# Respiratory system modeling, application to Covid-19

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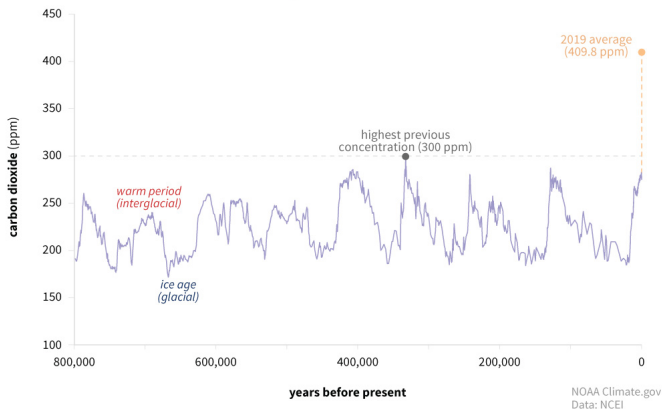
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# The Context

- The demand for energy is growing.
- Expansion in carbon dioxide emissions.
- Global warming, melting of the polar ice cups, rising of sea levels, disturbance of animals' natural habitat...

## CARBON DIOXIDE OVER 800,000 YEARS



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[1] https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

# Project Context



- ▶ 4fastsim-ibat project
- ▶ Reduce and control energy consumption in existing buildings
- ▶ Collaboration between Cemosis and Synapse-Concept

- ► Add a human being to the ibat model.
- ► Use of a human simulator: Pulse Physiology engine.
- ► Study the effect of the environment on a human, but also the effect of a human on the environment.
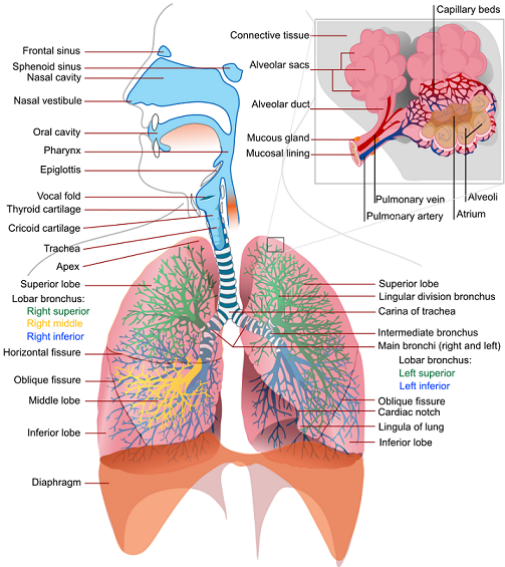
# Plan

- Respiratory model.
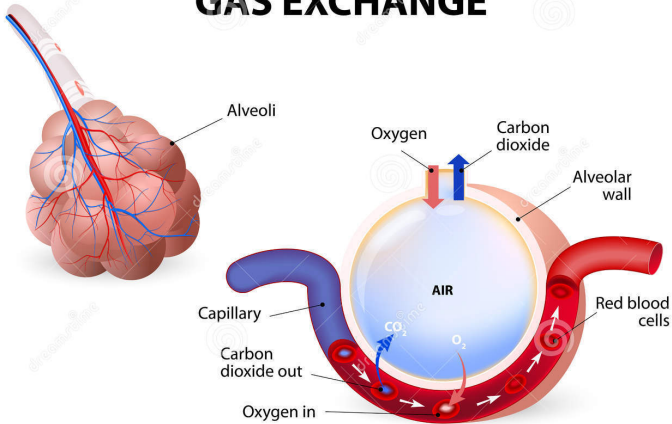- Simulations.
- Association with Covid-19.

# Respiratory Physiology

- 12/20 breaths/min.
- Inhale oxygen, exhale carbon dioxide.
- Upper-lower airways, lungs, respiratory muscles.
- Lower airway: trachea, bronchi, bronchioles and alveoli.

# Respiratory system diagram

**ALVEOLUS GAS EXCHANGE**

# Respiratory circuit

- Lumped parameter model of mechanical ventilation.
- Elastic behavior of the lungs.
- Flow resistance of the airways.
- Resistors, capacitors.

# Pulse Respiratory circuit

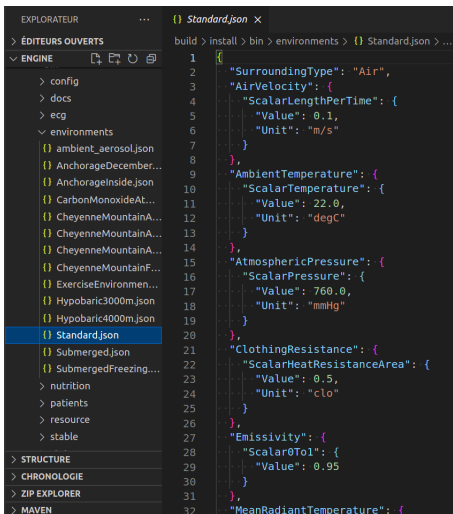---

# Patient

# Environment

# Output parameters

- heart rate
- arterial pressure
- respiration rate
- lung volume
- inspiratory flow
- expiratory flow

# Output

| | |
|---|---|
| 1 | Time(s),HeartRate(1/min),ArterialPressure(mmHg),SystolicArterialPressure(mmHg),DiastolicArterialPressure(mmHg),MeanArterialP |
| 2 | 0.02,75.00,108.6,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77014.328369,11365.409508,2480.462899,1120.687,2.40,824.9781,-824.97 |
| 3 | 0.04,75.00,110.7,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77015.698089,11365.425413,2480.093561,1120.687,2.42,839.3466,-839.34 |
| 4 | 0.06,75.00,112.1,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77016.812141,11365.382590,2479.809397,1120.687,2.43,852.1437,-852.14 |
| 5 | 0.08,75.00,113.1,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77017.662084,11365.398384,2479.609878,1120.687,2.45,863.5638,-863.56 |
| 6 | 0.10,75.00,113.6,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77018.260131,11365.356085,2479.491196,1120.687,2.47,873.7628,-873.76 |
| 7 | 0.12,75.00,113.7,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77018.615480,11365.370103,2479.448180,1120.687,2.49,882.8651,-882.86 |
| 8 | 0.14,75.00,113.5,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77018.741718,11365.328762,2479.477664,1120.687,2.50,890.9698,-890.96 |
| 9 | 0.16,75.00,112.8,114,73.8,95.1,0.0569,0.1875,12.00,33.2,77018.634899,11365.339845,2479.585227,1120.687,2.52,898.1556,-898.15 |

- ▶ 30 minutes of simulation
- ▶ Approximately 6 minutes of computing time
- ▶ CSV file
- ▶ A solution every 0.02 second

# A different simulation

- Medical conditions or actions.
- An asthma attack.
- Nitrogen $0.75 \rightarrow 0.85$.
- Oxygen $0.21 \rightarrow 0.11$.

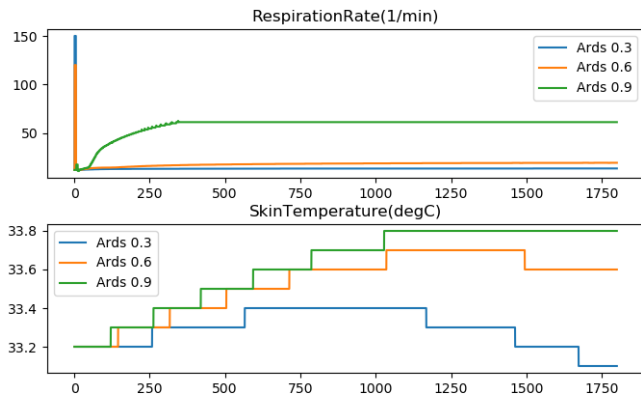# Some graphs
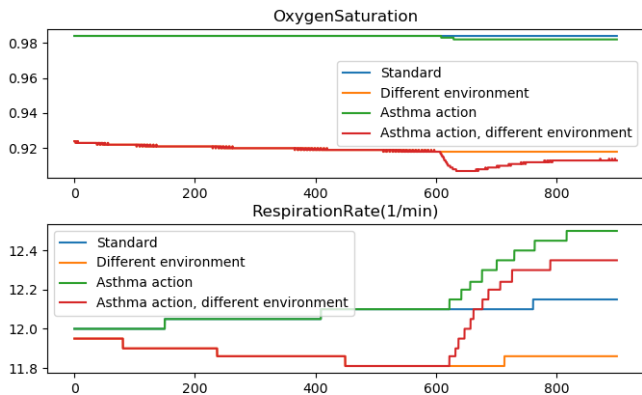
# Coronavirus patient

- Patients sharing a ventilator.
- Covid pneumonia.
- ARDS.

# ARDS

# Particles

- Airborne transmission of the virus.
- Particles we exhale.
- Viral load.
- ADR equation.

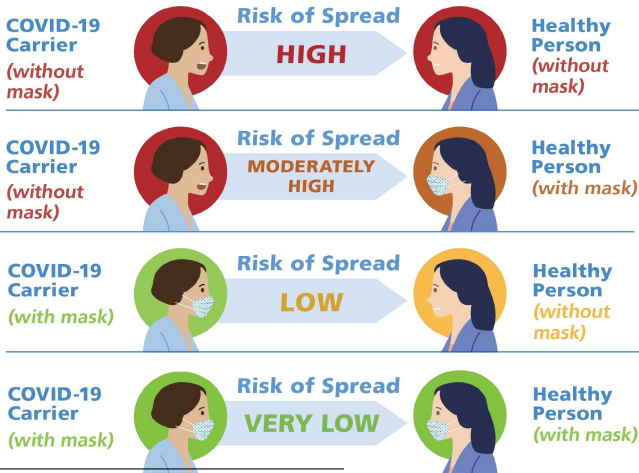| Infectious person state | Particles/s |
|---|---|
| Breathing | 0.5 |
| Talking | 5 |
| Breathing with mask | 0.25 |
| Talking with mask | 2.5 |

[4]

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[4]https://arxiv.org/pdf/2012.12267.pdf

# WEAR A FACE COVERING TO PROTECT YOURSELF AND OTHERS

## Help prevent the spread of COVID-19!

| | | |
|---|---|---|
| **COVID-19 Carrier** *(without mask)* | **Risk of Spread** HIGH | **Healthy Person** *(without mask)* |
| **COVID-19 Carrier** *(without mask)* | **Risk of Spread** MODERATELY HIGH | **Healthy Person** *(with mask)* |
| **COVID-19 Carrier** *(with mask)* | **Risk of Spread** LOW | **Healthy Person** *(without mask)* |
| **COVID-19 Carrier** *(with mask)* | **Risk of Spread** VERY LOW | **Healthy Person** *(with mask)* |

[5]Mount St. John's Medical Centre

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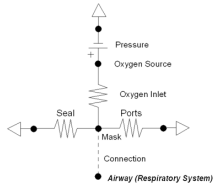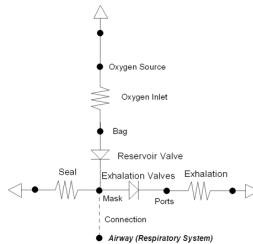# Oxygen supply



**Nasal Cannula**
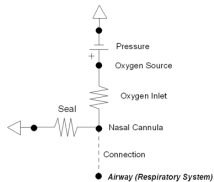
**Simple Mask**

**Nonrebreather Mask**

# Tools

- VS Code
- Pulse Physiology engine
- Gmsh
- Atlas
- Docker
- Feel++