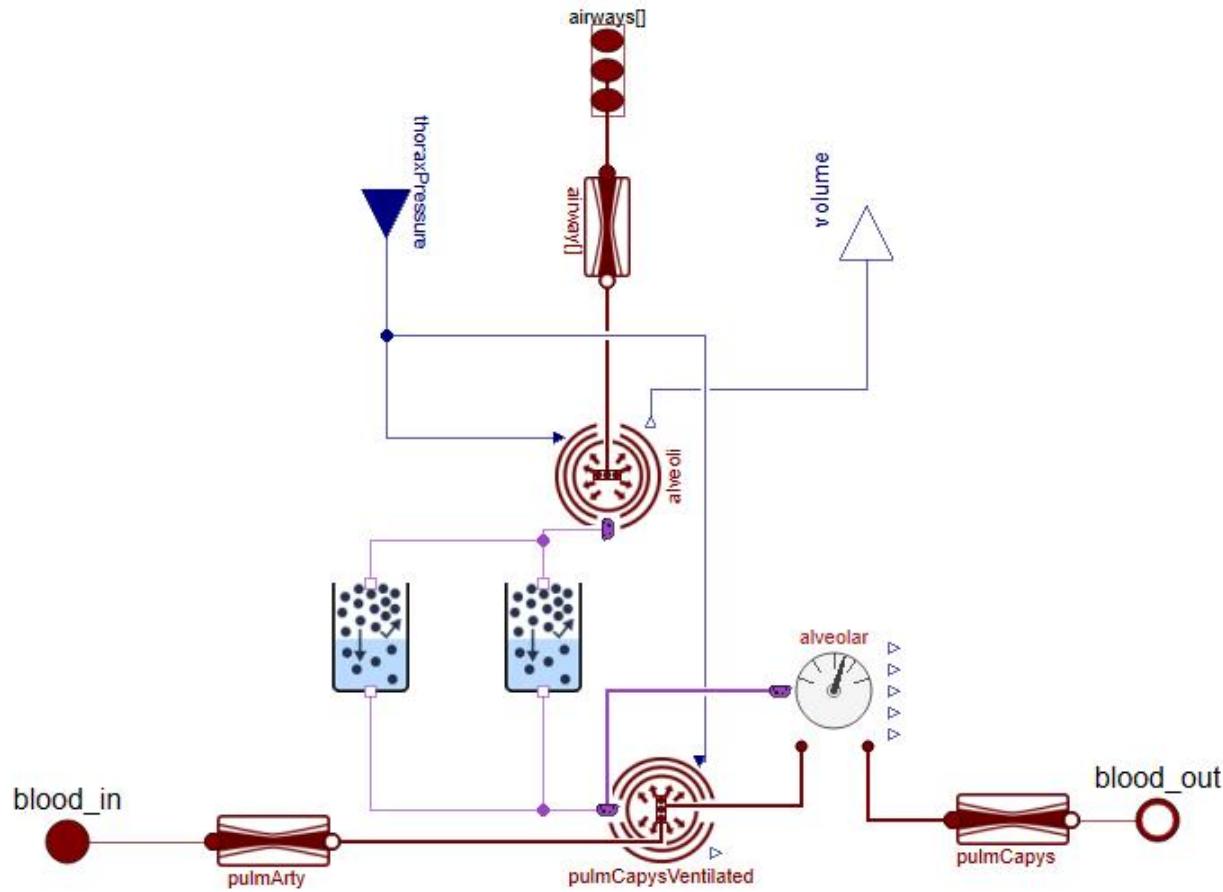
- Hemoglobin – O₂, CO₂, H+, CO binding
- Henderson-Hasselbalch: CO₂ + H₂O \leftrightarrow HCO₃⁻ + H⁺
- Chloride shift: Cl⁻, HCO₃⁻
- Electroneutrality
- Acid-base
- Osmosis



Mateják, Marek, Tomáš Kulhánek, and Stanislav Matoušek. 2015. "Adair-Based Hemoglobin Equilibrium with Oxygen, Carbon Dioxide and Hydrogen Ion Activity." *Scandinavian Journal of Clinical & Laboratory Investigation* 75 (2): 113–20.
<https://doi.org/10.3109/00365513.2014.984320>.



Respiratory unit



General Add modifiers Attributes

Component

Name

Icon



Comment

Model

Path Physilibrary.Organs.Lungs.Components.RespiratoryUnit

Comment Lungs respiratory unit

Ventilation

Air

	Media.Air	▼	Air medium model
AirVolume_initial	3020	▶ ml	Initial volume of alveolar space
Air_initial	Air.X(100, 40, 47, 760 - 187)	▶ 1	Initial composition of air inside alveoli
FunctionalResidualCapacity	2310	▶ ml	Functional residual capacity
TotalCompliance	135.951	▶ ml/mmHg	Pulmonary compliance
ResidualVolume	1300	▶ ml	Residual volume
TotalCapacity	6230	▶ ml	Total Capacity
BaseTidalVolume	500	▶ ml	Base Tidal Volume
TotalResistance	0.018388978381917	▶ (mmHg · min)/l	Total airways resistance

Perfusion

Blood

	Media.Blood	▼	Blood medium model
CapillariesVolume_initial	200.141	▶ ml	Initial volume of blood in capillaries
Blood_initial	Blood.ArterialDefault	▶ 1	Initial composition of blood
CapillariesZeroPressureVolume	140	▶ ml	Maximal volume of blood capillaries zero at zero blood pressure inside
CapillariesCompliance	4.6	▶ ml/mmHg	Blood capillaries compliance
CapillariesConductance	1.8	▶ l/(mmHg · min)	Blood capillaries conductance
ArteriesConductance	1.35	▶ l/(mmHg · min)	Blood arteries conductance

Diffusion

Diffusion

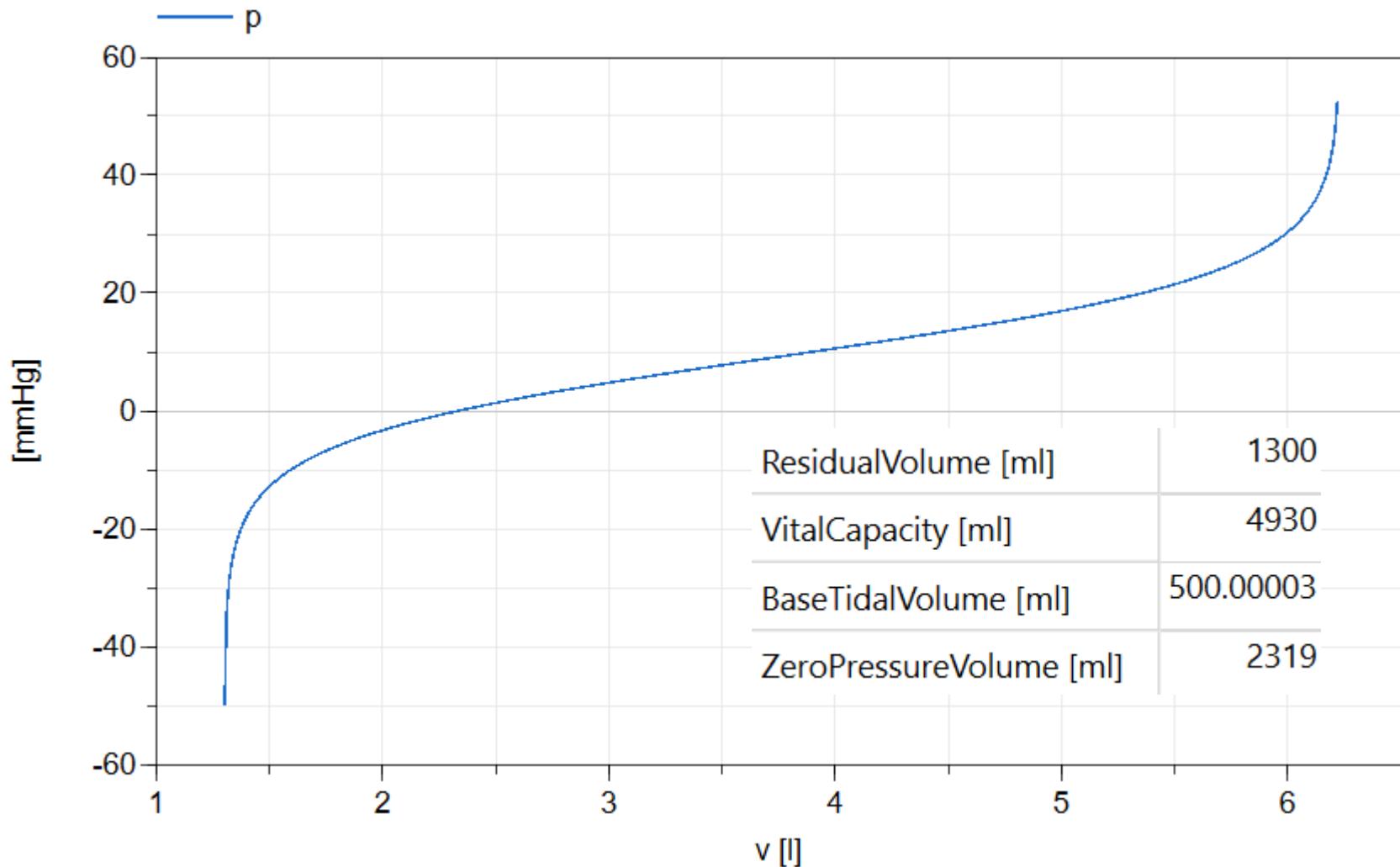
	1e-4	▶ mol ² · s ⁻¹ · J ⁻¹	Gasses diffusion
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OK

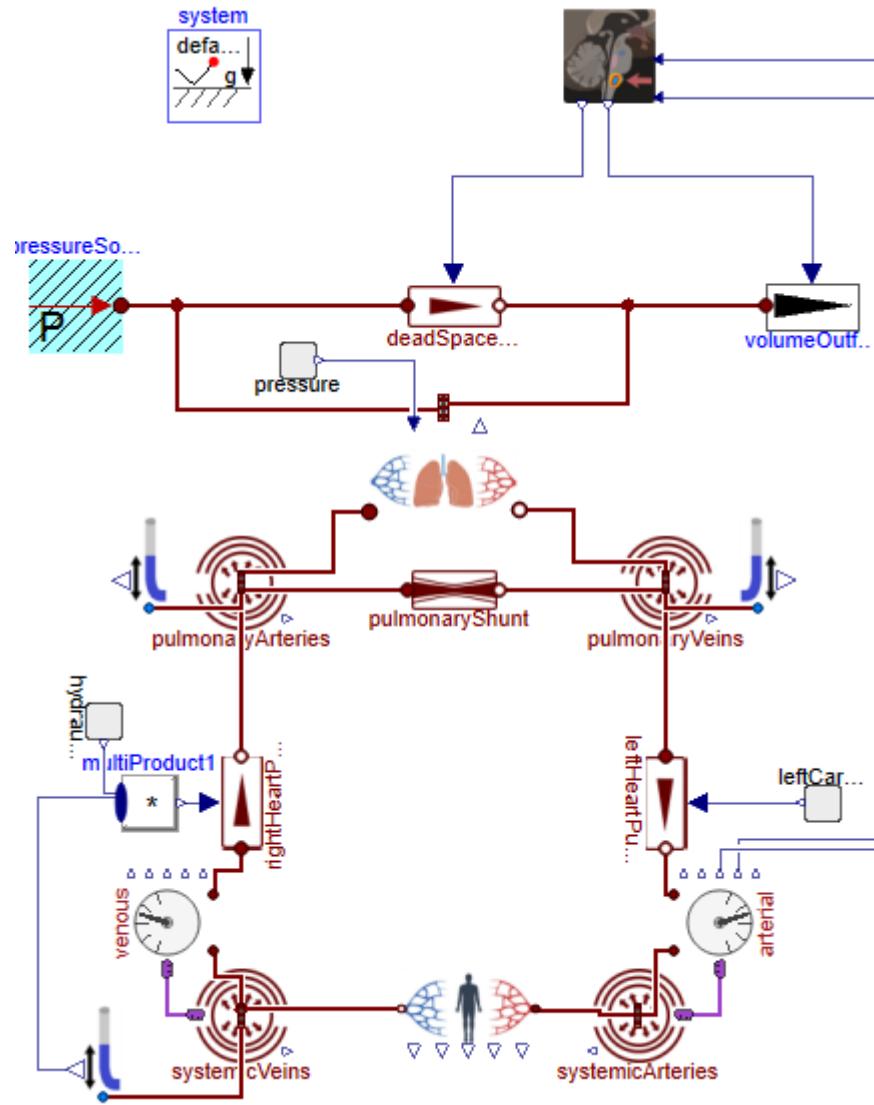
Cancel

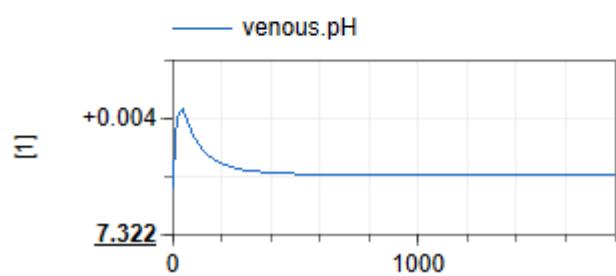
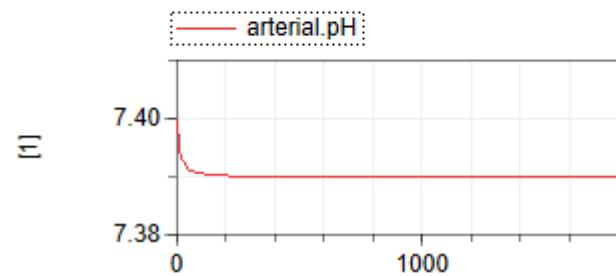
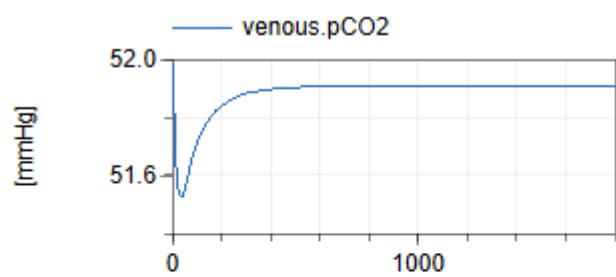
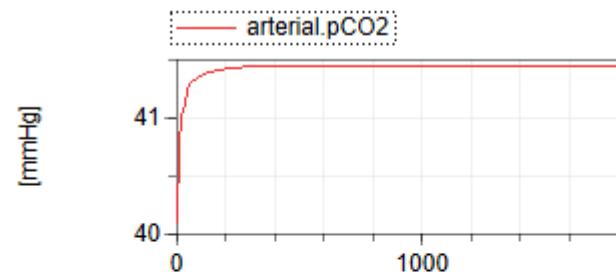
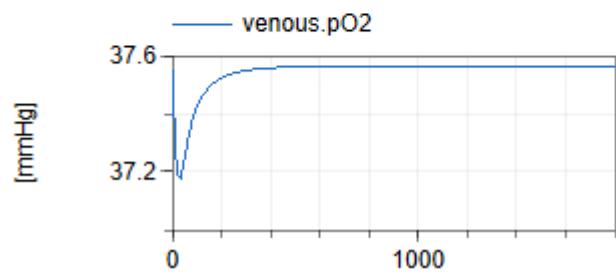
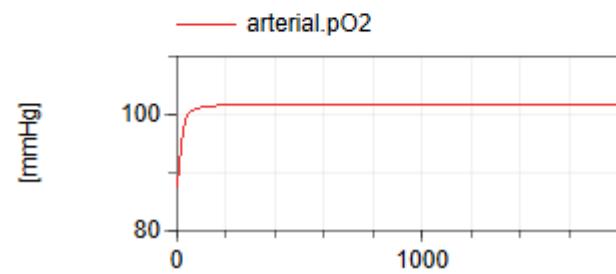
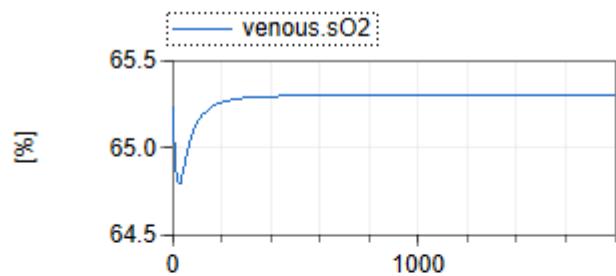
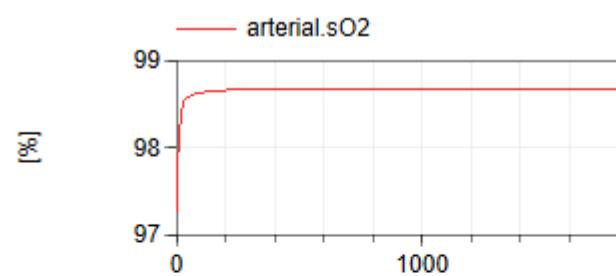
Info

Lungs pressure-volume relation



Mean respiration and circulation





Blood medium

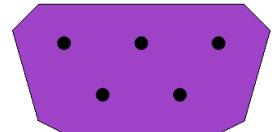
```
extends Media.Interfaces.PartialMedium(
    mediumName = "Blood",
    substanceNames={"H2O_P", "H2O_E", "O2", "CO2_P", "CO2_E", "CO", "eHb", "MetHb", "HbF", "Alb", "Glb", "PO4", "DPG",
    "Glucose", "Lactate", "Urea", "AminoAcids", "Lipids", "KetoAcids",
    "Na_P", "K_P", "Na_E", "K_E", "Cl_P", "Cl_E",
    "Epinephrine", "Norepinephrine", "Vasopressin",
    "Insulin", "Glucagon", "Thyrotropin", "Thyroxine", "Leptin",
    "Desglymidodrine",
    "Angiotensin2", "Renin", "Aldosterone",
    "Other_P", "Other_E"),
extraPropertiesNames={
    "AlphaBlockers",
    "BetaBlockers",
    "AnesthesiaVascularConductance"},

    redeclare replaceable record extends ThermodynamicState
        "A selection of variables that uniquely defines the thermodynamic state"
        extends Modelica.Icons.Record;
        AbsolutePressure p "Absolute pressure of medium";
        SpecificEnthalpy h "Specific enthalpy";
        MassFraction X[nS] "Mass fractions of substances";
        Types.ElectricPotential v "Electric potential";
    end ThermodynamicState;

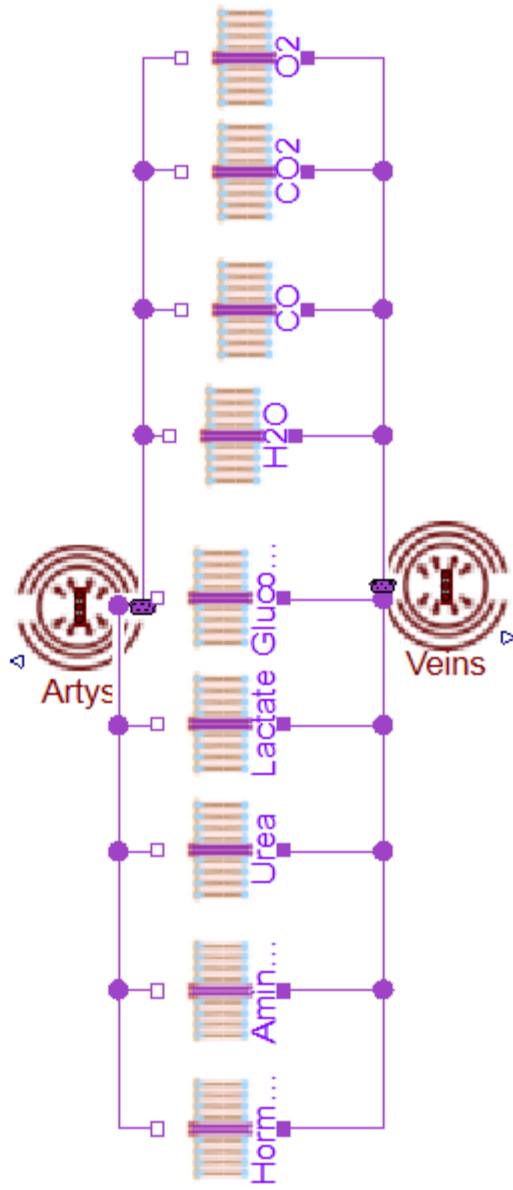
redeclare connector extends SubstancesPort "Blood chemical substances interface"
    Chemical.Interfaces.SubstancePort_a CO2 "Free carbon dioxide molecule";
    Chemical.Interfaces.SubstancePort_a O2 "Free oxygen molecule";
    Chemical.Interfaces.SubstancePort_a CO "Free carbon monoxide moelcule";
    Chemical.Interfaces.SubstancePort_a HCO3 "Free bicarbonate molecule";
    Chemical.Interfaces.SubstancePort_a H "Free protons";
    Chemical.Interfaces.SubstancePort_a H2O "Free water molecule (in pure water is only cca 1 mol/kg free

    Chemical.Interfaces.SubstancePort_a Glucose, Lactate, Urea, AminoAcids, Lipids, KetoAcids;

    Chemical.Interfaces.SubstancePort_a Epinephrine, Norepinephrine, Vasopressin;
    Chemical.Interfaces.SubstancePort_a Insulin, Glucagon, Thyrotropin, Thyroxine, Leptin;
    Chemical.Interfaces.SubstancePort_a Desglymidodrine;
    Chemical.Interfaces.SubstancePort_a Angiotensin2, Renin, Aldosterone;
end SubstancesPort;
```



SubstancesPort



```
equation
    connect(O2.port_a, Artys.substances.O2) □ ;
    connect(O2.port_b, Veins.substances.O2) □ ;
    connect(CO2.port_a, Artys.substances.CO2) □ ;
    connect(CO2.port_b, Veins.substances.CO2) □ ;
    connect(CO.port_a, Artys.substances.CO) □ ;
    connect(CO.port_b, Veins.substances.CO) □ ;
    connect(H2O.port_a, Artys.substances.H2O) □ ;
    connect(H2O.port_b, Veins.substances.H2O) □ ;

    connect(Glucose.port_a, Artys.substances.Glucose) □ ;
    connect(Glucose.port_b, Veins.substances.Glucose) □ ;
    connect(Lactate.port_a, Artys.substances.Lactate) □ ;
    connect(Lactate.port_b, Veins.substances.Lactate) □ ;
    connect(Urea.port_a, Artys.substances.Urea) □ ;
    connect(Urea.port_b, Veins.substances.Urea) □ ;
    connect(AminoAcids.port_a, Artys.substances.AminoAcids) □ ;
    connect(AminoAcids.port_b, Veins.substances.AminoAcids) □ ;

    connect(Hormones[1].port_a, Artys.substances.Epinephrine) □ ;
    connect(Hormones[1].port_b, Veins.substances.Epinephrine) □ ;
    connect(Hormones[2].port_a, Artys.substances.Norepinephrine) □ ;
    connect(Hormones[2].port_b, Veins.substances.Norepinephrine) □ ;
```

ArterialDefault

VenousDefault

CDefault



ArterialComposition

VenousComposition

```
package InitialValues
import Physiobase.Media.Substances.*;

constant Types.Density D_BloodDensity=1057 "Density of blood";
constant Types.Density D_BloodPlasmaDensity=1025 "Density of blood plasma";

constant Types.VolumeFraction D_Hct = 0.44 "Default hematocrit [ml/ml]";

constant Types.Concentration
    D_Na = 138.5 "Default sodium in blood plasma",
    D_K = 4 "Default potassium in blood plasma",
    D_Cl = 103 "Default chloride in blood plasma",
    D_Na_RBC = 7 "Default sodium in blood red cells",
    D_K_RBC = 96 "Default potassium in blood red cells",
    D_Cl_RBC = 50 "Default chloride in blood red cells";

constant Real D_SID_P = D_Na+D_K-D_Cl;
constant Real D_SID_RBC = D_Na_RBC+D_K_RBC-D_Cl_RBC;

constant Types.Concentration
    D_Glucose = 6.08 "Default glucose in blood plasma",
    D_Lactate = 1.04 "Default lactate in blood plasma",
    D_Urea = 6.64 "Default urea in blood plasma",
    D_AminoAcids = 4.97 "Default amino acids in blood plasma",
    D_Lipids = 1.23 "Default lipids in blood plasma",
    D_Ketoacids = 4.88e-2 "Default keto acids in blood plasma";

constant Types.Concentration D_Arterial_O2 = 8.16865 "Default Total oxygen in arterial blood",
```

Blood - output

```
function glucose "Total glucose in blood plasma"
  extends GetConcentration;
algorithm
  C :=(plasmaDensity(state)*state.X[i("Glucose")]/Constants.MM_Glucose) /
    plasmaMassFraction(state);
end glucose;
```

```
function sO2 "Oxygen saturation on effective hemoglobin"
  extends GetFraction;
algorithm
  F := (state.X[i("O2")] / O2.MolarWeight) / (state.X[i("eHb")] / Constants.MM_Hb);
end sO2;
```

```
replaceable function GetConcentration =
  Physilibrary.Media.Blood.tO2
constrainedby
  Medium.GetConcentration
"Get concentration from medium state"
annotation (choicesAllMatching=true);
```

```
replaceable function GetFraction =
  Physilibrary.Media.Blood.hematocrit
constrainedby Medium.GetFraction
"Get fraction from medium state"
  ;
```

Total glucose in blood plasma

Total albumine in blood plasma

Total anorganic phosphates in blood plasma

Total diphosphoglycerate in erythrocytes

Strong ion difference of blood

Total glucose in blood plasma

Total lactate in blood plasma

Total urea in blood plasma

Total amino acids in blood plasma

Total fatty acids in blood plasma

Total ketoacids in blood plasma

Oxygen saturation on effective hemoglobin

<Remove modifier>

Oxygen saturation on effective hemoglobin

Methemoglobin fraction

Foetalhemoglobin fraction

Blood plasmacrit [mL/mL]

Blood hematocrit [mL/mL]

Blood hematocrit [kg/kg]

Blood plasmacrit [kg/kg]

Thank you for your attention!

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