

SEICov App

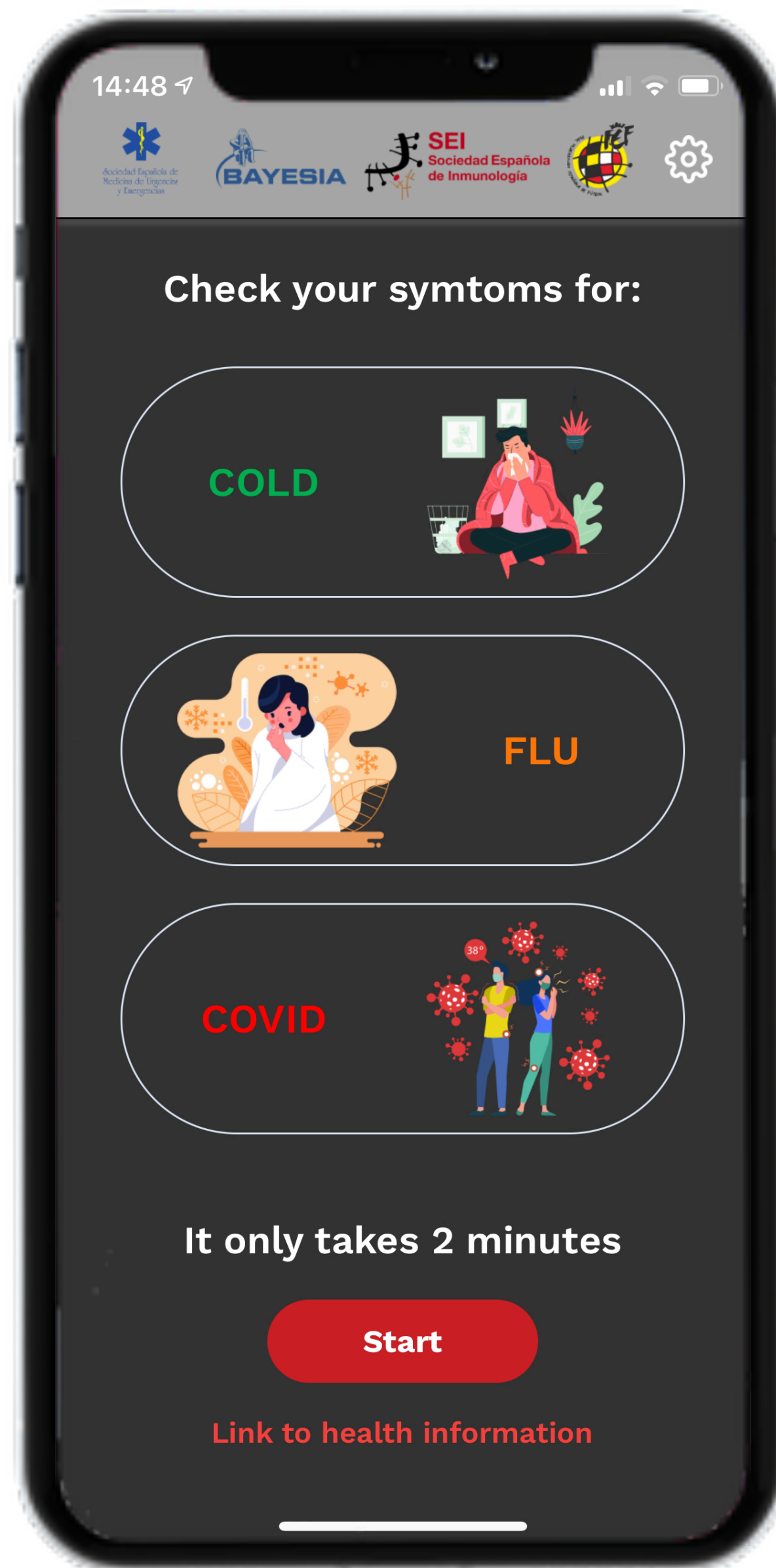
Differential Diagnosis with Bayesian Networks

Networks

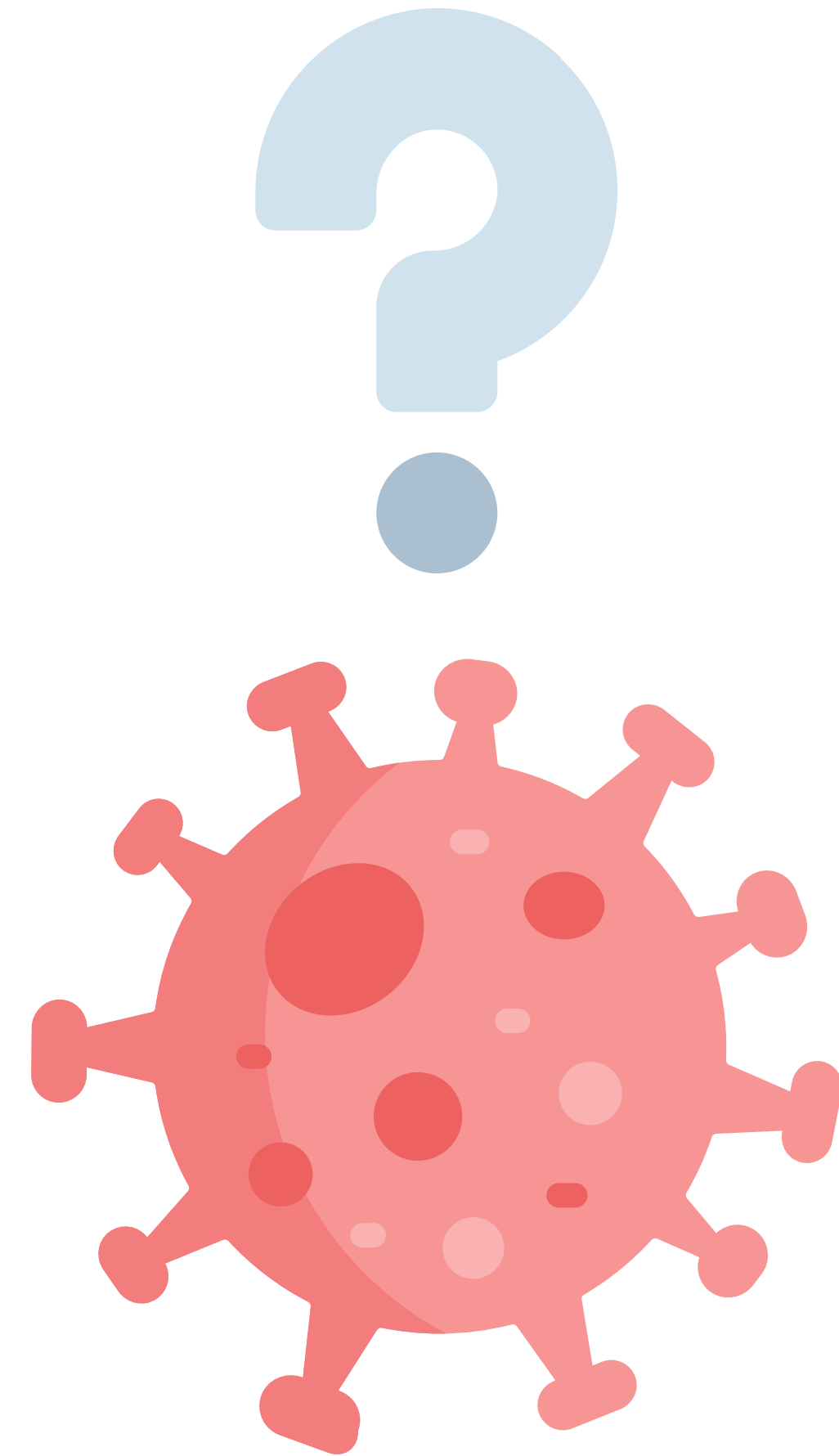
Dr Lionel Jouffe

Bayesia CEO

March 10, 2021



- Motivation
- Bayes Theorem and Incremental Updating
- Analysis of the PCR Test
- COVID-19 Model
- BayesiaLab Adaptive Questionnaire
- BayesiaLab WebSimulator
- REST API





Symptoms of COVID-19

Symptoms of COVID-19	Strep Throat	Common Cold	Flu	Asthma	Seasonal Allergies
FEVER 	✓		✓		
COUGH 		✓	✓	✓	✓
SORE THROAT 	✓	✓	✓		✓
SHORTNESS OF BREATH 				✓	
FATIGUE 		✓	✓	✓	✓
DIARRHEA OR VOMITING 	✓		✓		
RUNNY NOSE 		✓	✓		✓
BODY/ MUSCLE ACHES 	✓	✓	✓		

✓ Symptom of illness



[cdc.gov/coronavirus](https://www.cdc.gov/coronavirus)

316917-A July 23, 2020 10:04 AM

Flu or Covid?





Cold, Flu, or COVID-19?			
COVID-19 RESOURCE			
Signs & Symptoms	Cold	Flu	COVID-19
Onset of symptoms	Gradual	Abrupt, 1–4 days after infection	Less abrupt, generally 5 days after exposure, ranging between 2–14 days Type and severity varies by person; some may test positive without showing symptoms (asymptomatic)
Fever	Rare	Usual*	Usual
Muscle pain, body aches	Slight	Usual, severe	Usual
Chills	Uncommon	Fairly common	Fairly common
Fatigue	Sometimes	Usual	Usual, extreme
Sneezing	Mild/Moderate	Sometimes	Uncommon
Cough	Common	Common	Usual
Shortness of breath	Rare	Rare	Usual
Runny or stuffy nose	Common	Sometimes	Sometimes
Sore throat	Common	Sometimes	Sometimes
Headache	Rare	Common	Sometimes
Diarrhea, vomiting, nausea	Rare	Sometimes (more common in children)	Sometimes (more common in children)
Loss of taste and smell	Rare	Rare	Common

*Not everyone with the flu will have a fever.
As of 09/25/2020

Cold, Flu or
Covid?

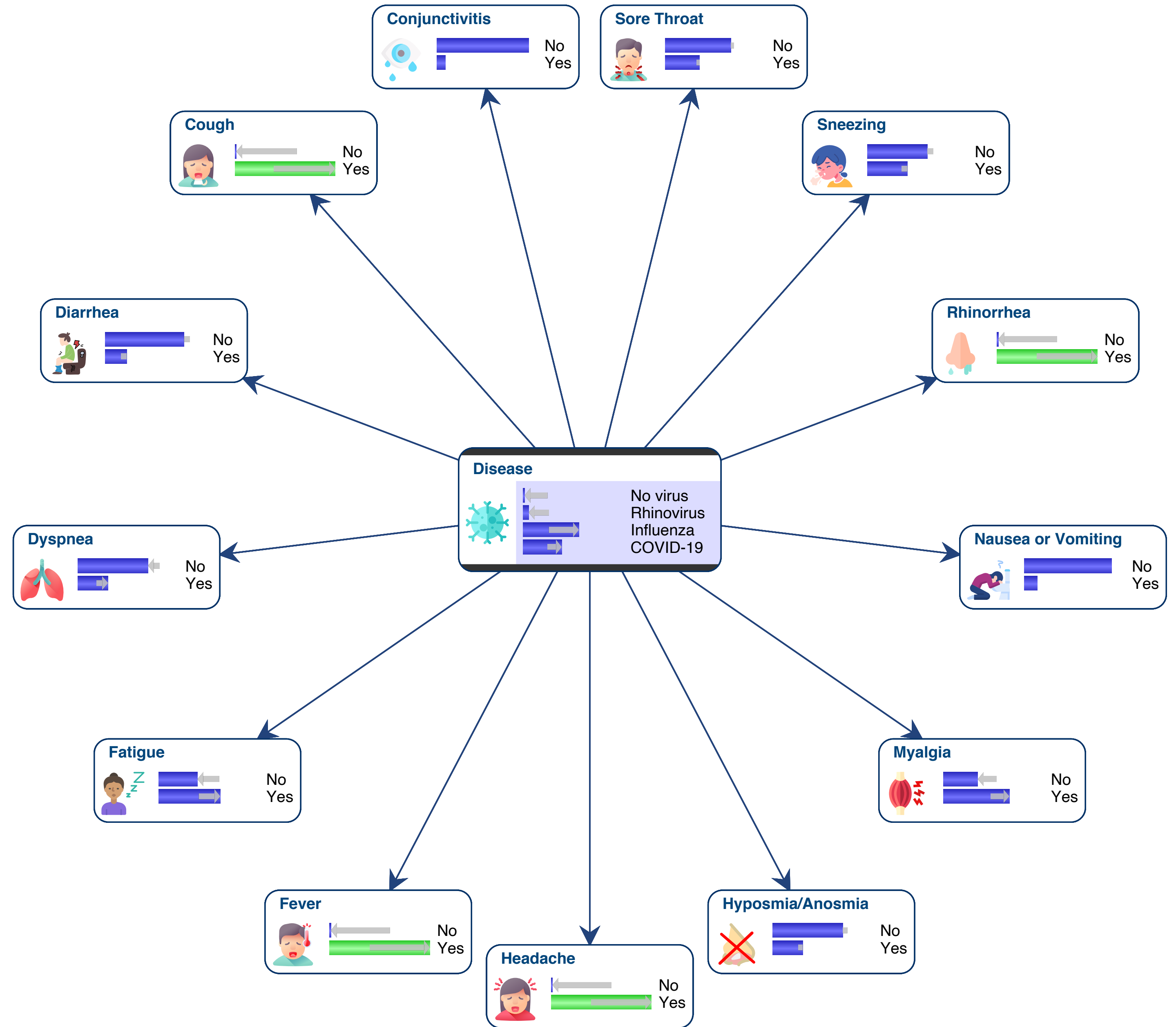
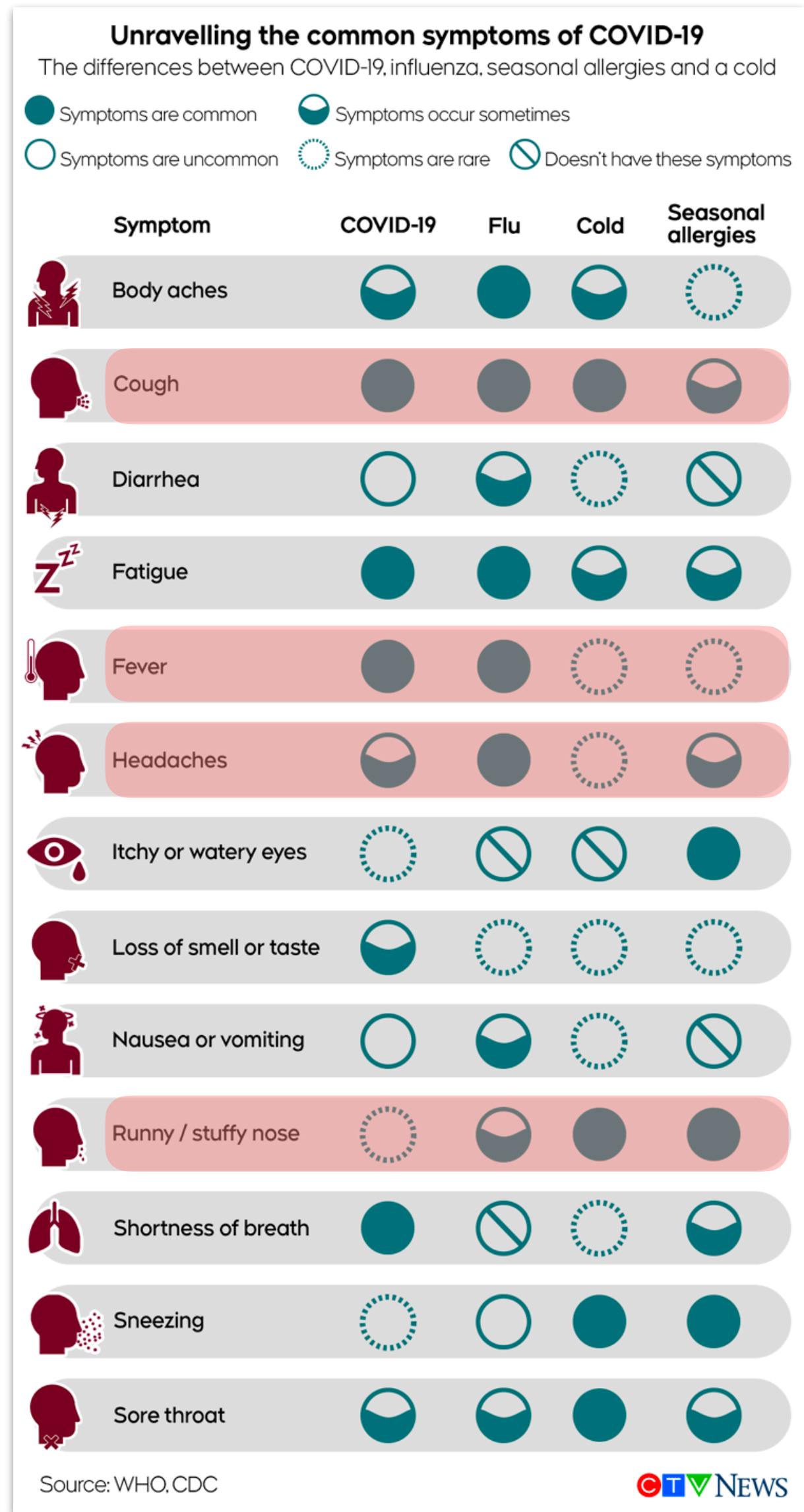


Unravelling the common symptoms of COVID-19				
The differences between COVID-19, influenza, seasonal allergies and a cold				
● Symptoms are common ◐ Symptoms occur sometimes ○ Symptoms are uncommon ⦿ Symptoms are rare ⊘ Doesn't have these symptoms				
Symptom	COVID-19	Flu	Cold	Seasonal allergies
 Body aches	◐	●	◐	⦿
 Cough	●	●	●	◐
 Diarrhea	○	◐	⦿	⊘
 Fatigue	●	●	◐	◐
 Fever	●	●	⦿	⦿
 Headaches	◐	●	⦿	◐
 Itchy or watery eyes	⦿	⊘	⊘	●
 Loss of smell or taste	◐	⦿	⦿	⦿
 Nausea or vomiting	○	◐	⦿	⊘
 Runny / stuffy nose	⦿	◐	●	●
 Shortness of breath	●	⊘	⦿	◐
 Sneezing	⦿	○	●	●
 Sore throat	◐	◐	●	◐

Source: WHO, CDC

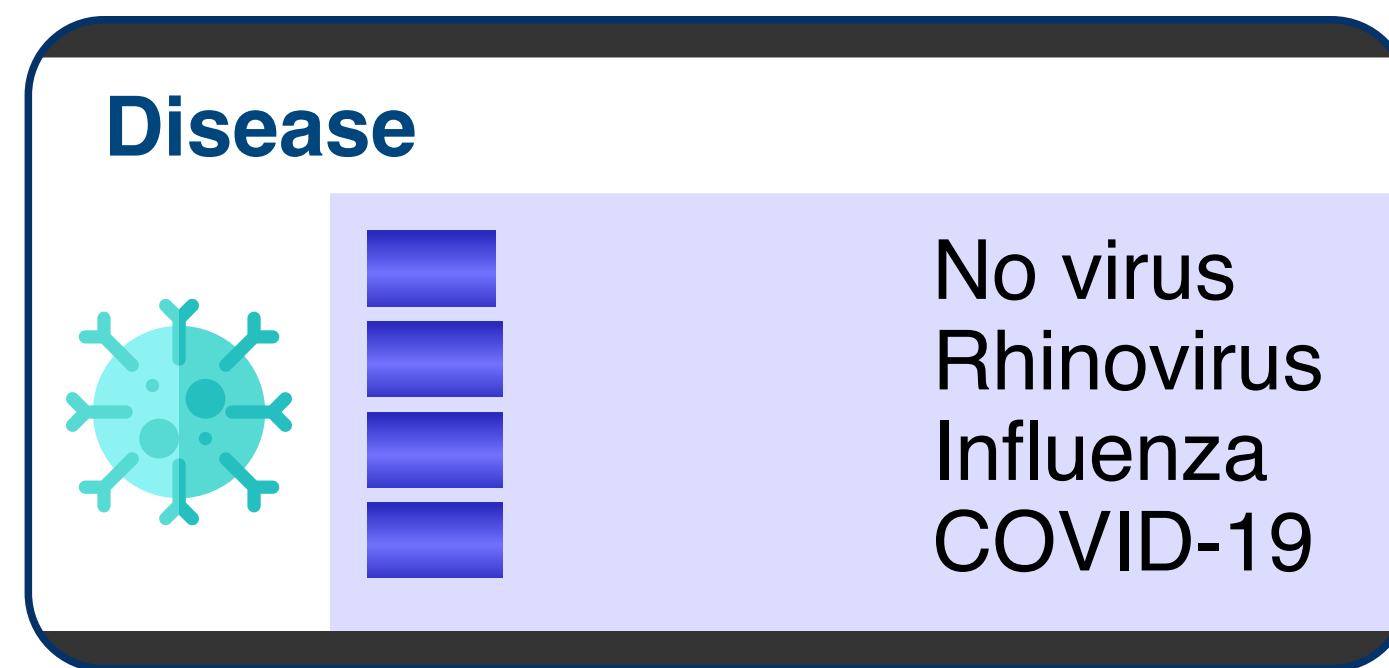
CTV NEWS

Cold, Flu or Covid?

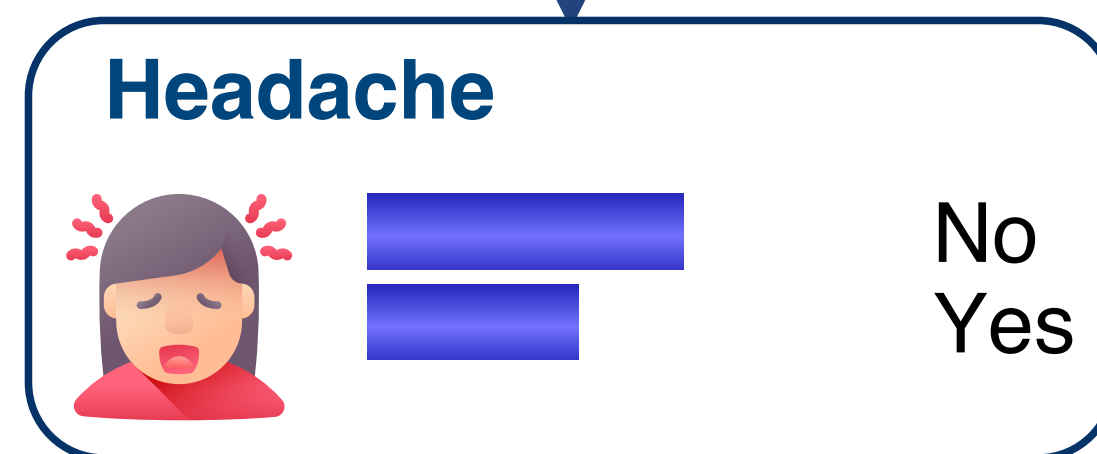


Diagnosis with the Bayes Theorem

What are our priors on the diseases?

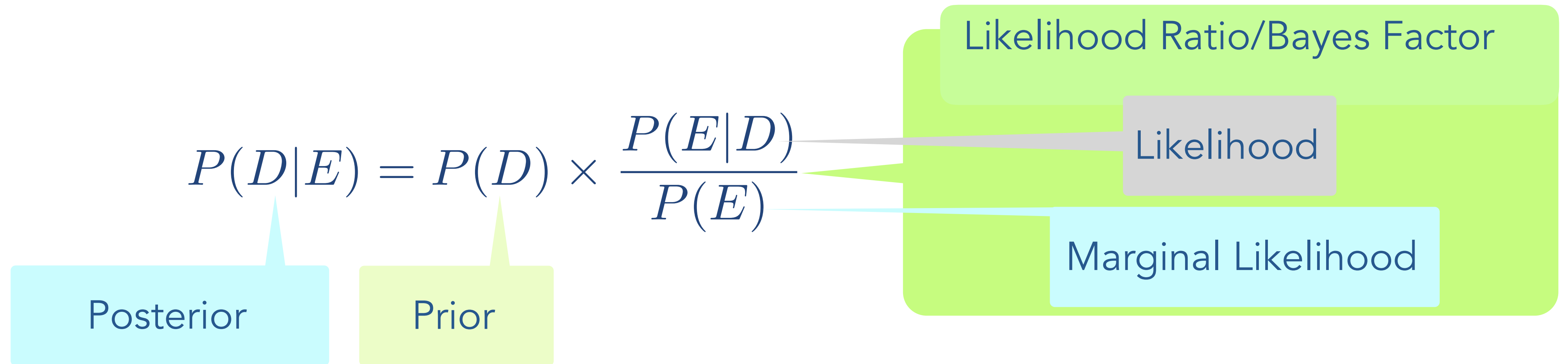


What are the probabilities of the symptoms given the diseases



disease	false	true
no_virus	 68.362	 31.638
rhinovirus	 70.797	 29.203
influenza	 58.649	 41.351
covid_19	 43.361	 56.639

Bayes Theorem



Incremental Belief Updating

$$P(D|E) = P(D) \times \frac{P(E|D)}{P(E)}$$

Prior -
Belief at t_0

$$P_0(D)$$

$$E_0 = \emptyset$$

Evidence at t_0

$$P_t(e^i) = P(e^i|E_t)$$

Marginal Likelihood

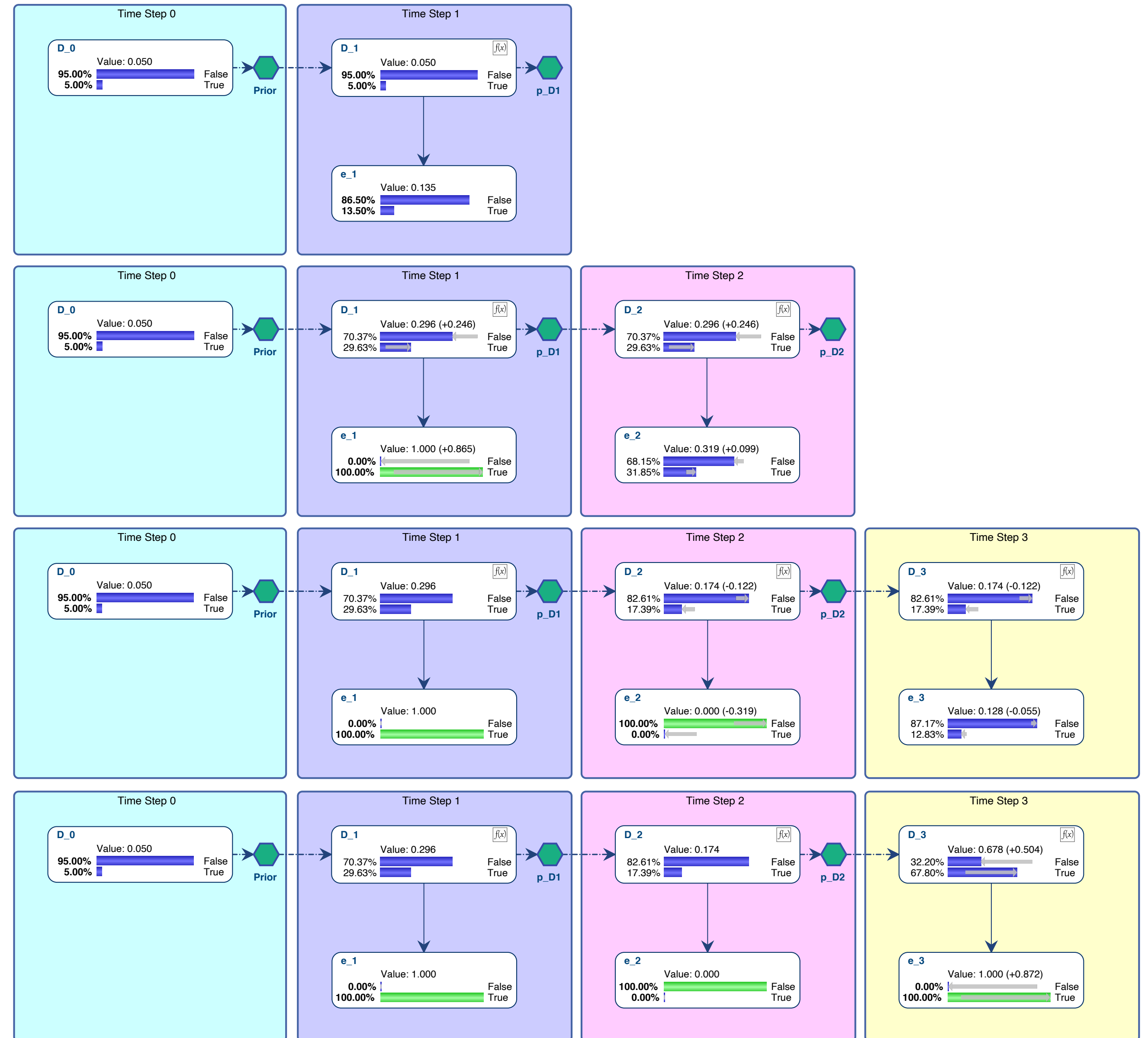
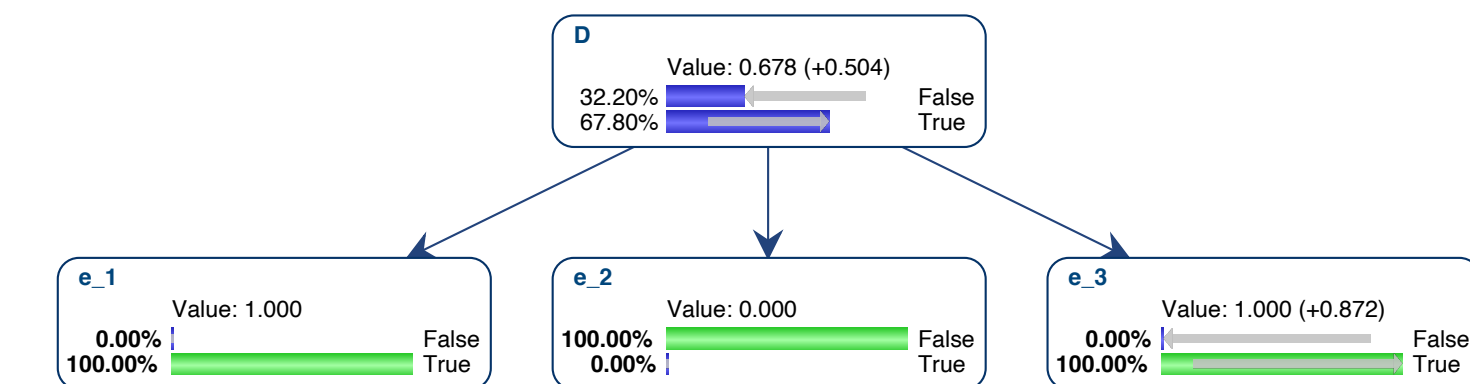
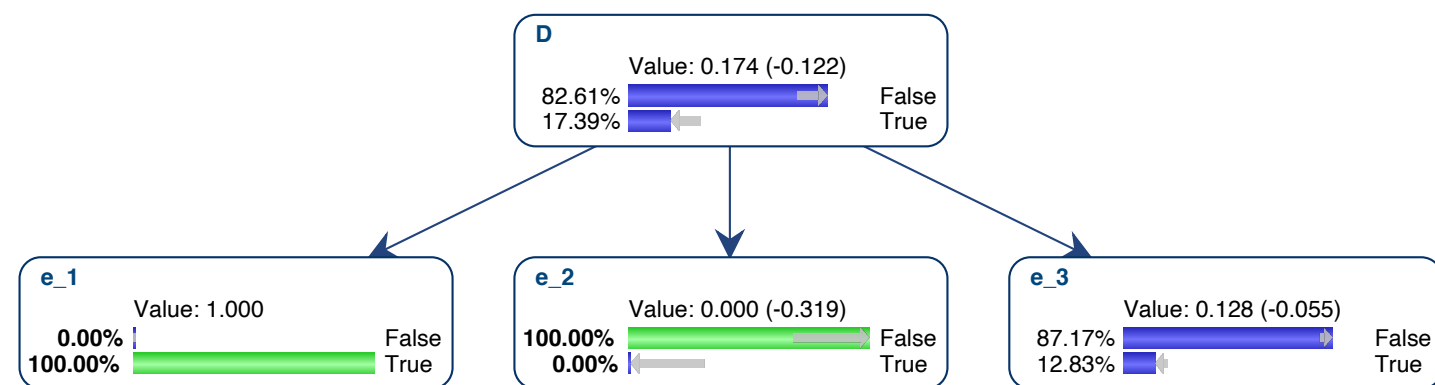
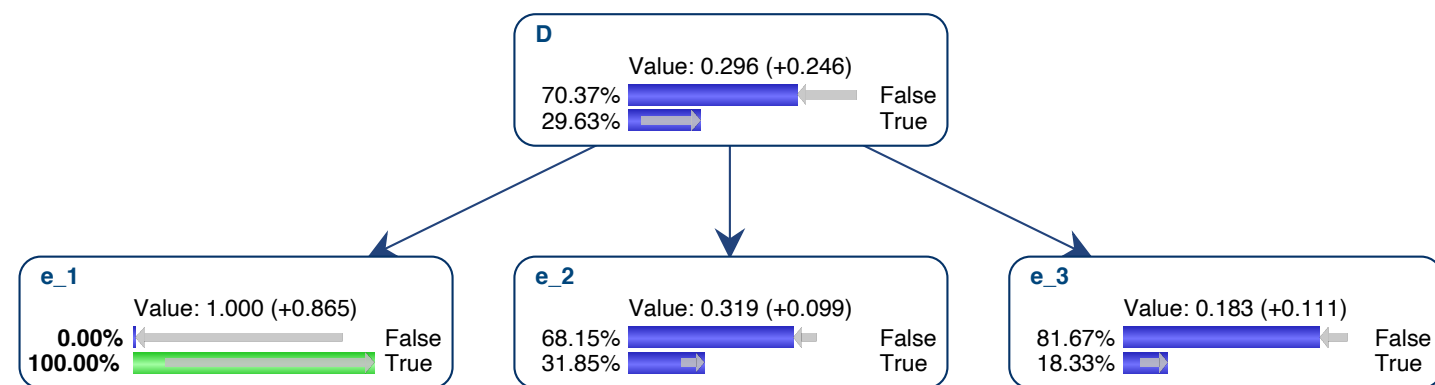
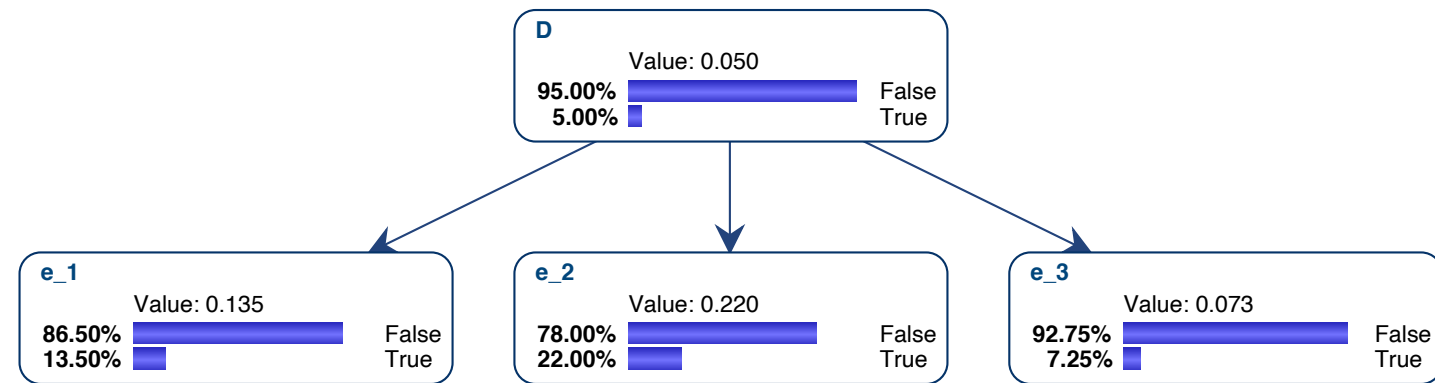
Posterior -
Belief at $t+1$

$$P_{t+1}(D) = P_t(D) \times \frac{P(e^i|D)}{P_t(e^i)}$$

$$E_{t+1} = \{e^i\} \cup E_t$$

Evidence at $t+1$

Incremental Belief Updating

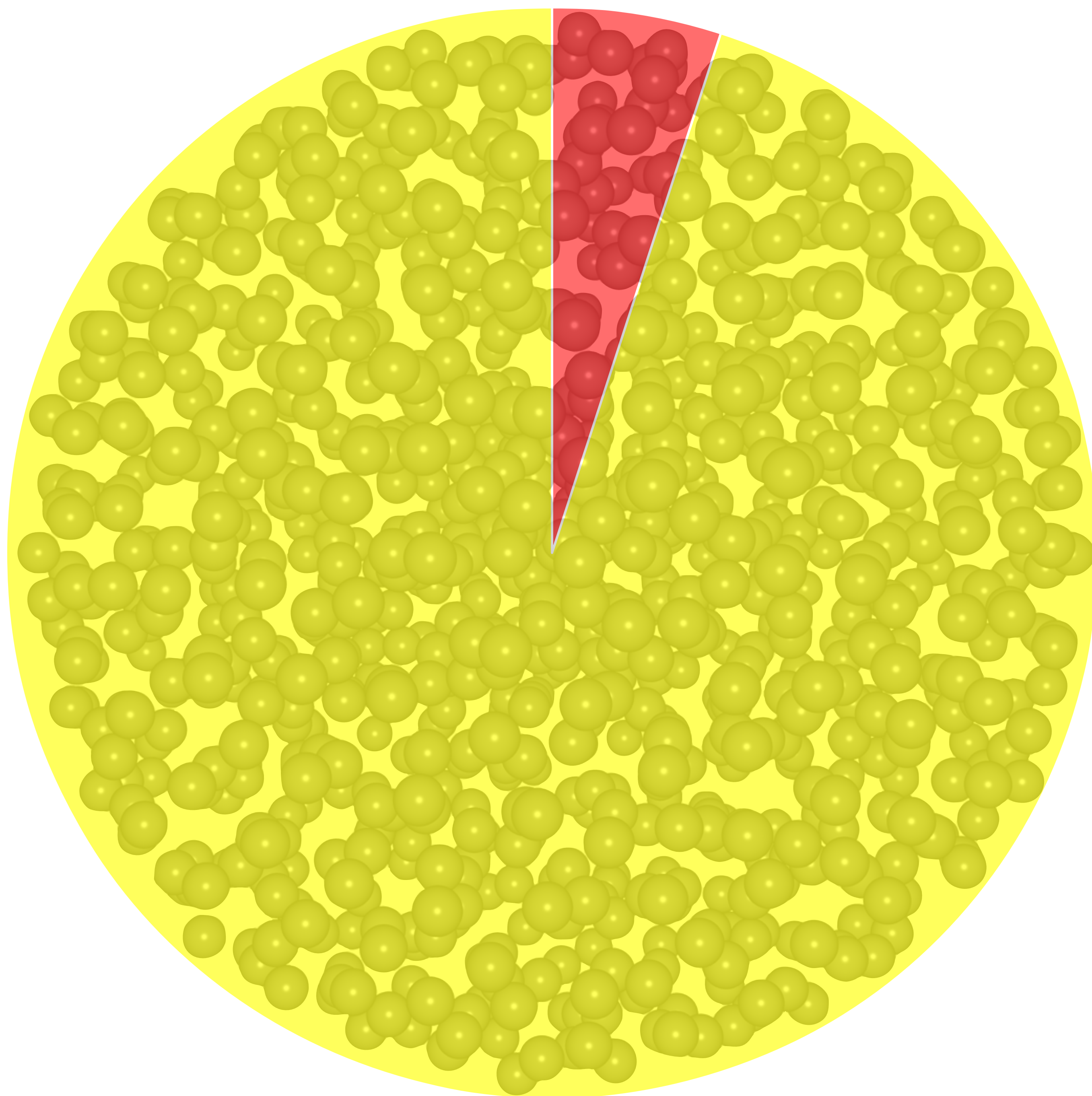


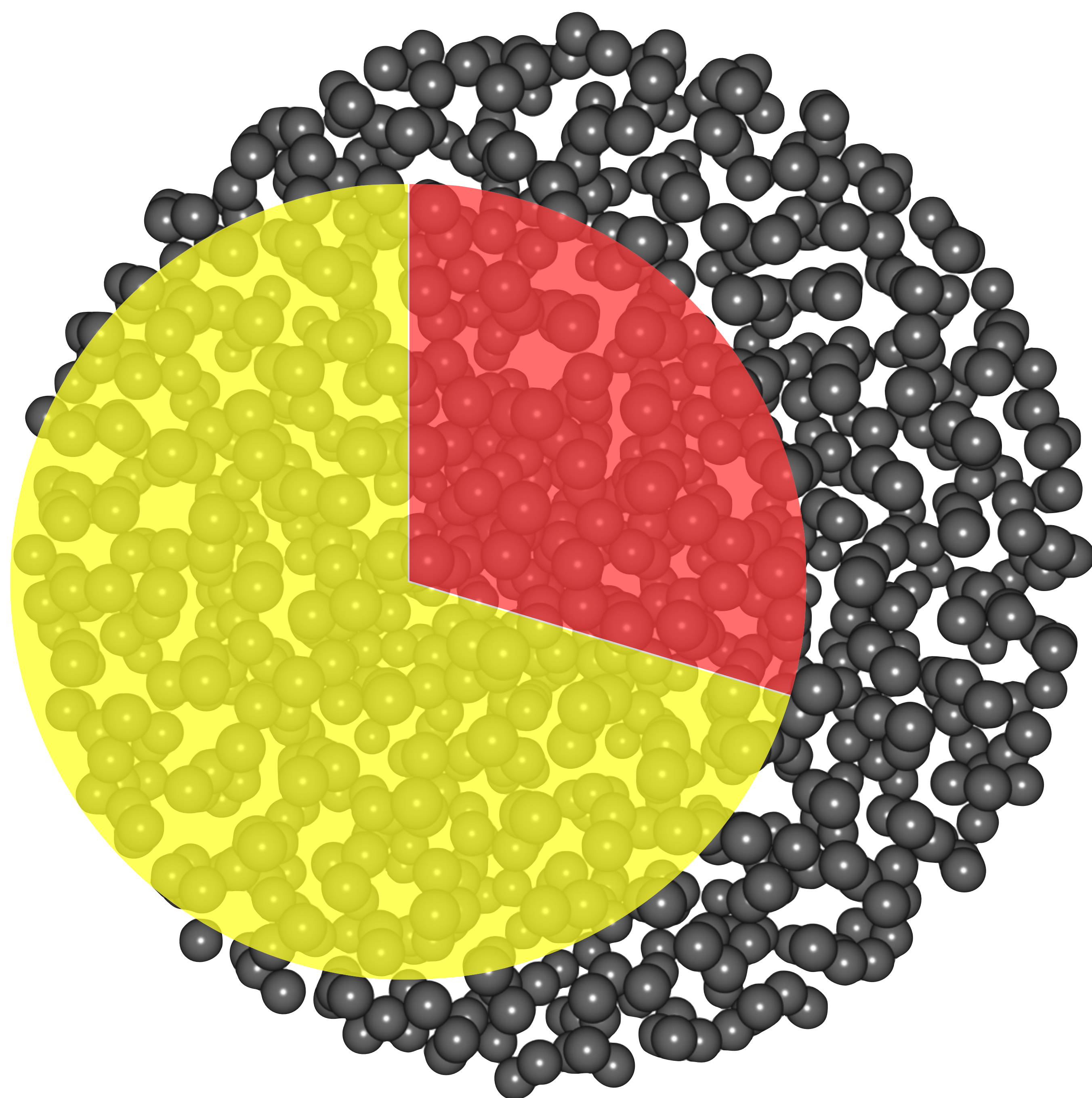
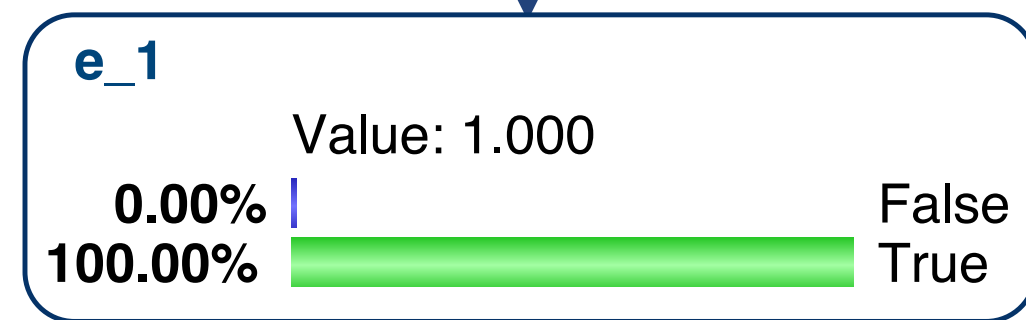
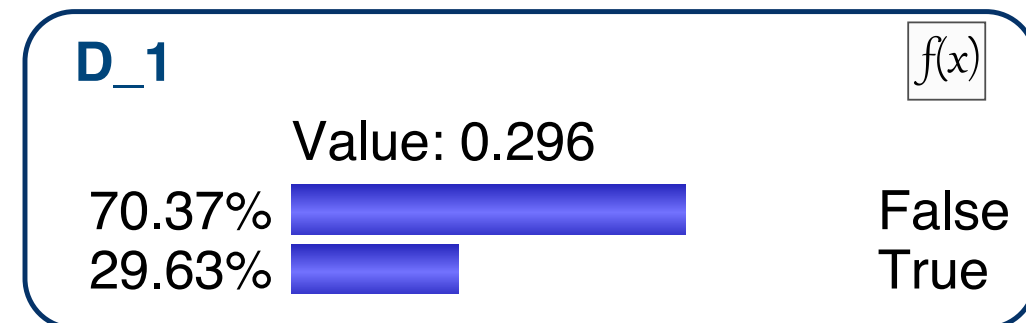
D_0

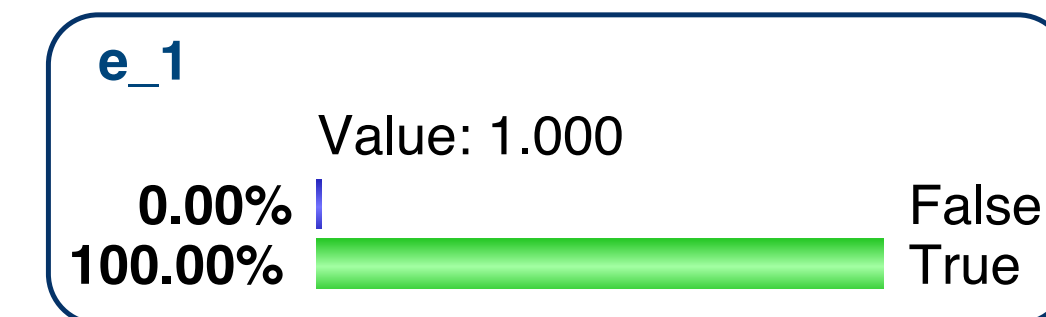
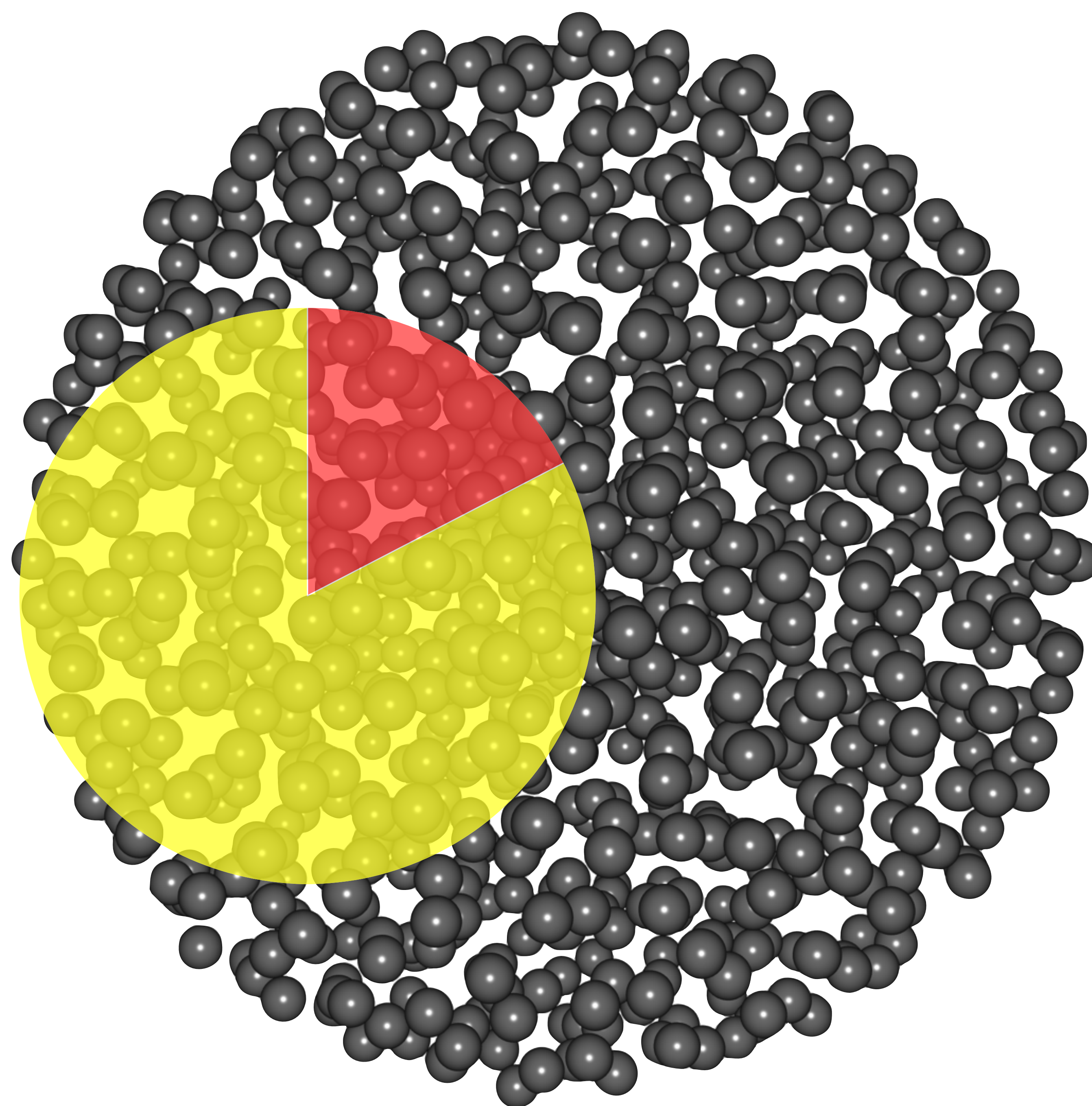
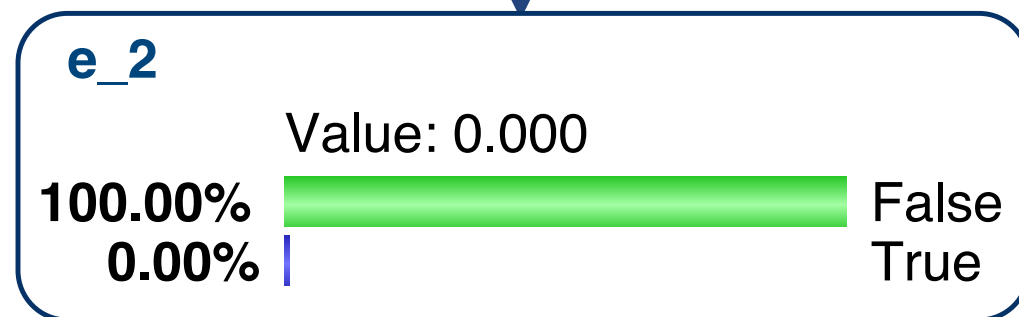
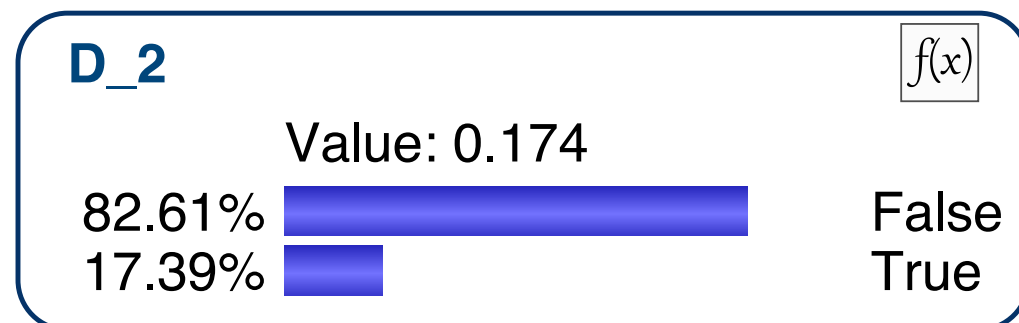
Value: 0.050

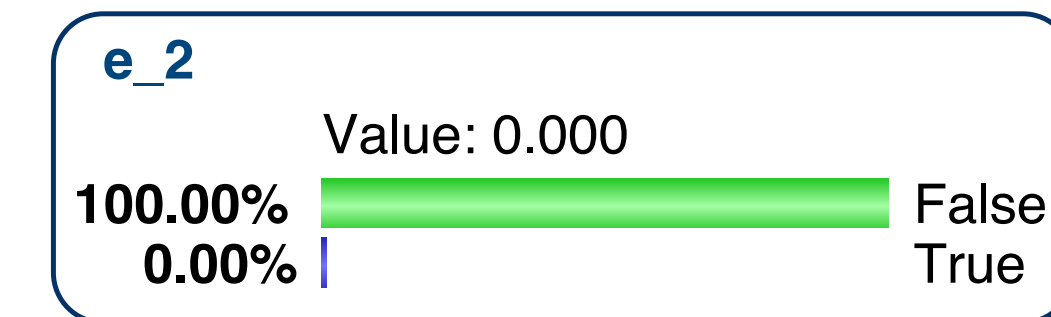
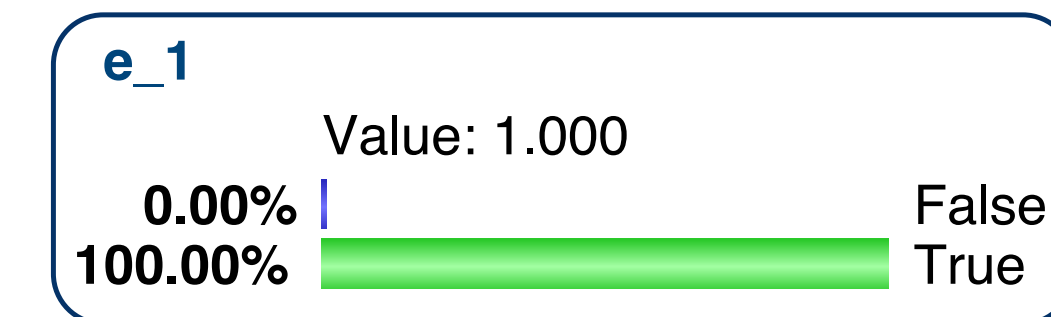
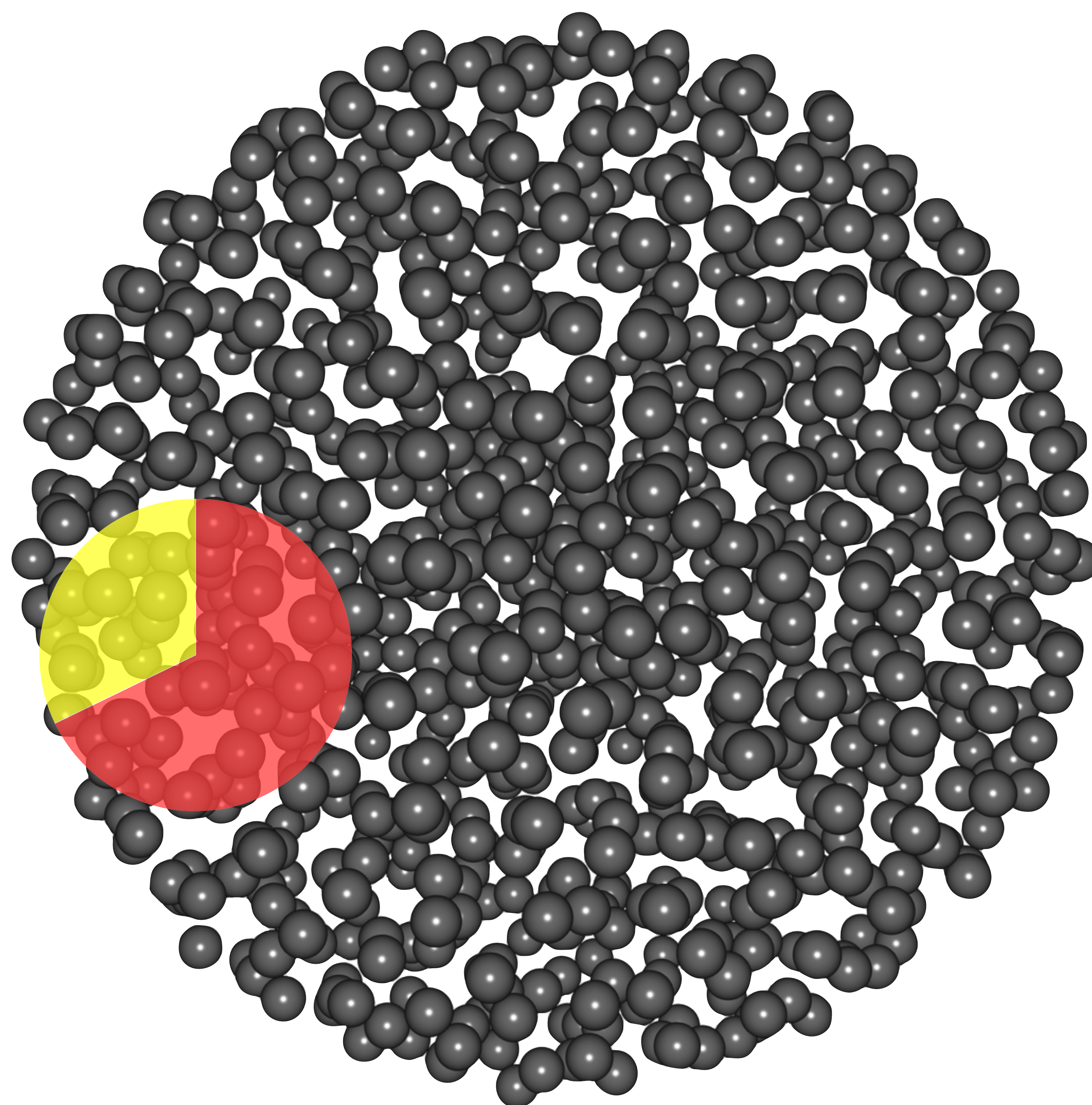
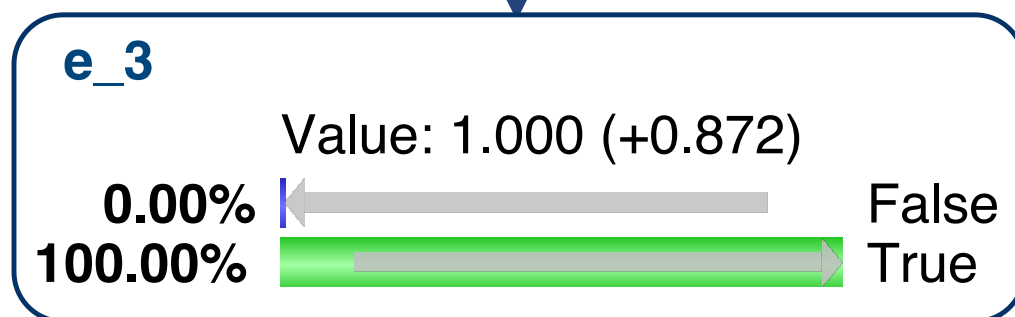
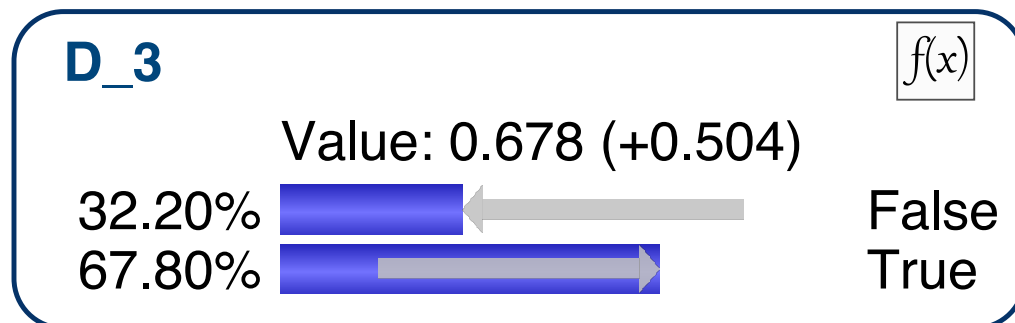
95.00%
5.00%

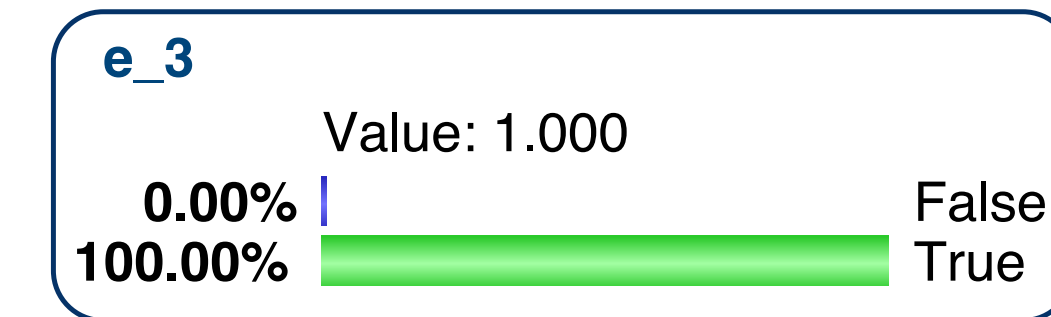
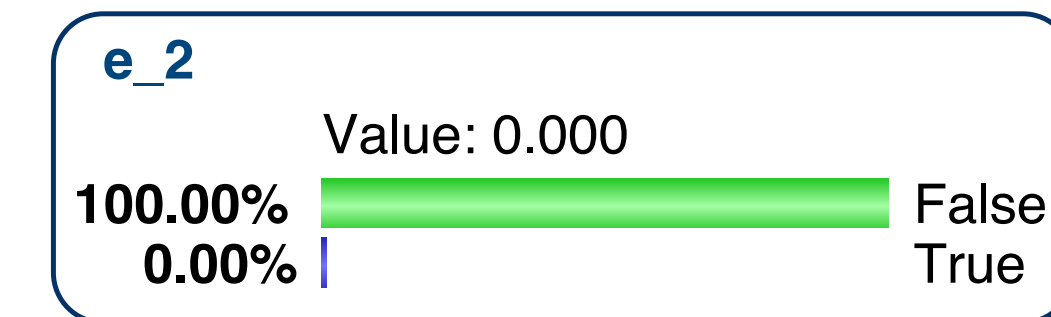
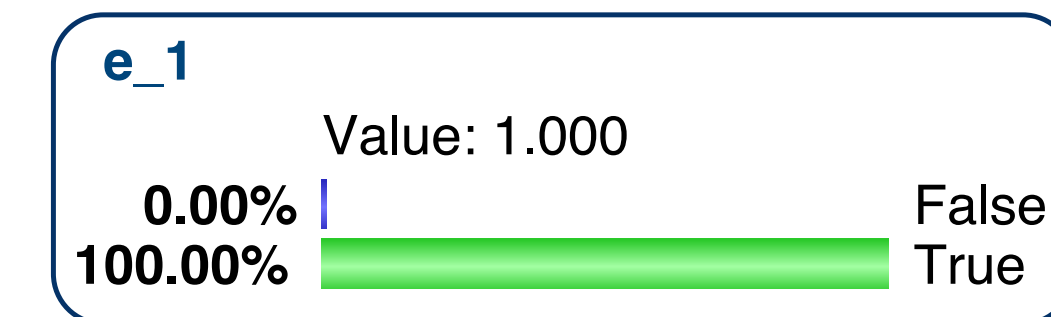
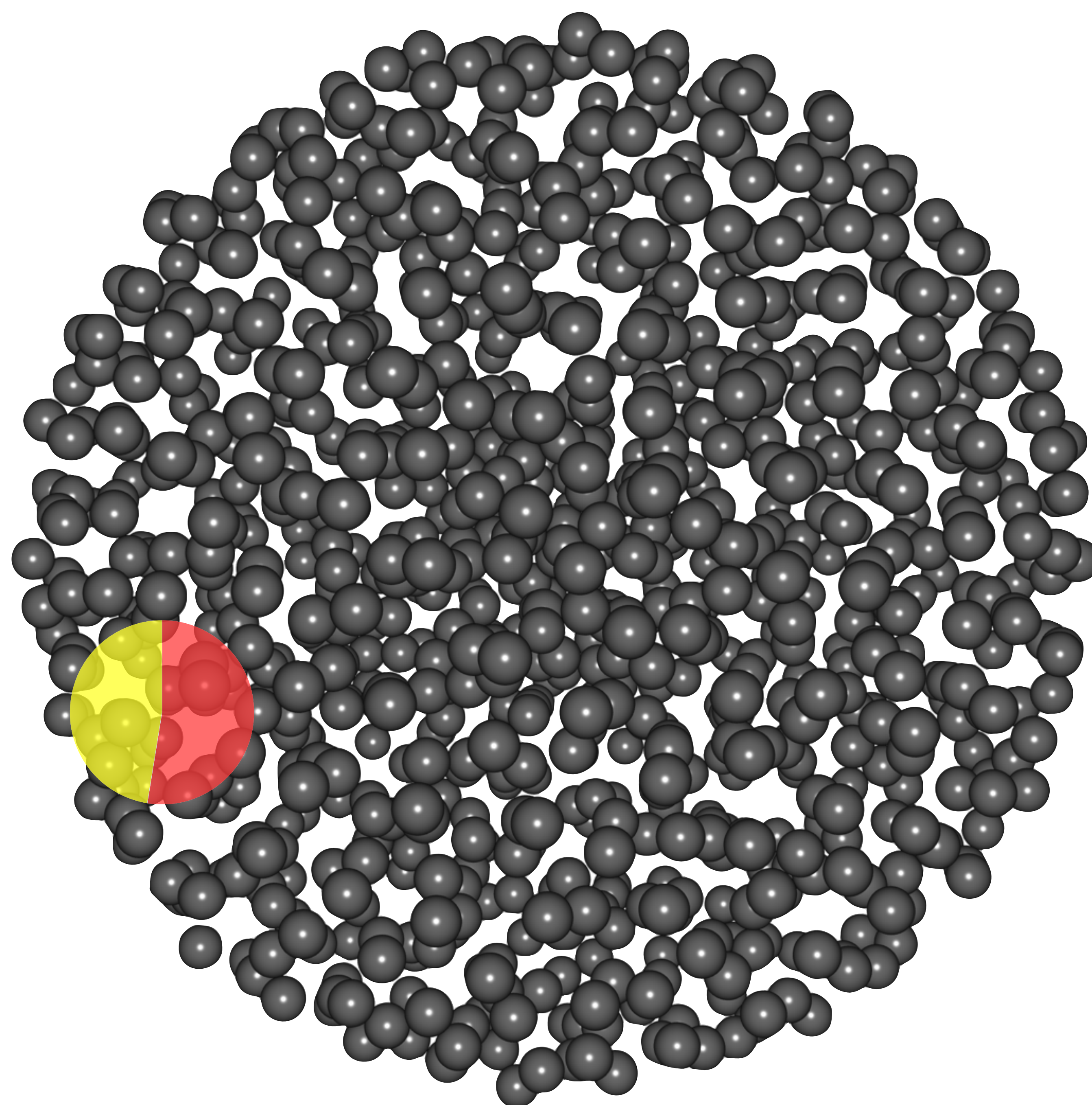
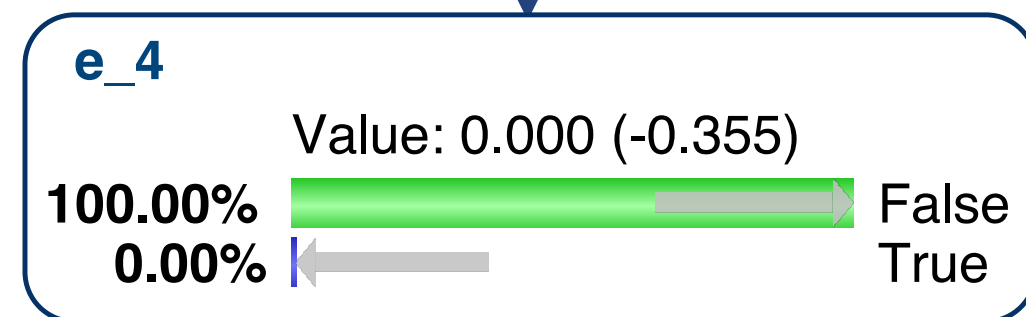
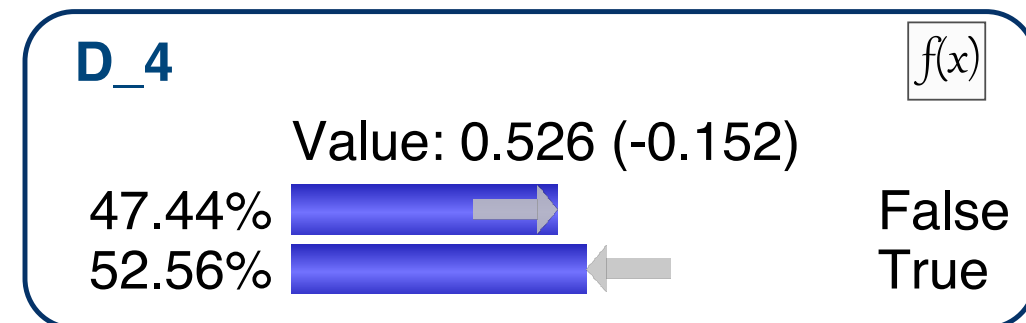
False
True











Incremental Belief Updating

Prior $P_0(D)$

Initial belief on D, without any specific evidence on the **particle** (e.g. the patient)

Probability of being infected by Covid-19 this week in France

Evidence e^i

Specific piece of information on the **particle**

The patient has been tested PCR Positive?

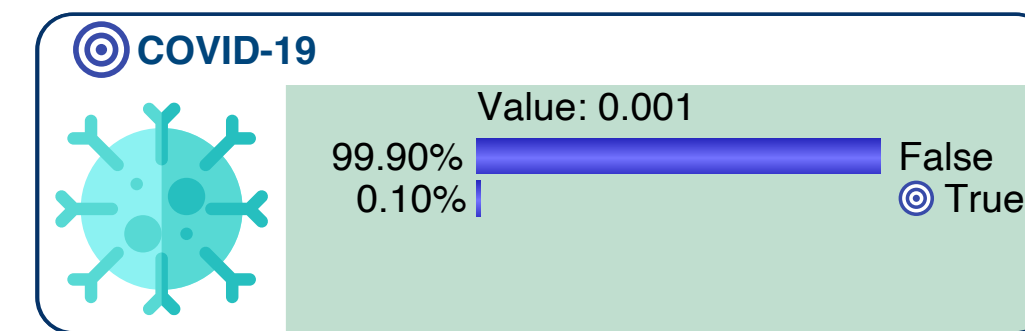
Posterior $P_t(D)$

Updated belief on D that takes into account the specific evidence on the **particle**

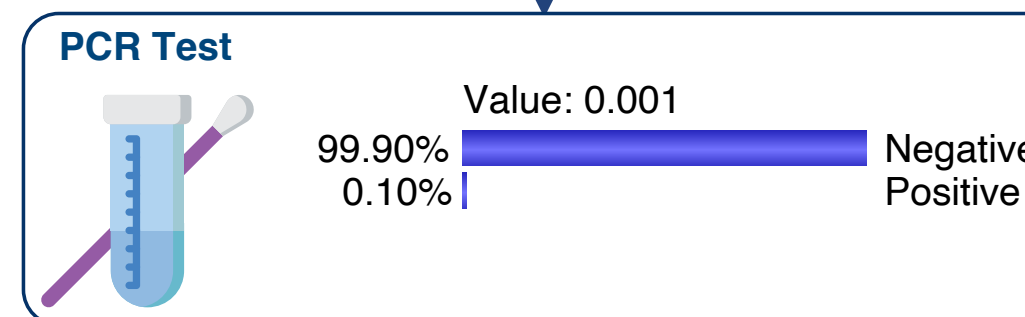
Updated risk given the positive PCR Test result



PCR Test - Causal Model



$P(\text{COVID-19})$



$P(\text{PCR Test} | \text{COVID-19})$

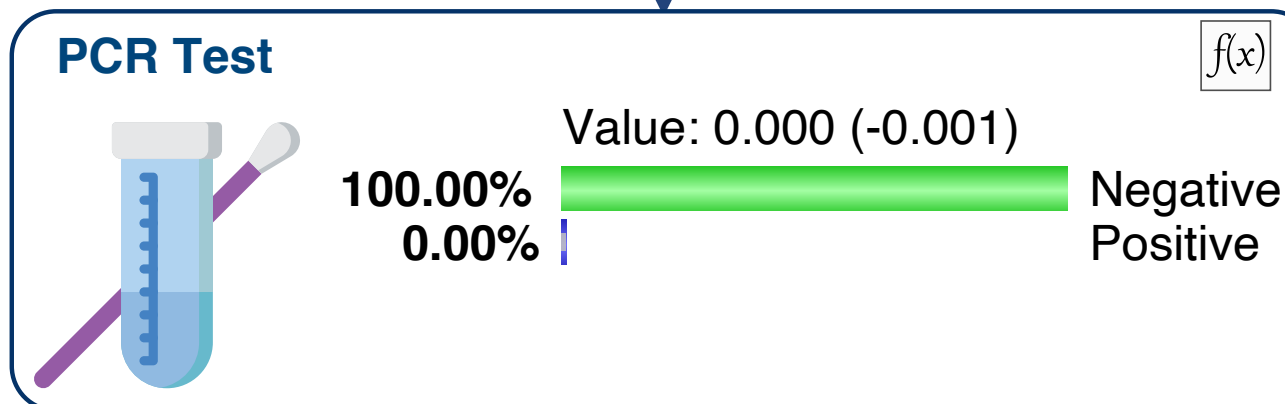
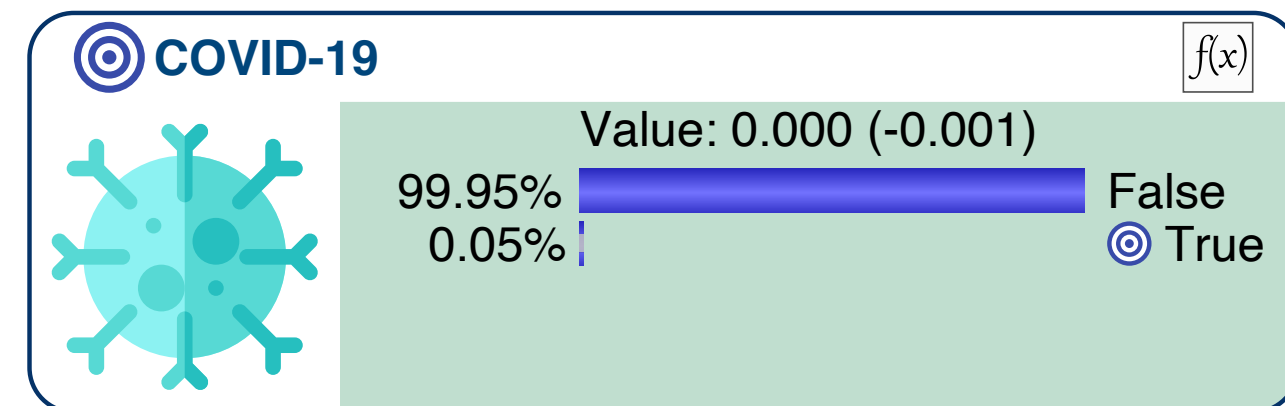
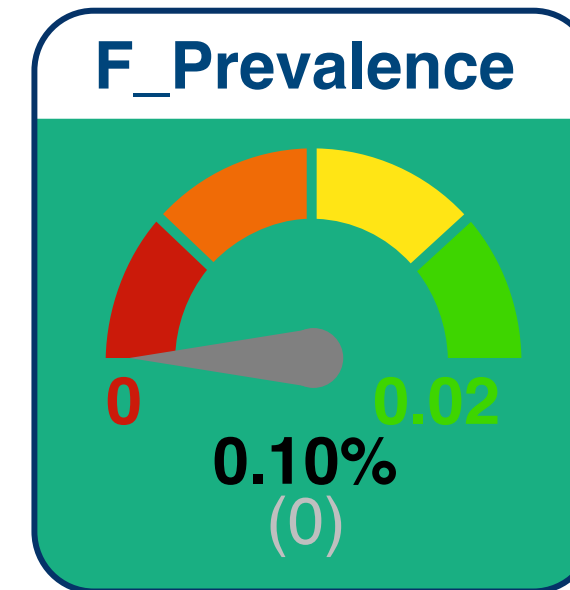
Specificity

Likelihood Function

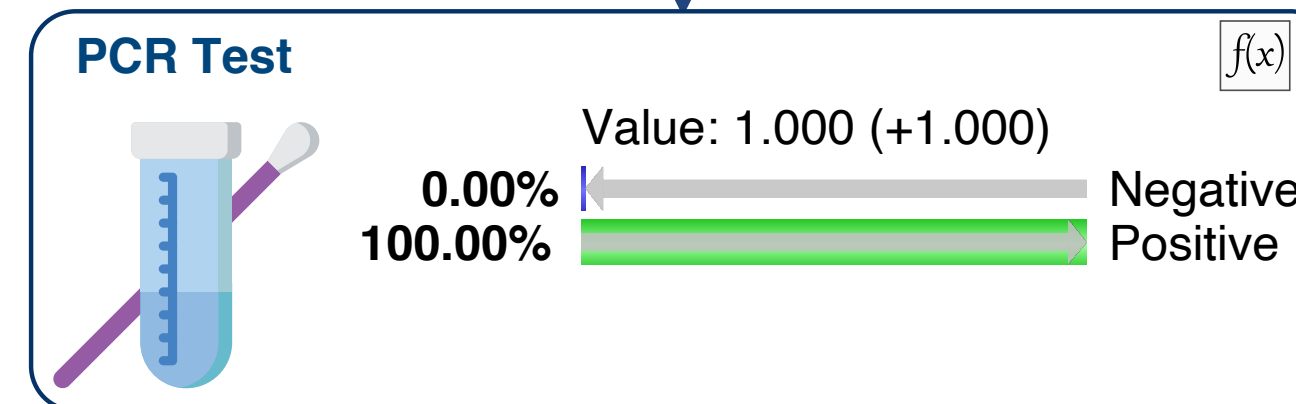
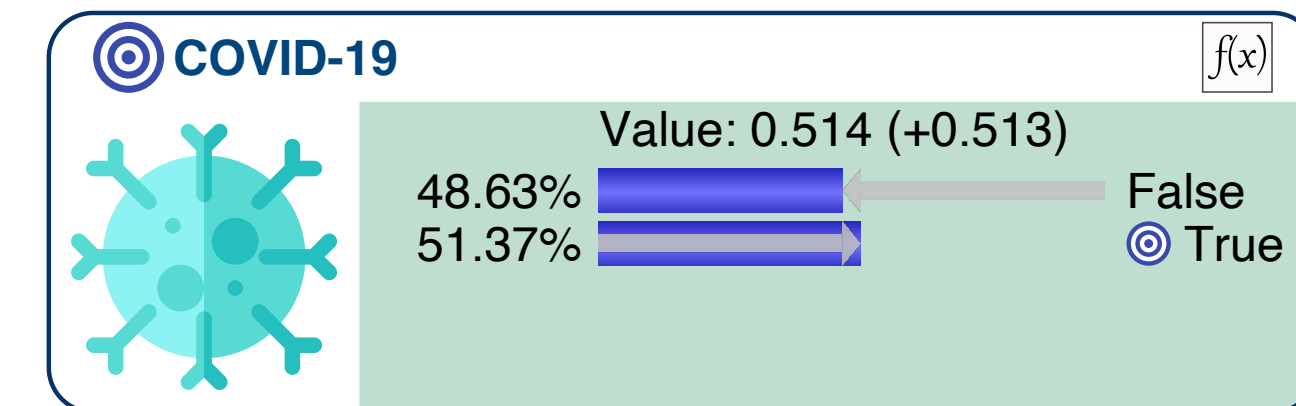
COVID-19	False	True
False	99.950	0.050
True	47.333	52.667

Sensitivity

PCR Test - Examples -/+

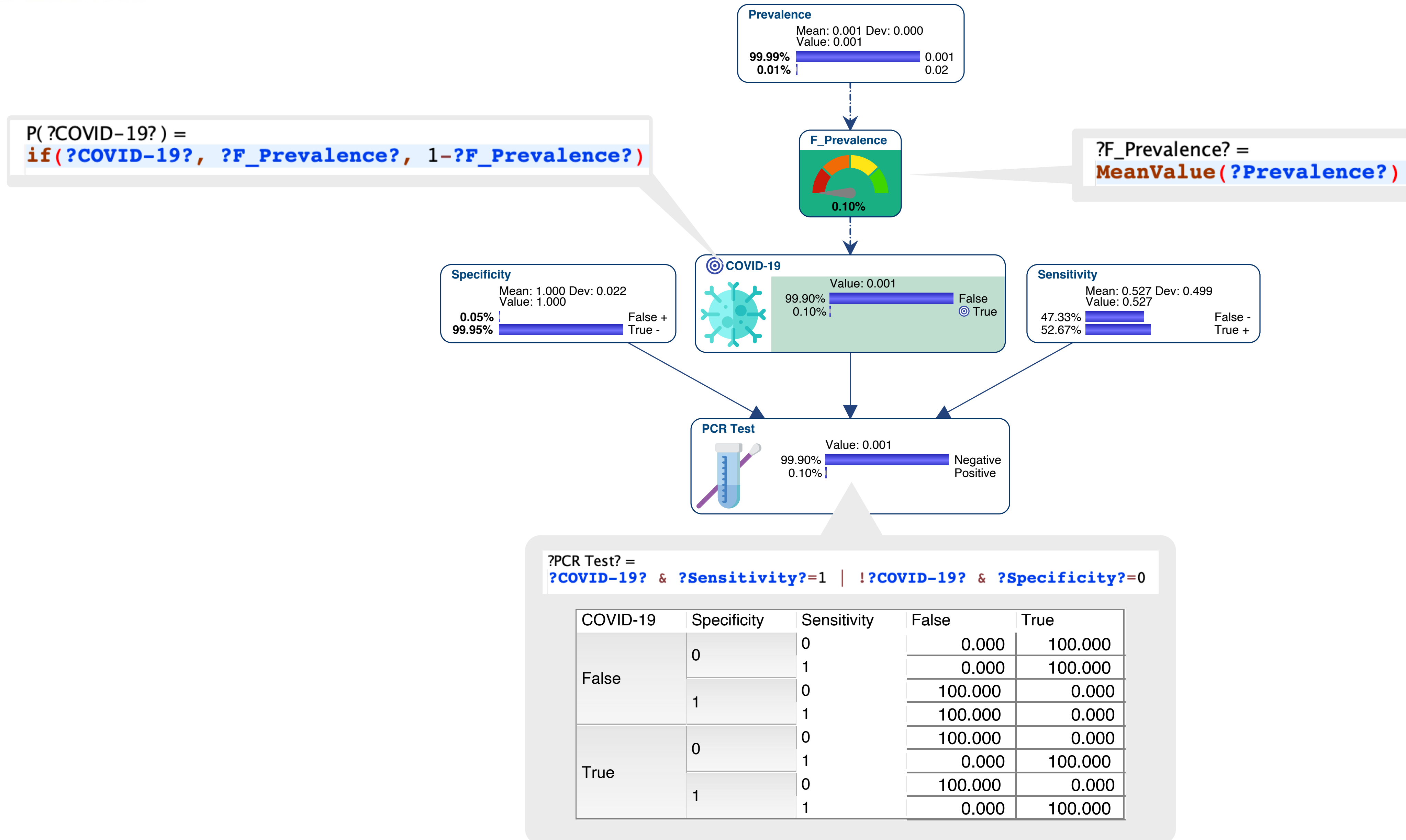


$$BF(c, \bar{p}) = \frac{P(c|\bar{p})}{P(c)} = 0.47$$



$$BF(c, p) = \frac{P(c|p)}{P(c)} = 513.71$$

PCR Test - Model with Hyper-Parameters



PCR Test - Conditional Sensitivity

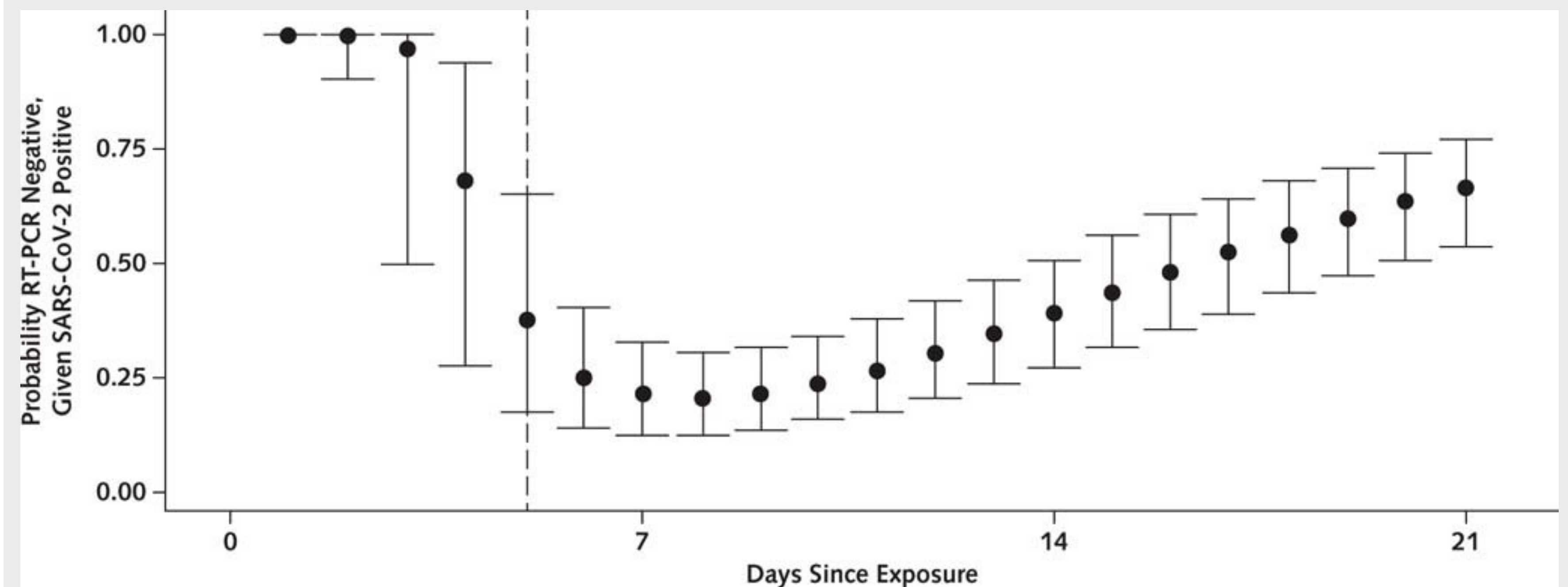
Symptoms

Sensitivity

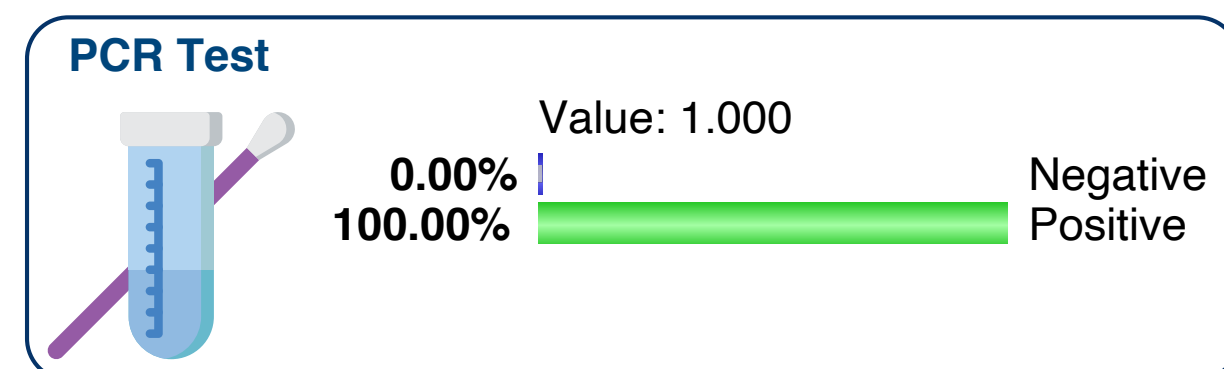
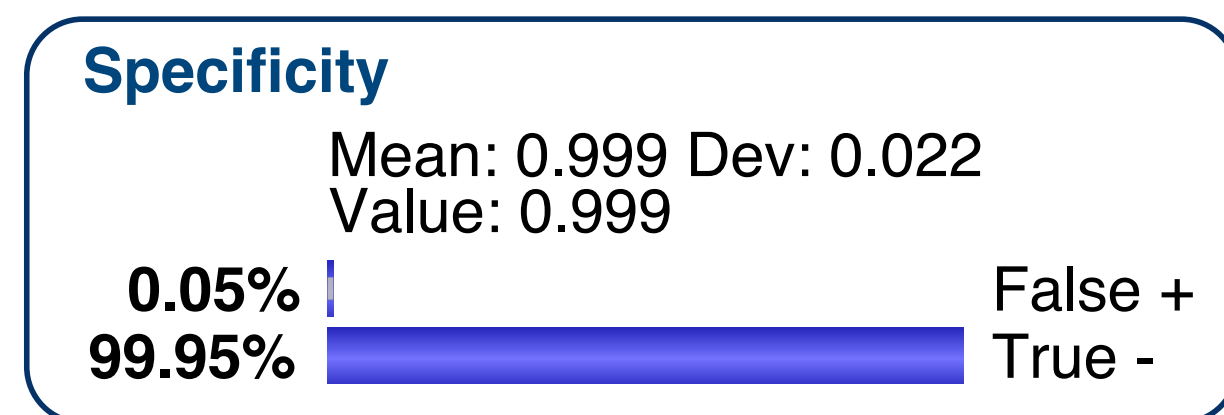
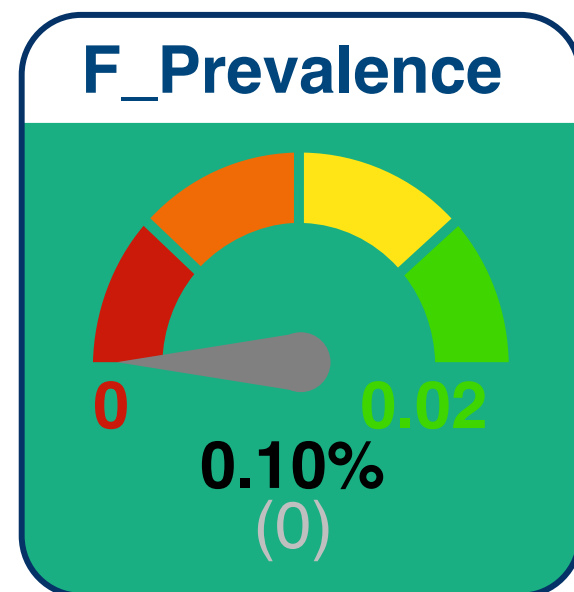
Mean: 0.527 Dev: 0.499
Value: 0.527 (+0.314)

47.33%  False -
52.67%  True +

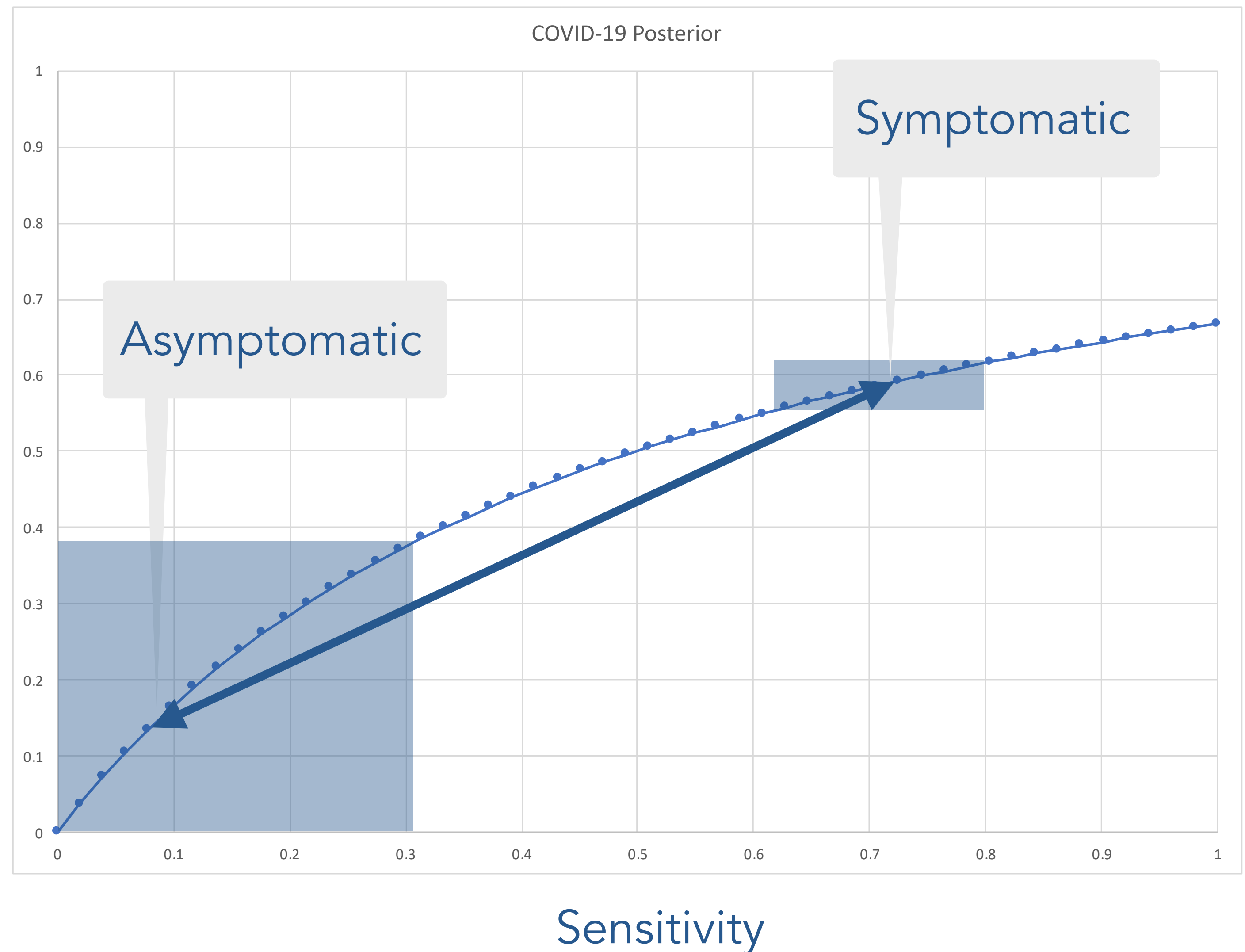
Symptoms	0	1
False	91.750	8.250
True	25.125	74.875



PCR Test - Sensitivity Analysis of the Test Sensitivity



$P(c|p)$



PCR Test - Impact of the Prevalence

Specificity

Mean: 0.999 Dev: 0.022
Value: 0.999

0.05% | 99.95% False + True -

PCR Test

Value: 1.000

0.00% | 100.00% Negative Positive

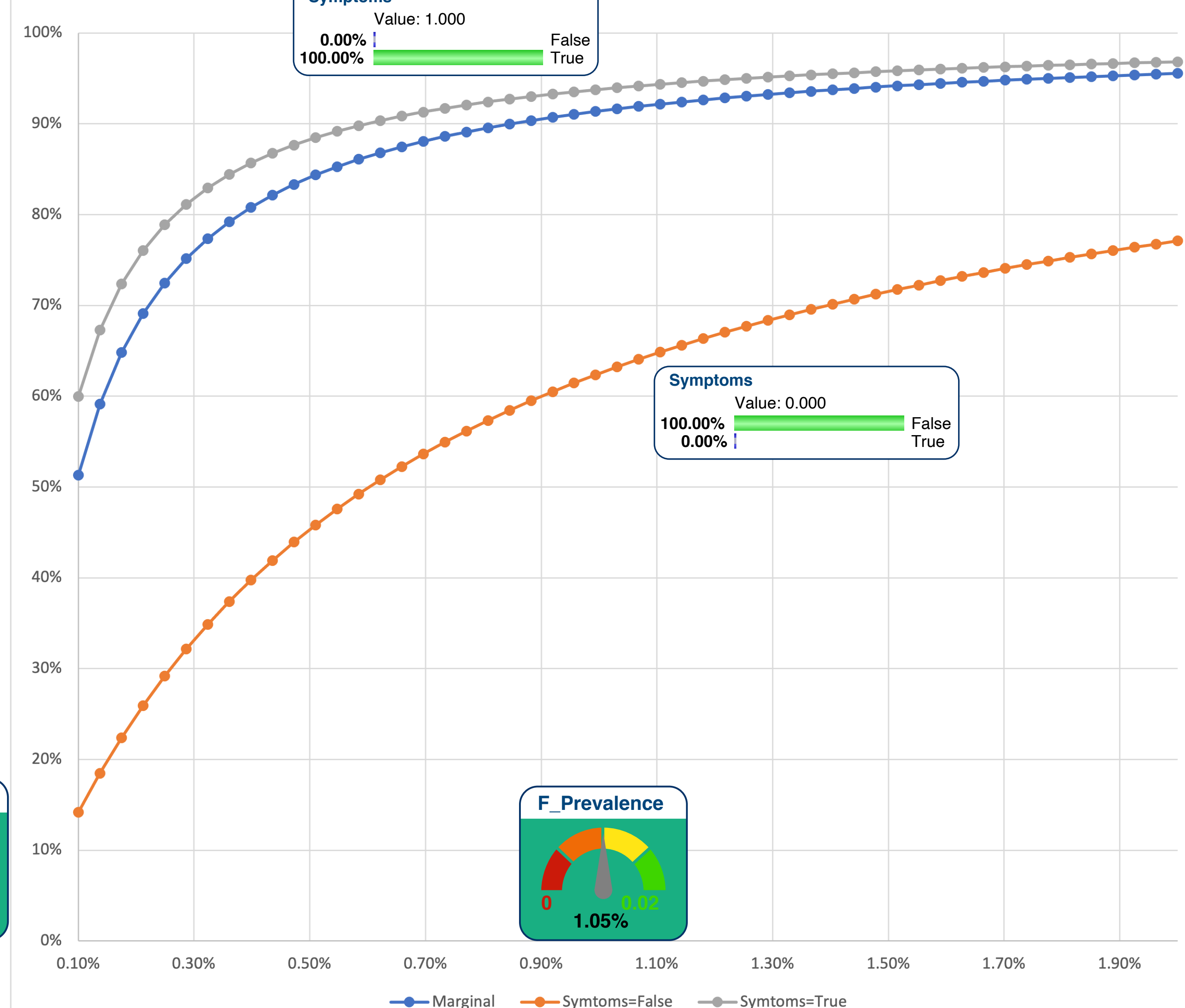
Symptoms

Sensitivity

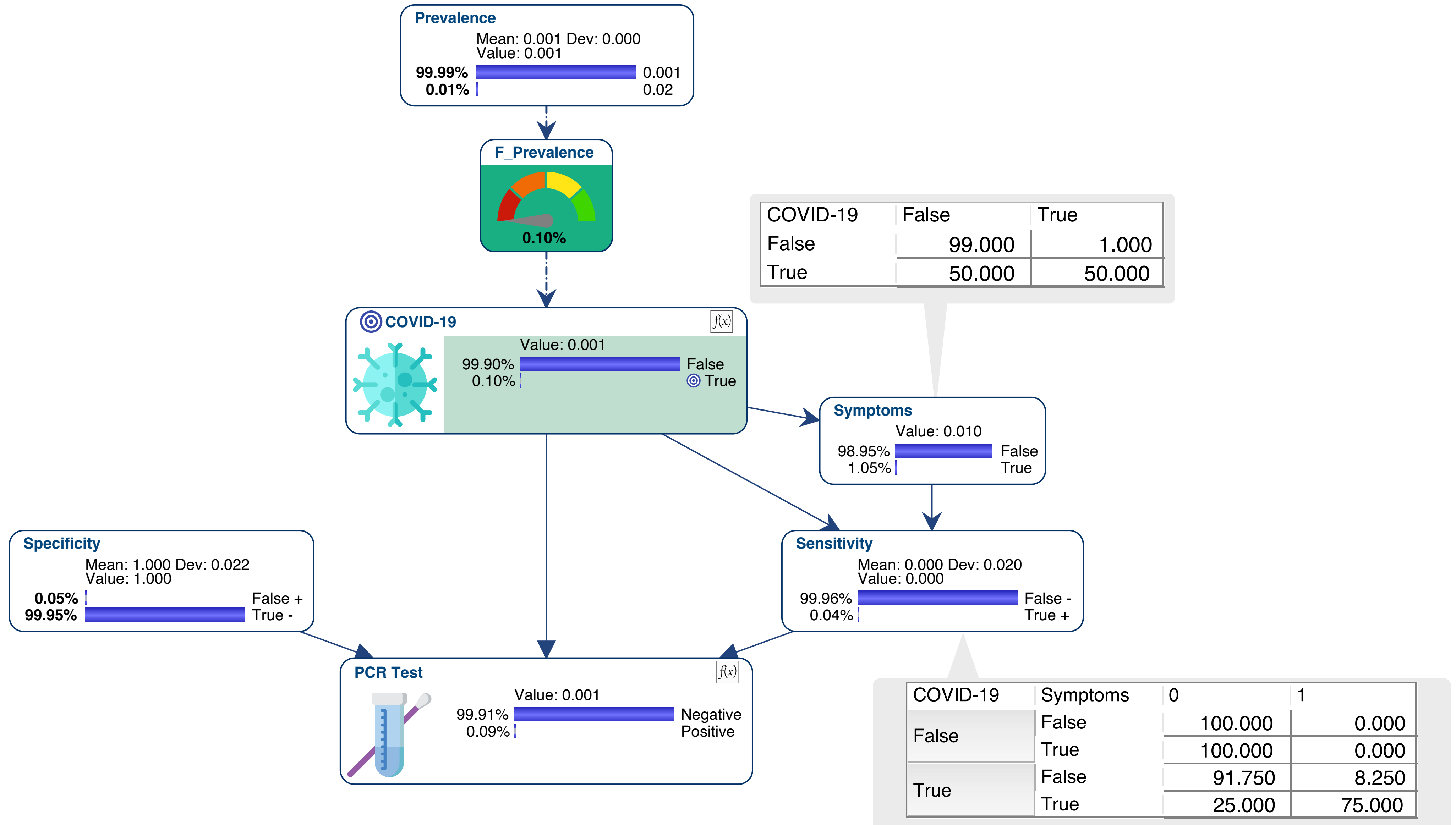
Mean: 0.527 Dev: 0.499
Value: 0.527 (+0.314)

47.33% | 52.67% False - True +

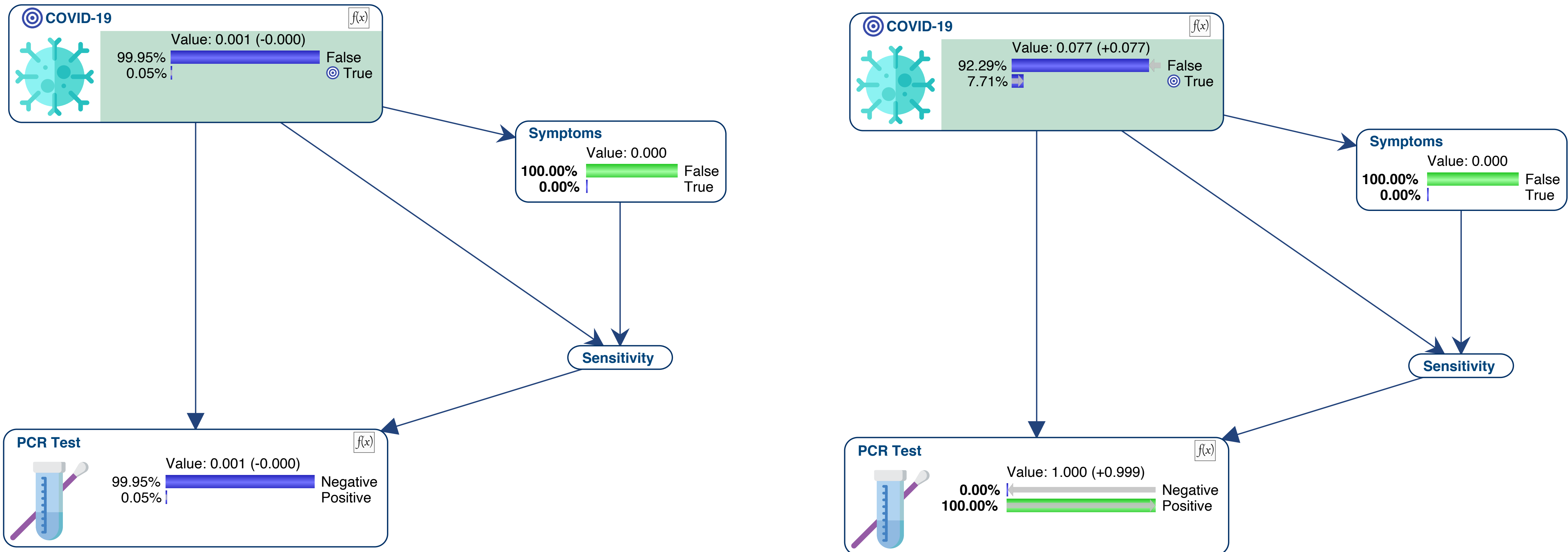
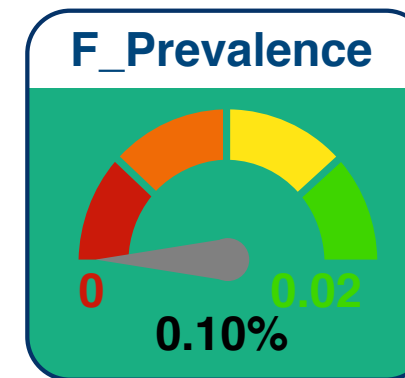
P(Covid | PCR Test+)



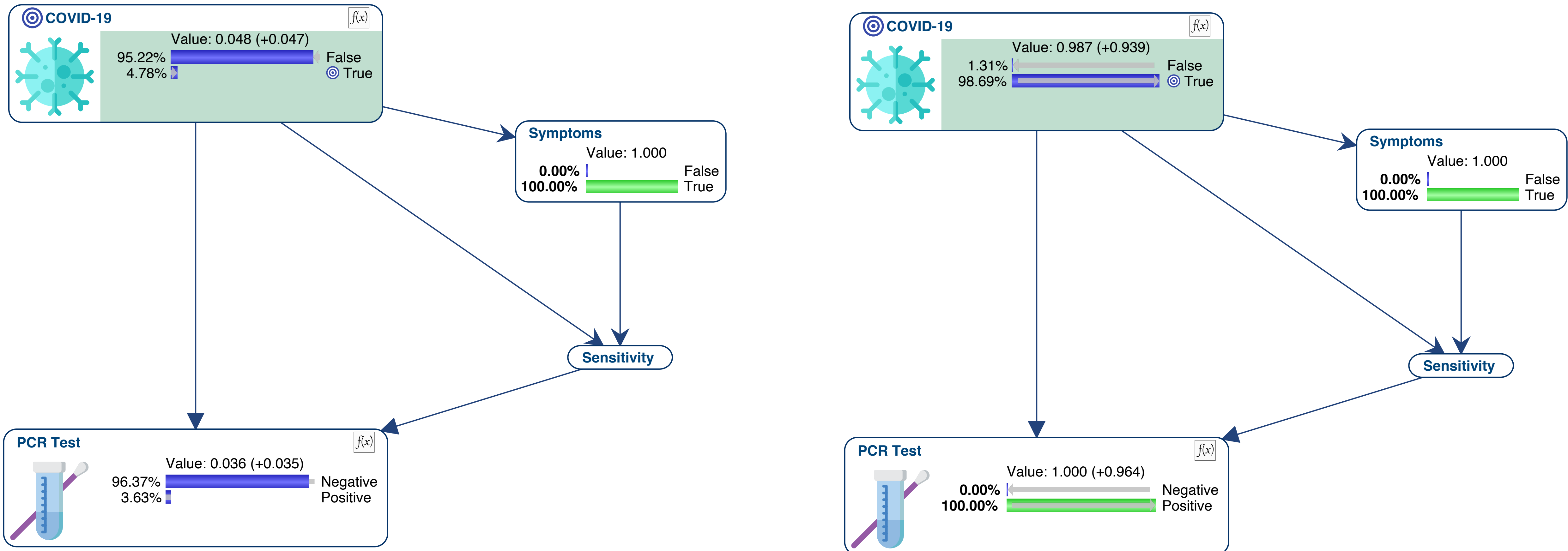
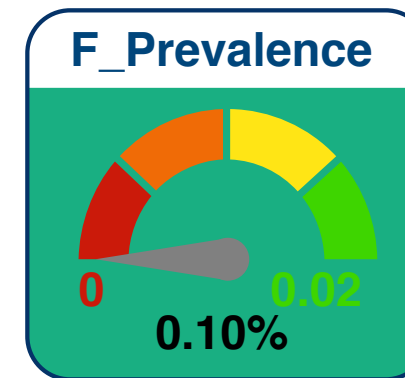
PCR Test - Augmented Model



PCR Test - Augmented Model - Asymptomatic



PCR Test - Augmented Model - Symptomatic



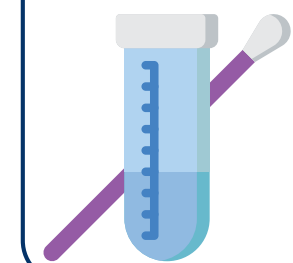
PCR Test - Impact of the Prevalence

Specificity

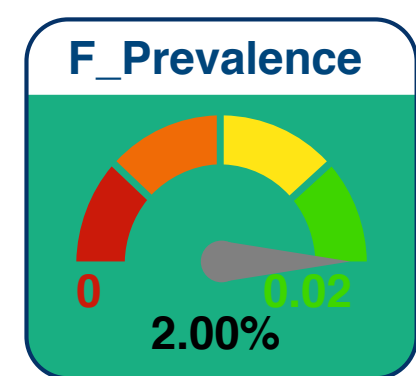
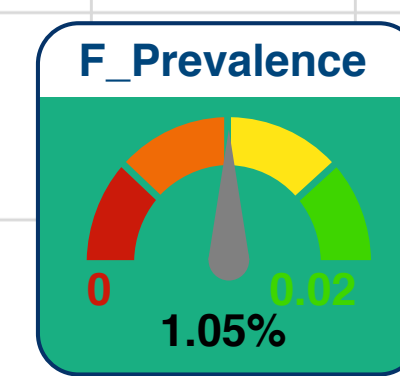
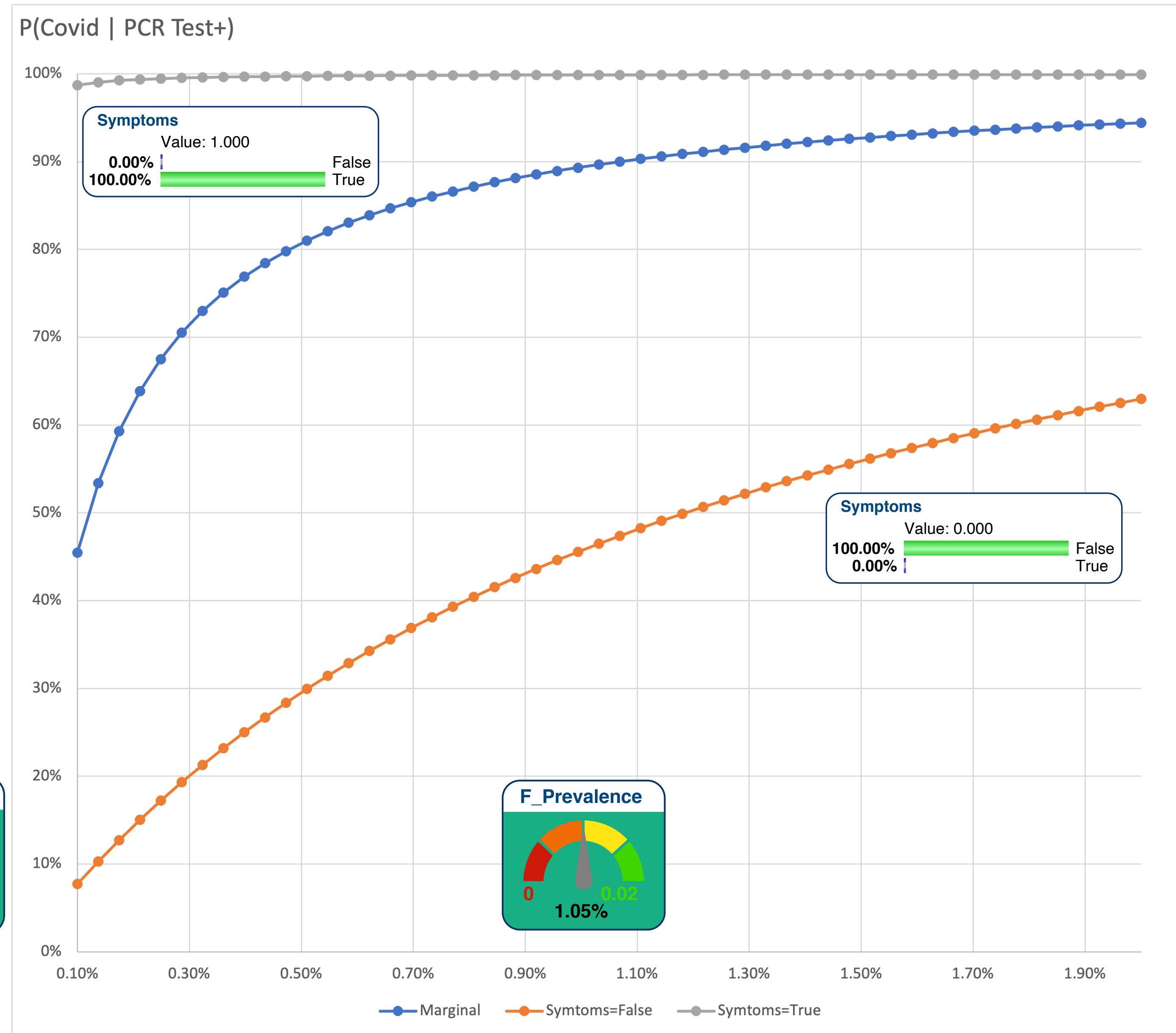
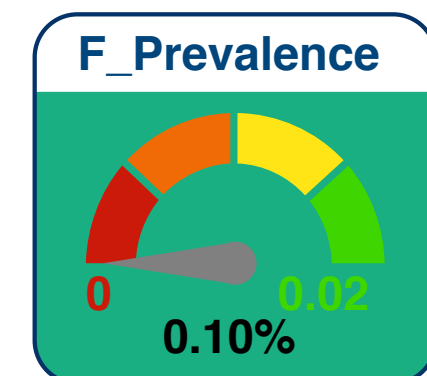
Mean: 0.999 Dev: 0.022
Value: 0.999

0.05% | False +
99.95% | True -

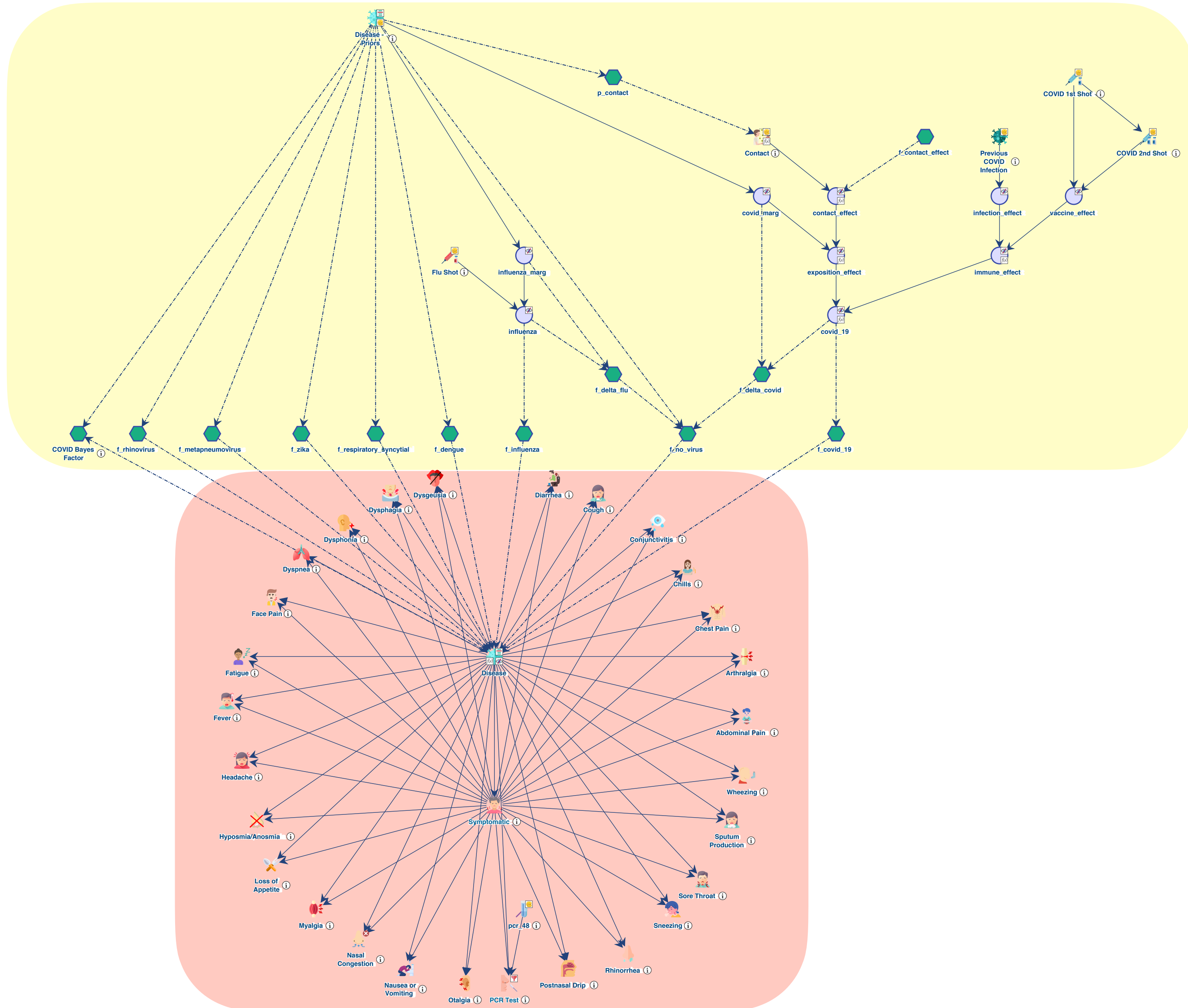
PCR Test



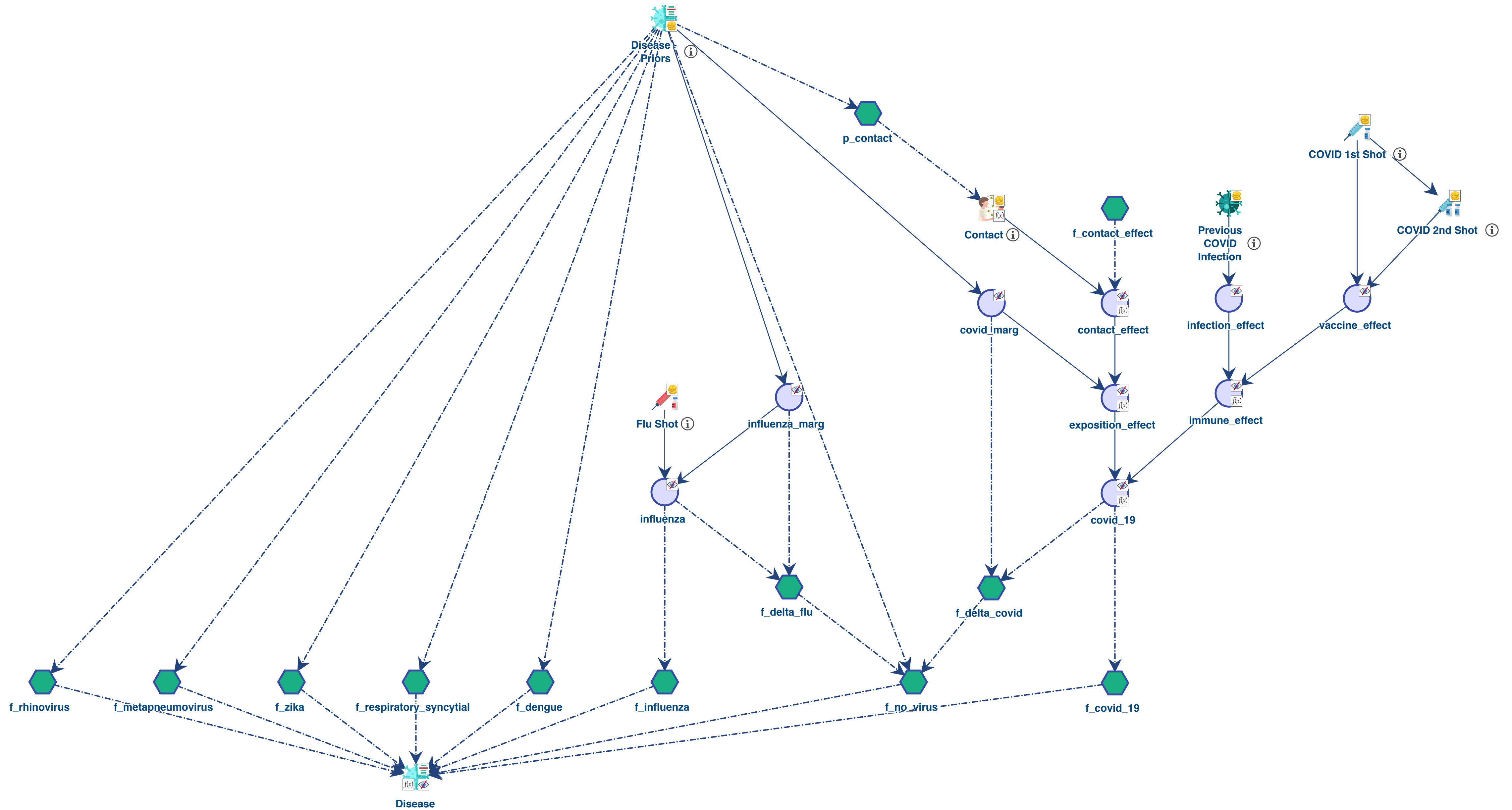
Value: 1.000
0.00% | Negative
100.00% | Positive



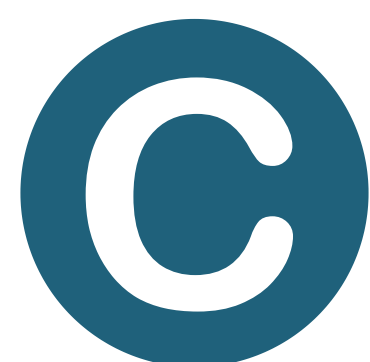
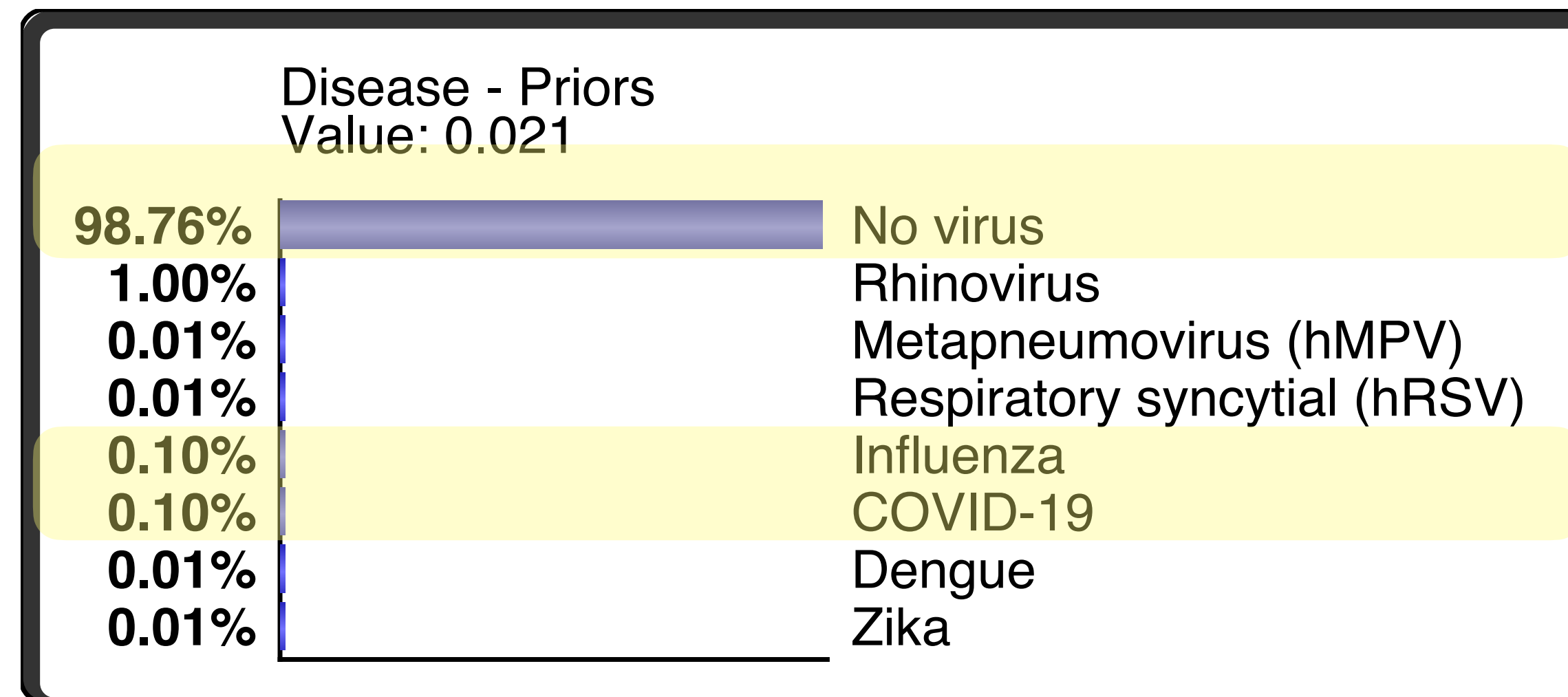
Covid-19 Model



Covid-19 Model - Upper Part (Context)

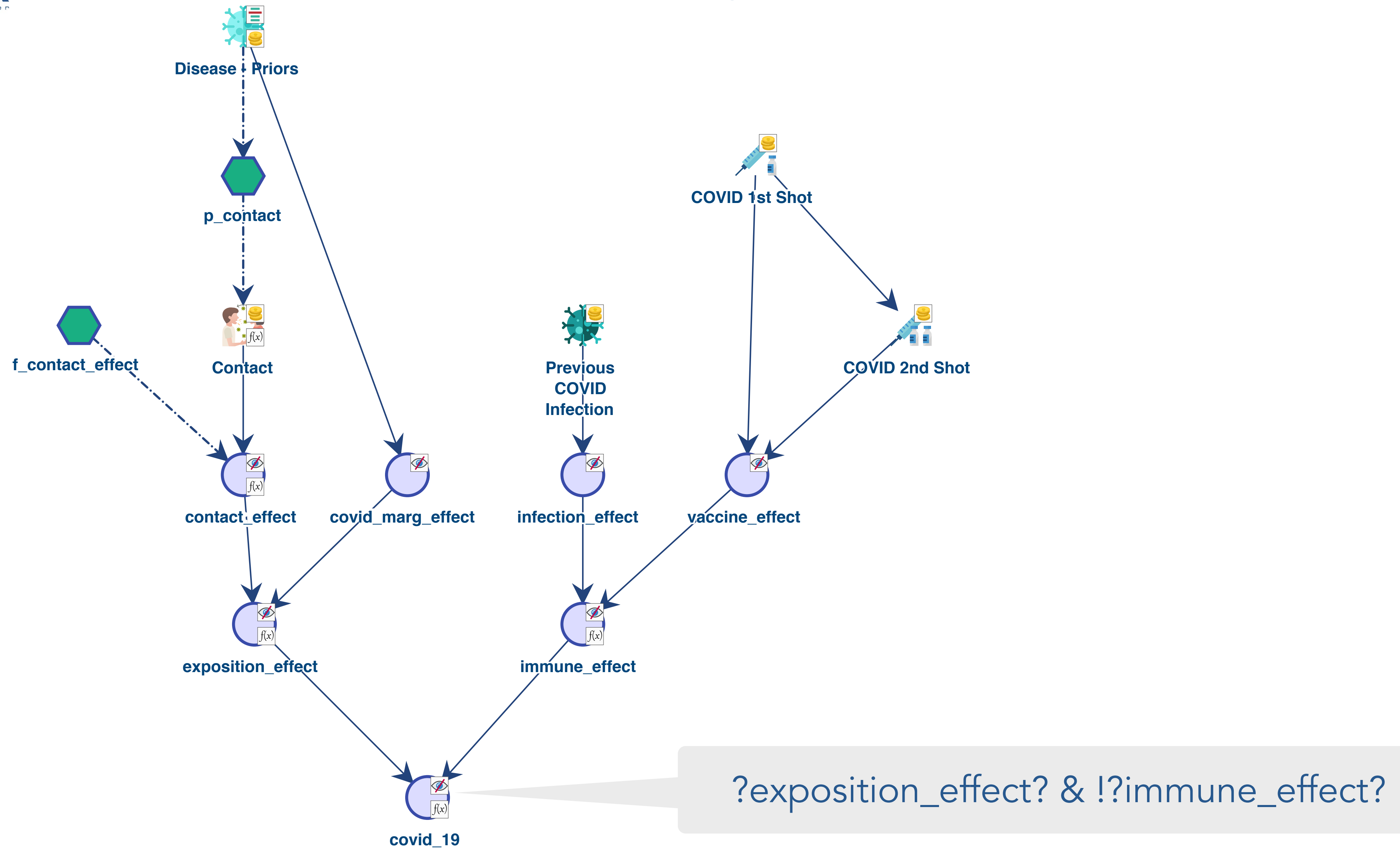


Priors

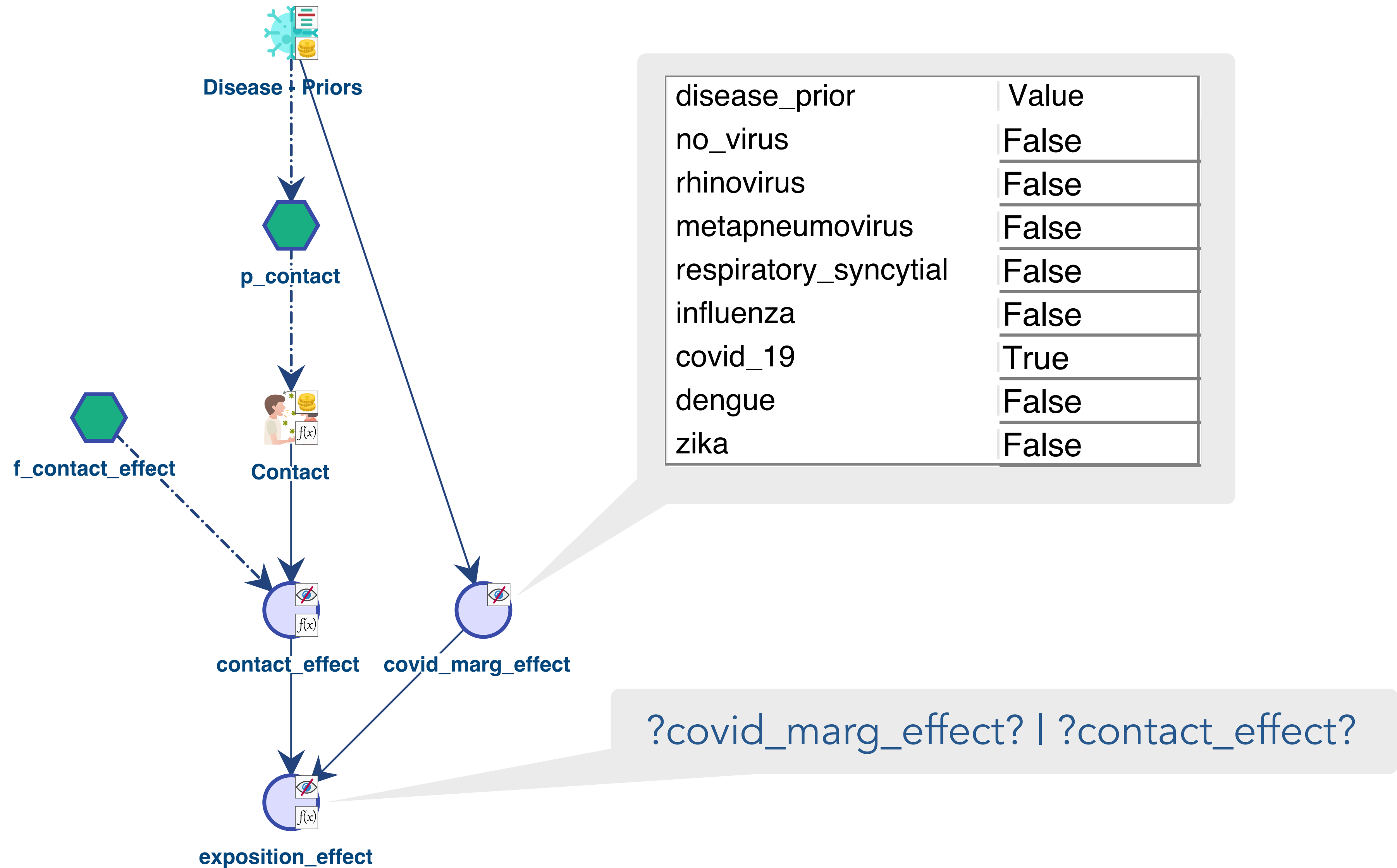


Name (2)	Type	Value
R	Real	1.15
NbContacts	Integer	10

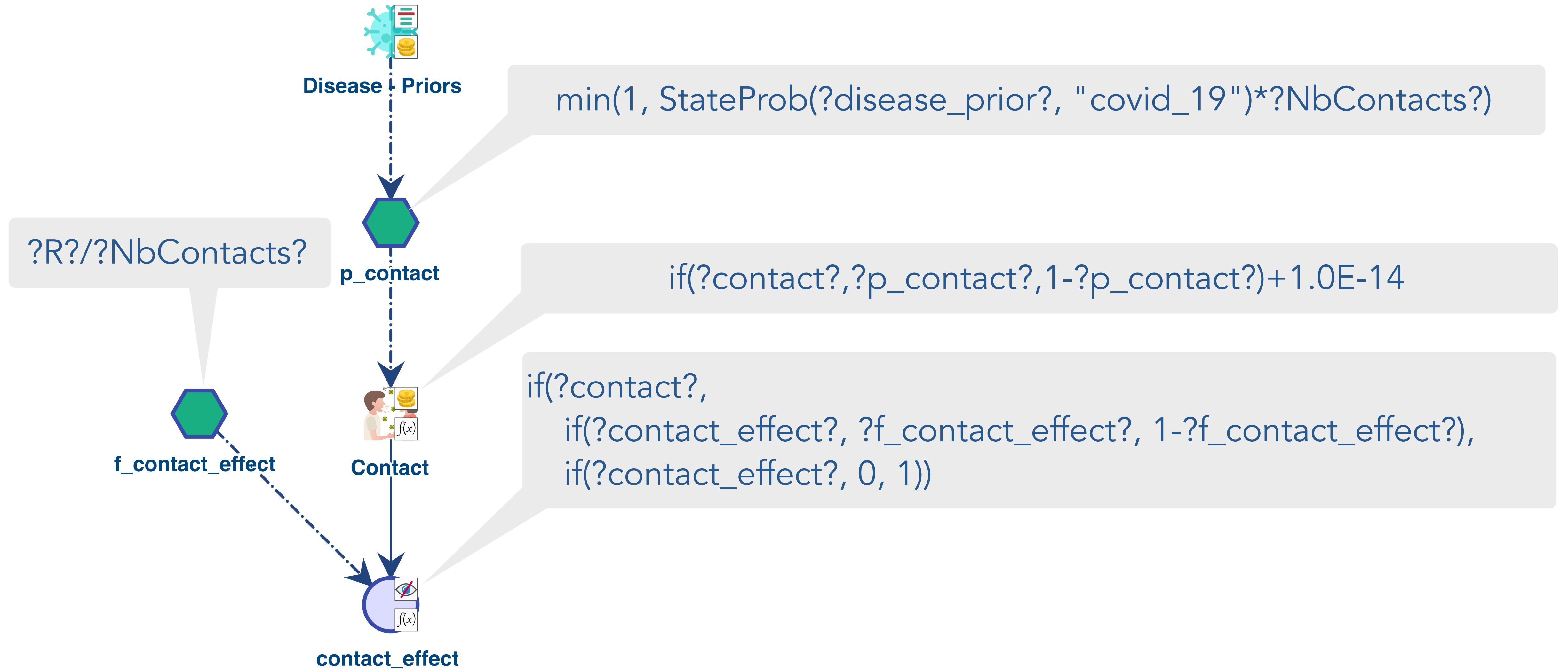
Covid Probability with Context



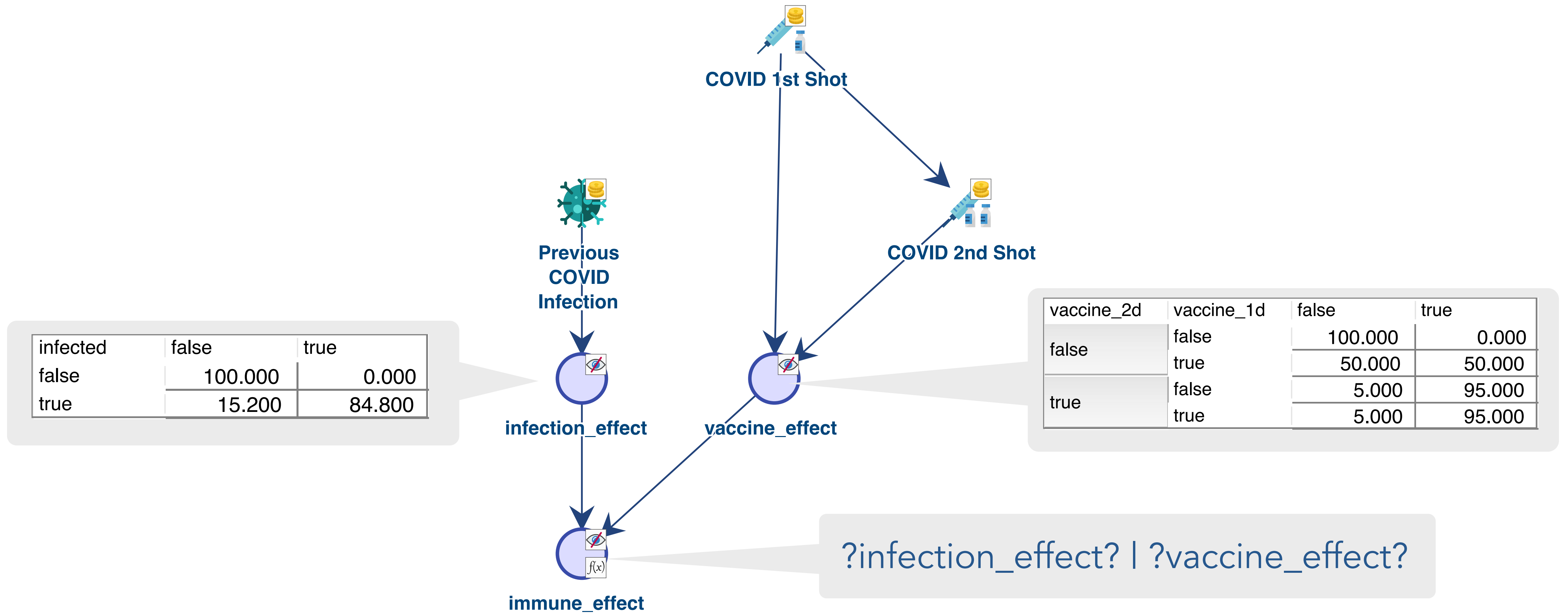
Exposition Effect



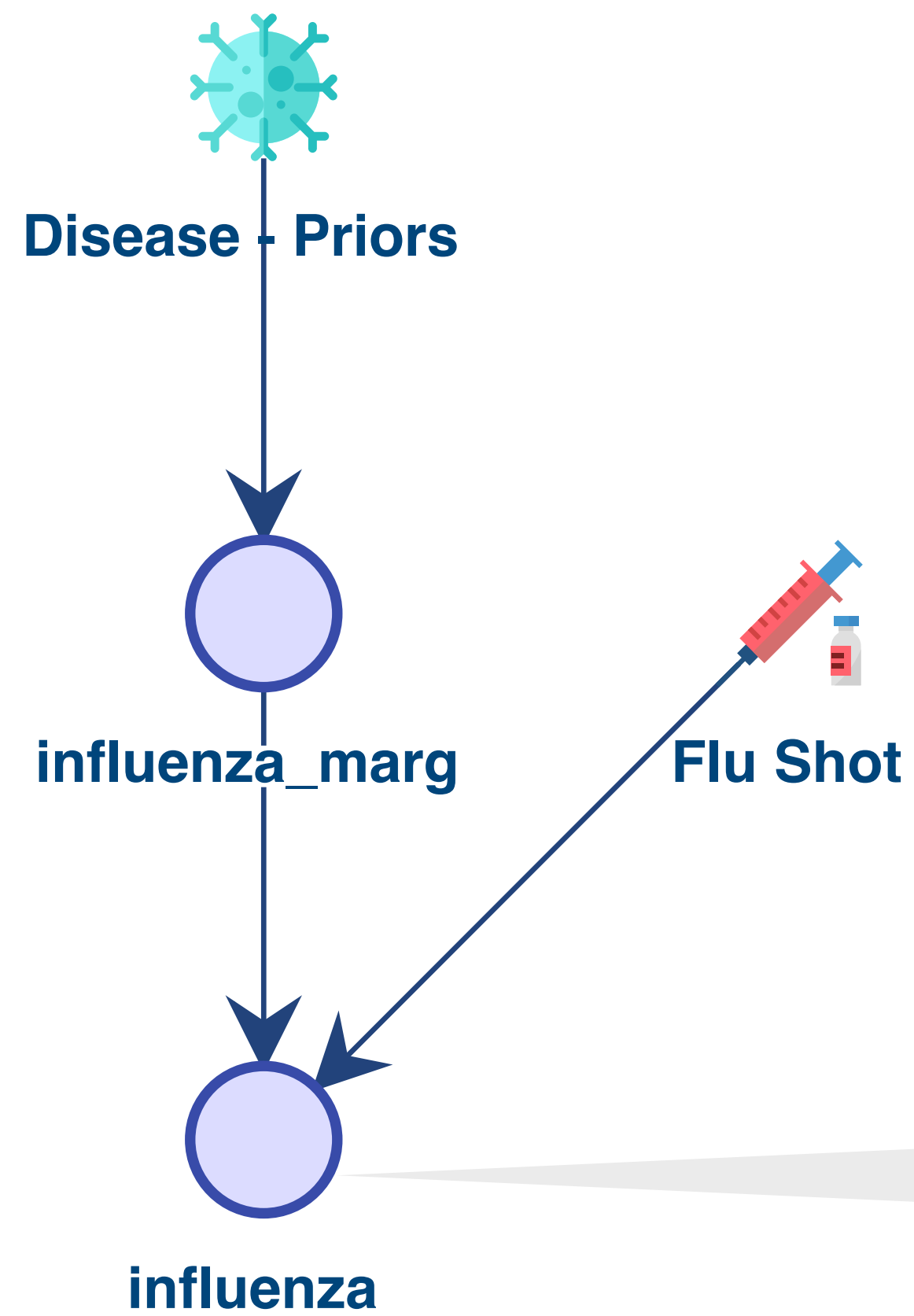
Contact Effect



Immune Effect

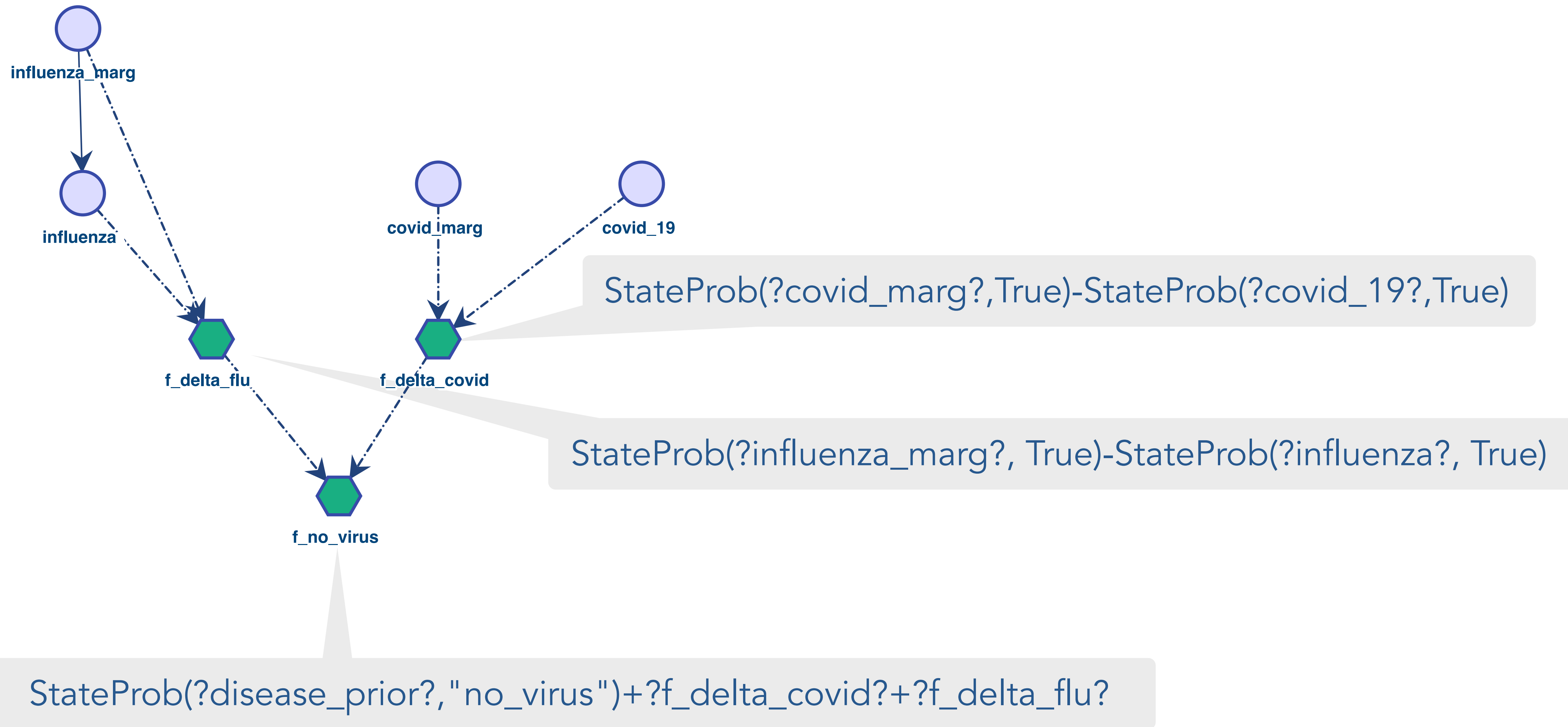


Flu Probability with Context

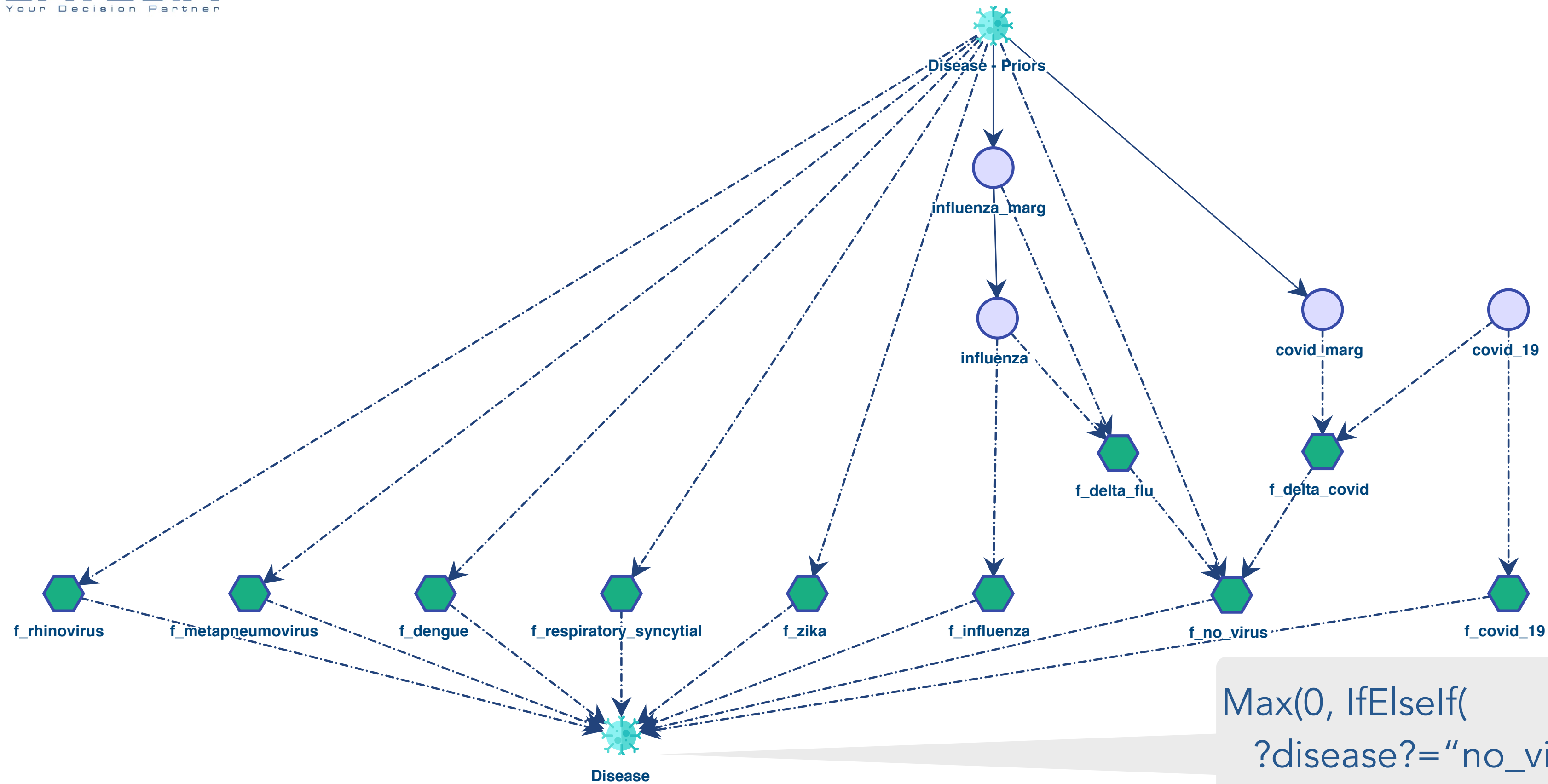


influenza_...	flu_shot	False	True
False	false	100.000	0.000
	true	100.000	0.000
True	false	0.000	100.000
	true	50.000	50.000

Deltas with Context



Diseases Probabilities with Deltas



```
Max(0, IfElseIf(
  ?disease?="no_virus", ?f_no_virus?,
  ?disease?="rhinovirus", ?f_rhinovirus?,
  ?disease?="metapneumovirus", ?f_metapneumovirus?,
  ?disease?="respiratory_syncytial", ?f_respiratory_syncytial?,
  ?disease?="influenza", ?f_influenza?,
  ?disease?="covid_19", ?f_covid_19?,
  ?disease?="dengue", ?f_dengue?,
  ?f_zika?))
```



Conditional Probabilities given by a group of Doctors

Assessment Editor

disease

covid_19

false	true	Expert	Confidence	Comment	Time
20	80	Mathilde L...	1		0
9	91	UMons MS	1		0
12	88	UMons MG	1		0
53.2	46.8	Alma Tost...	1		0
40	60	Melina Mic...	1		0
32	68	Carol Yan	1		0
56	44	Caroline A...	1		0
35	65	Carlos Chi...	1		0
30	70	Rossana C...	1		0
70	30	Carlos Fri...	1		0
30	70	Jesus Enri...	1		0

Add

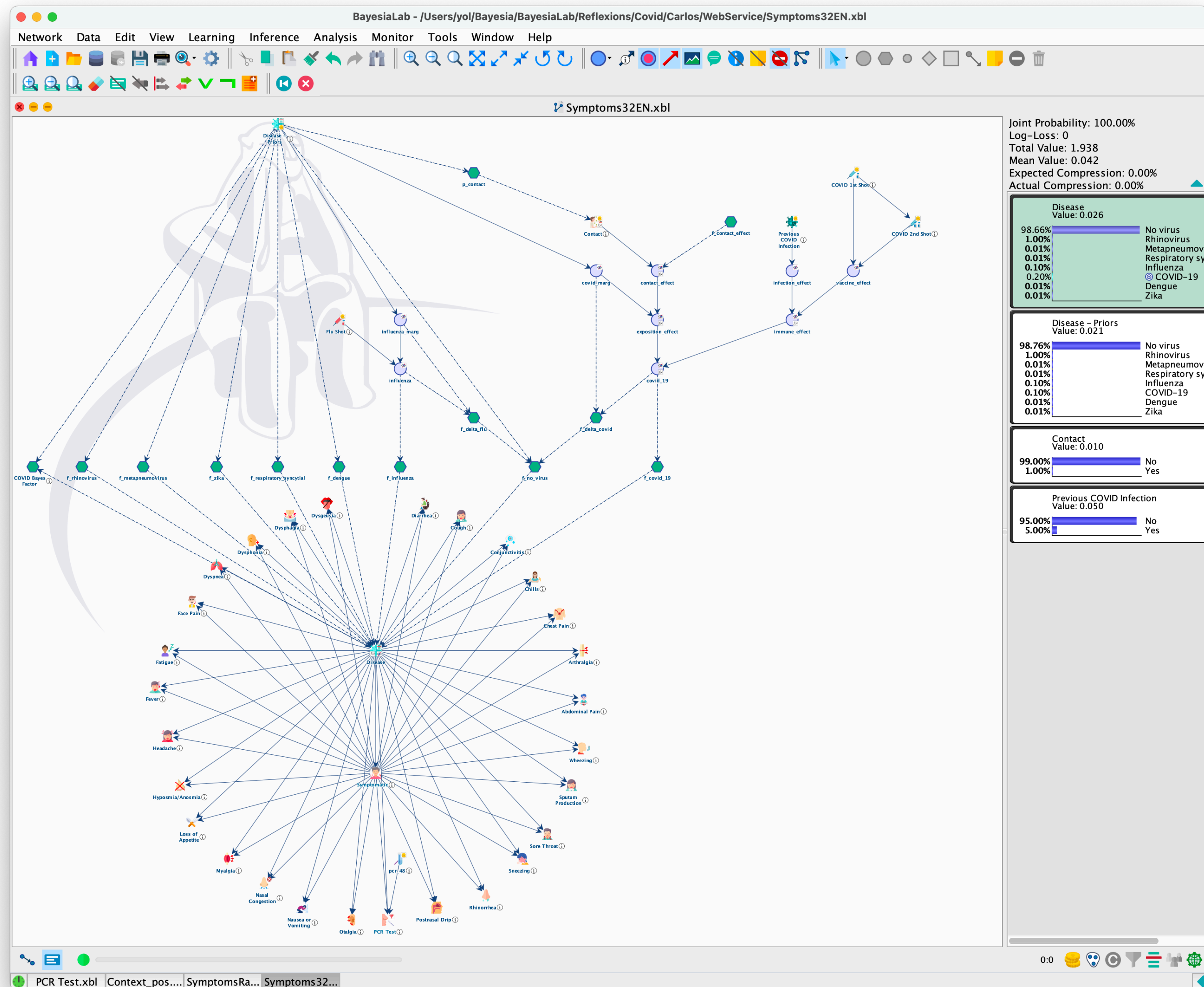
Delete

OK

Cancel

disease	false	true
no_virus	95.192	4.808
rhinovirus	71.105	28.895
metapneumovirus	80.153	19.847
respiratory_syncytial	77.483	22.517
influenza	93.572	6.428
covid_19	34.697	65.303
dengue	100.0...	0.000
zika	91.667	8.333

BayesiaLab Adaptive Questionnaire



BayesiaLab WebSimulator

Available Nodes

abdominal_pain
arthralgia
bf_covid
chest_pain
chills
conjunctivitis
contact_effect
contact
cough
covid_19
covid_marg
diarrhea
disease_prior
disease
dysgeusia
dysphagia
dysphonia
dyspnea
exposition_effect
f_contact_effect
f_covid_19
f_delta_covid
f_delta_flu
f_dengue
f_influenza
f_metapneumovirus
f_no_virus
f_respiratory_syncytial
f_rhinovirus
f_zika
face_pain
fatigue
fever
flu_shot
headache
hyposmia_anosmia
immune_effect
infected
infection_effect
influenza_marg
influenza
loss_of_appetite
myalgia
nasal_congestion
nausea_or_vomiting
otalgia
p_contact
postnasal_drip
rhinorrhea
sneezing
sore_throat
sputum_production
vaccine_1d
vaccine_2d

Available Metrics

Joint Probability
Log Loss

WebSimulator Editor

Simulator

Inputs

Outputs

Name

Differential Diagnosis of COVID-19 and Influenza-Like Diseases

Title

Differential Diagnosis of COVID-19 and Influenza-Like Diseases (FOR EXPERIMENTAL USE ONLY)

Author

Lionel Jouffe - Bayesia

Field of Study

Medicine and Health Care

Analysis Type

Evidential Reasoning

Theme Color

✓

Description

The application is provided free of charge. The completeness, accuracy, timeliness of the information and content made available in this application, or its suitability for particular purposes, is not guaranteed.

The user acknowledges that the application does not constitute in any way an opinion, recommendation, examination, diagnosis, prescription, or any other act of a medical nature established or performed by a physician or pharmacist. The use of the application and its contents in no way replaces the necessary advice given by your doctor or pharmacist or any other competent health professional in each individual case.

Description Picture



✓



Logo Picture



✓

Logo URL

https://forum.bayesia.us/category/covid

Font Size

Normal

Input Layout

Flow

History Layout

Flow

Output Layout

Flow

Show Variations

✓

Reference State

✓

Targets

disease

OK

Cancel

Preview

 Differential Diagnosis of COVID-19 and Influenza-Like Diseases (FOR EXPERIMENTAL USE ONLY)

Adaptive Questionnaire

Differential Diagnosis of COVID-

→













Disease - Priors

No virus

98.76%

☐

Rhinovirus

1.00%

☐

Metapneumovirus (hMPV)

0.01%

☐

Respiratory syncytial (hRSV)

0.01%

☐

Influenza

0.10%

☐

COVID-19

0.10%

☐

Dengue

0.01%

☐

Zika

0.01%

☐

☐ Observed



COVID 1st Shot



No

☐

Yes

☐

☐ Observed

Disease

No virus

87% (-11%)

Rhinovirus

1% (0%)

Metapneumovirus (hMPV)

0% (0%)

Respiratory syncytial (hRSV)

0% (0%)

Influenza

0% (0%)

COVID-19

11% (11%)

Dengue

0% (0%)

Zika

0% (0%)



COVID Bayes Factor

114.551
2.034

COVID 2nd Shot



No

☐

Yes

☐

☐ Observed

Symptomatic



No

☐

Yes

☐

☐ Observed

Hyposmia/Anosmia



No

☐

Yes

☐

☐ Observed

Cough



No

☐

Yes

☐

☐ Observed

Previous COVID Infection



No

☐

Yes

☐

☐ Observed

Contact



No

☐

Yes

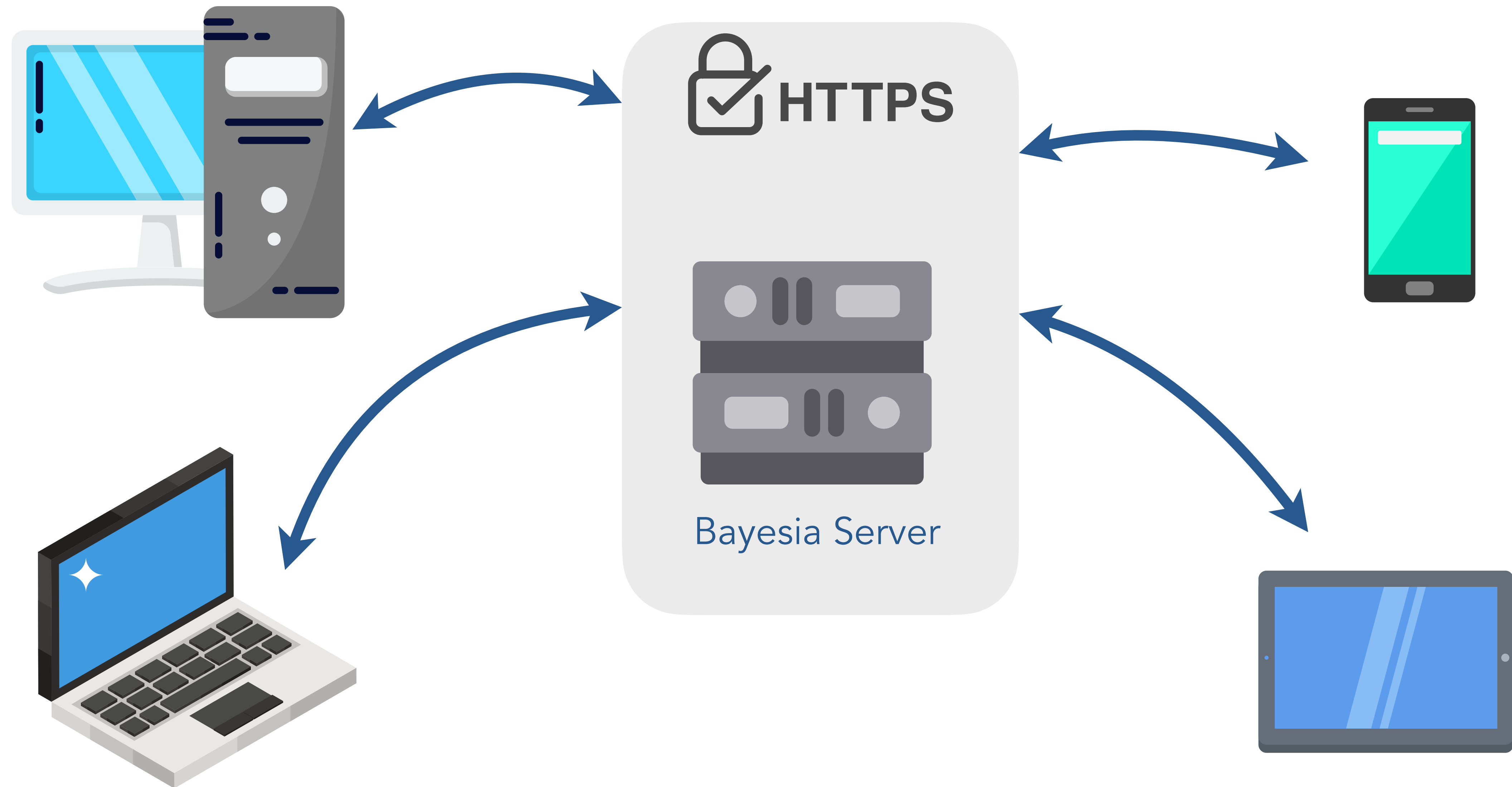
☐

☐ Observed

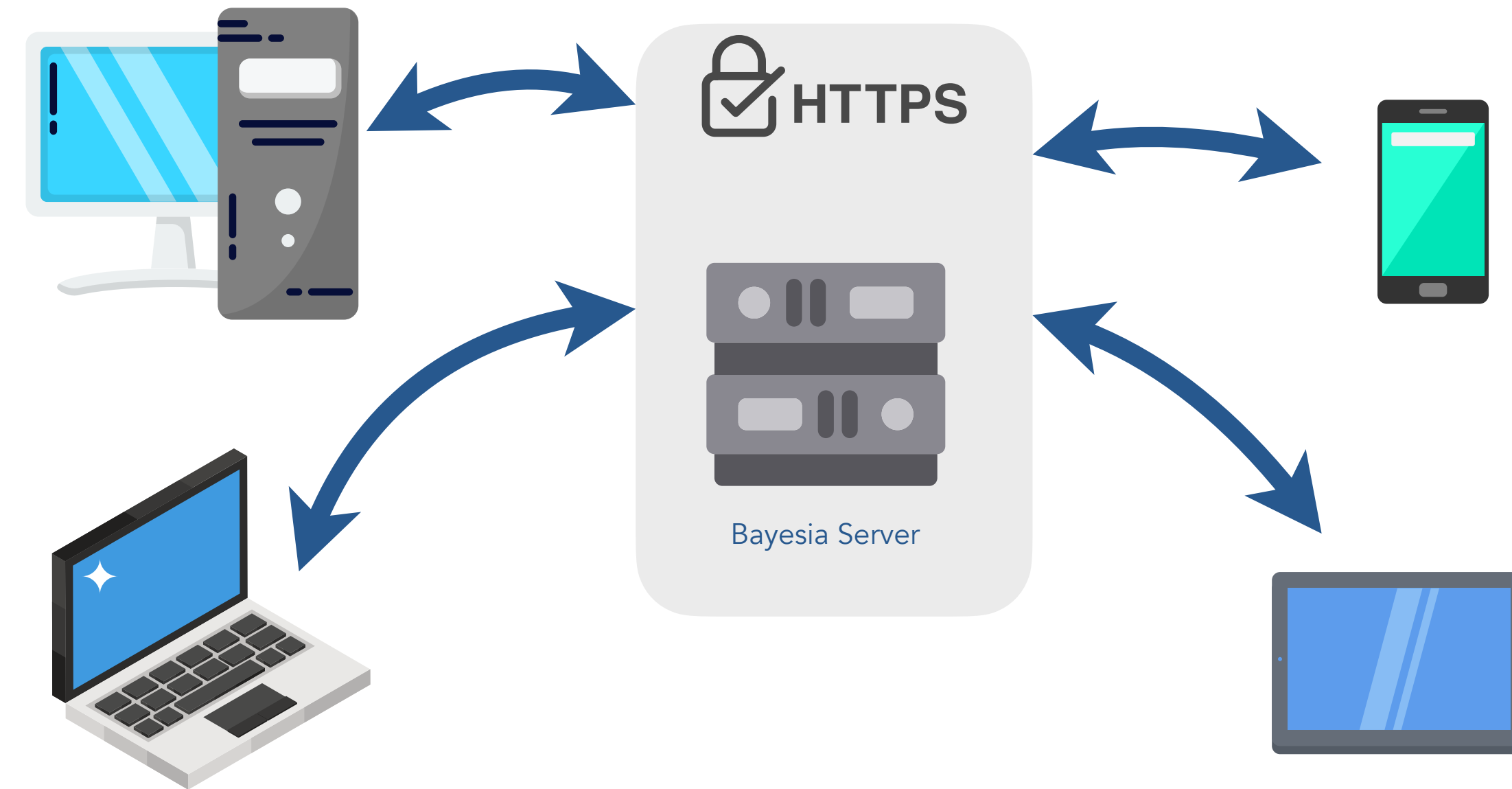
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Bayesia Covid-19 REST API



Bayesia Covid-19 REST API

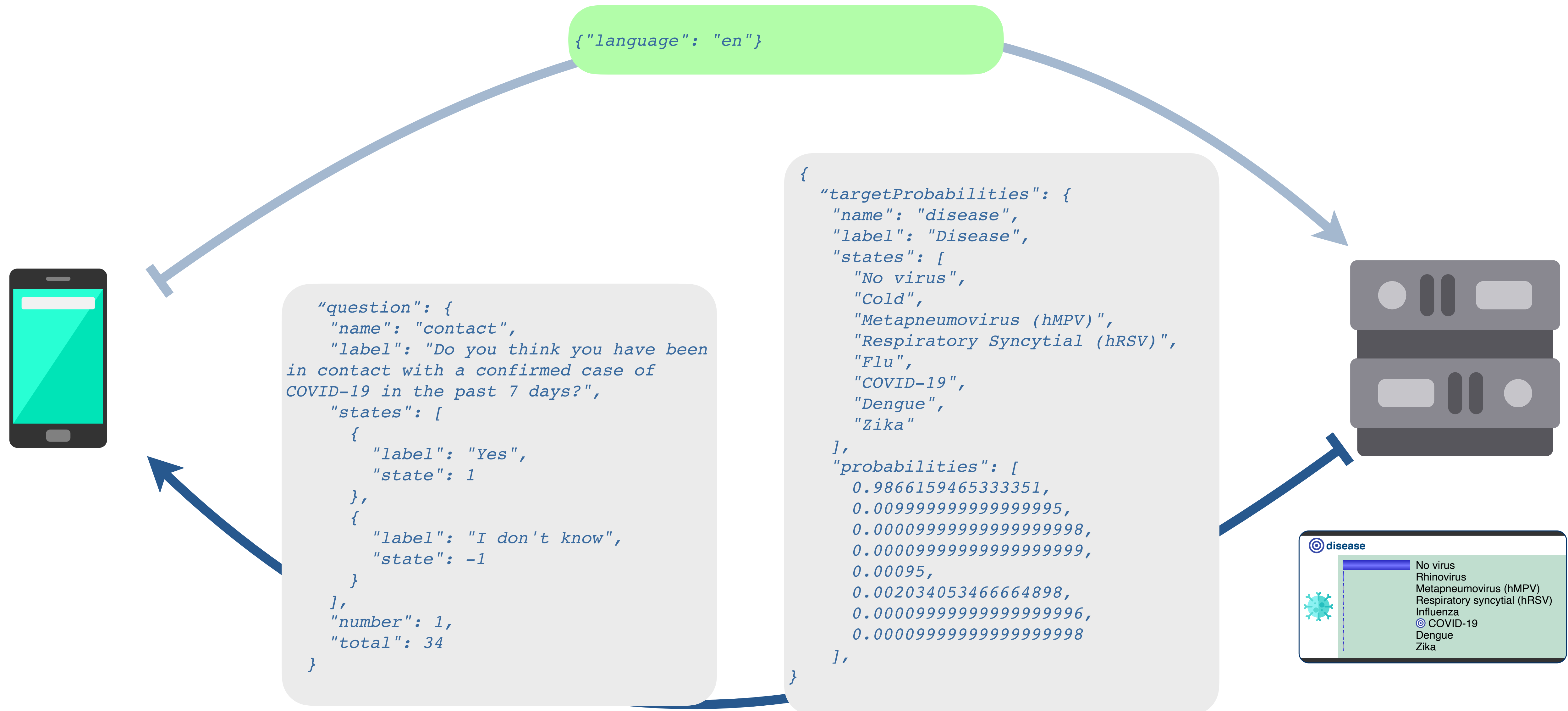


The pieces of evidence are sent in HTTPS to the WebService

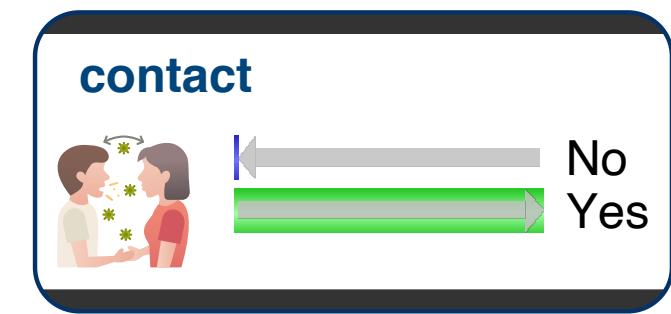
The WebService returns the posterior probability distribution of the Target node Disease and the next question

Each request sent to the WebService carries all the information associated with the diagnosis session

Bayesia Covid-19 REST API - Example Step 1



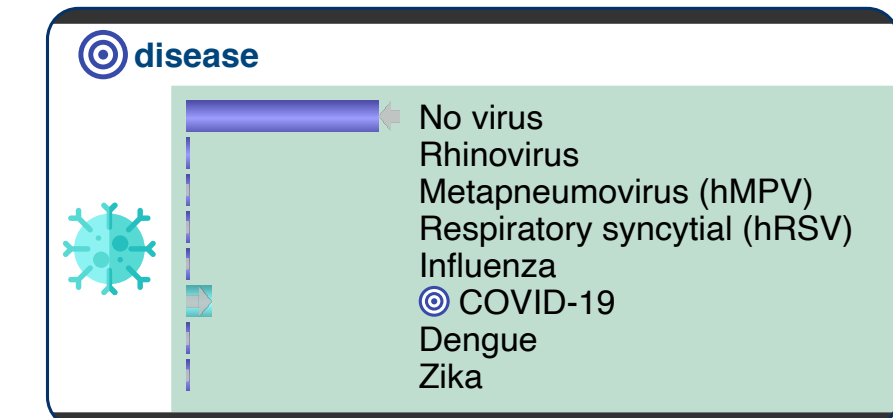
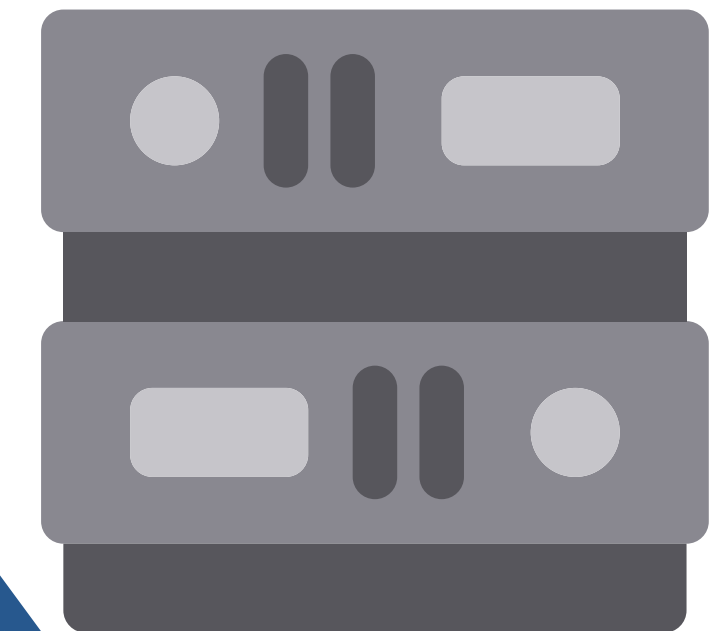
Bayesia Covid-19 REST API - Example Step 2



```
{
  "language": "en",
  "observations": [
    {
      "name": "contact",
      "state": 1
    }
  ]
}
```

```
{
  "question": {
    "name": "infected",
    "label": "Did you get COVID during the last 6 months?",
    "states": [
      {
        "label": "Yes",
        "state": 1
      },
      {
        "label": "No",
        "state": 0
      },
      {
        "label": "I don't know",
        "state": -1
      }
    ]
  },
  "number": 2,
  "total": 34
},
```

```
{
  "targetProbabilities": {
    "name": "disease",
    "label": "Disease",
    "states": [
      "No virus",
      "Cold",
      "Metapneumovirus (hMPV)",
      "Respiratory Syncytial (hRSV)",
      "Flu",
      "COVID-19",
      "Dengue",
      "Zika"
    ],
    "probabilities": [
      0.8789558445287765,
      0.009999999999999995,
      0.00009999999999999998,
      0.00009999999999999999,
      0.00094999999999999997,
      0.1096941554712233,
      0.00009999999999999996,
      0.00009999999999999998
    ]
  },
}
```



Bayesia Covid-19 REST API - Example Step 3

contact


☐ No
 ☒ Yes

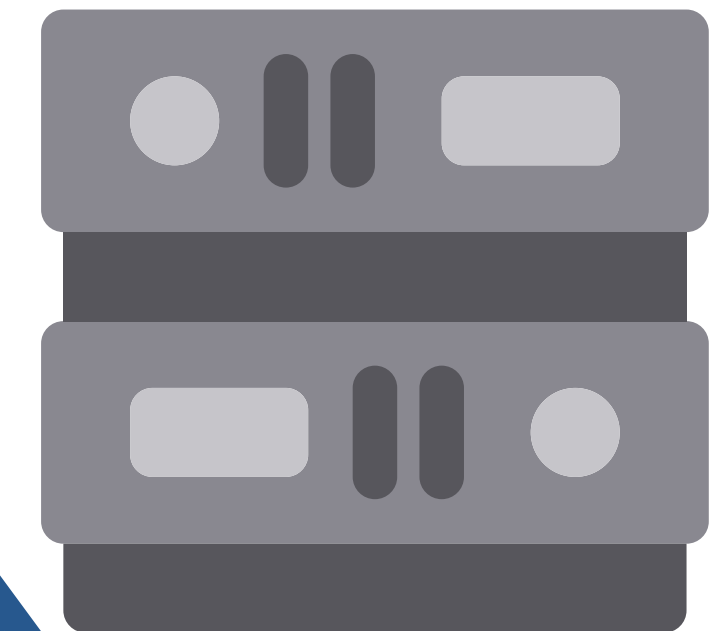
infected


☒ No
 ☐ Yes

```
{
  "language": "en",
  "observations": [
    { "name": "contact", "state": 1 },
    { "name": "infected", "state": 0 }
  ]
}
```

```
{
  "question": {
    "name": "vaccine_1d",
    "label": "Did you get your first shot of COVID vaccine?",
    "states": [
      {
        "label": "Yes",
        "state": 1
      },
      {
        "label": "No",
        "state": 0
      },
      {
        "label": "I don't know",
        "state": -1
      }
    ],
    "number": 3,
    "total": 34
  },
  "targetProbabilities": {
    "name": "disease",
    "label": "Disease",
    "states": [
      "No virus",
      "Cold",
      "Metapneumovirus (hMPV)",
      "Respiratory Syncytial (hRSV)",
      "Flu",
      "COVID-19",
      "Dengue",
      "Zika"
    ],
    "probabilities": [
      0.8740988769097501,
      0.009999999999999997,
      0.0001,
      0.00010000000000000002,
      0.00095000000000000002,
      0.11455112309024998,
      0.00009999999999999999,
      0.0001
    ]
  }
}
```

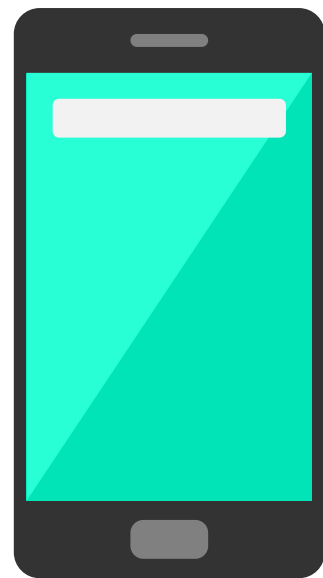
```
{
  "targetProbabilities": {
    "name": "disease",
    "label": "Disease",
    "states": [
      "No virus",
      "Cold",
      "Metapneumovirus (hMPV)",
      "Respiratory Syncytial (hRSV)",
      "Flu",
      "COVID-19",
      "Dengue",
      "Zika"
    ],
    "probabilities": [
      0.8740988769097501,
      0.009999999999999997,
      0.0001,
      0.00010000000000000002,
      0.00095000000000000002,
      0.11455112309024998,
      0.00009999999999999999,
      0.0001
    ]
  }
}
```




disease



☒ No virus
 ☐ Rhinovirus
 ☐ Metapneumovirus (hMPV)
 ☐ Respiratory syncytial (hRSV)
 ☐ Influenza
 ☒ COVID-19
 ☐ Dengue
 ☐ Zika



Bayesia Covid-19 REST API - Example Step 4

```
{
  "language": "en",
  "observations": [
    { "name": "contact", "state": 1 },
    { "name": "infected", "state": 0 },
    { "name": "vaccine_1d", "state": 0 }
  ]
}
```

```
{
  "question": {
    "name": "infected",
    "label": "Did you get COVID during the last 6 months?",
    "states": [
      {
        "label": "Yes",
        "state": 1
      },
      {
        "label": "No",
        "state": 0
      },
      {
        "label": "I don't know",
        "state": -1
      }
    ]
  },
  "number": 2,
  "total": 34
},
```

```
{
  "targetProbabilities": {
    "name": "disease",
    "label": "Disease",
    "states": [
      "No virus",
      "Cold",
      "Metapneumovirus (hMPV)",
      "Respiratory Syncytial (hRSV)",
      "Flu",
      "COVID-19",
      "Dengue",
      "Zika"
    ],
    "probabilities": [
      0.8789558445287765,
      0.009999999999999995,
      0.00009999999999999998,
      0.00009999999999999999,
      0.00094999999999999997,
      0.1096941554712233,
      0.00009999999999999996,
      0.00009999999999999998
    ]
  },
}
```

contact

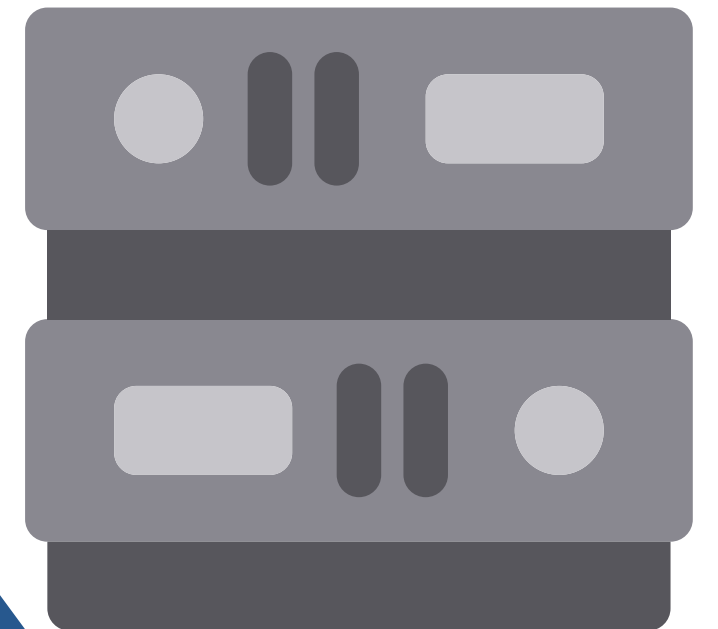
☐ No
☒ Yes

infected

☐ No
☒ Yes

vaccine_1d

☐ No
☒ Yes



disease


☒ No virus
☐ Rhinovirus
☐ Metapneumovirus (hMPV)
☐ Respiratory syncytial (hRSV)
☒ Influenza
☐ COVID-19
☐ Dengue
☐ Zika

REST API - Swagger

<https://simcovidval.bayesialab.com/swagger-ui.html#/inference-service>

 **swagger**

Select a spec default

Bayesia Covid-19 Simulator Service 1.0.44

[Base URL: covid19wstest.bayesialab.com/]
<https://covid19wstest.bayesialab.com/v2/api-docs>

Webservice for Covid-19 discrimination

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basic-error-controller Basic Error Controller

inference-service API to perform adaptive questionnaire on the Covid19 Bayesian Network.

Models

FutCov Website & SEICov App

**Futcov**ES / EN / FR

What is your risk of having?

COVID-19**FLU****COLD**

Start[Legal notice](#)

The **RFEF** makes this tool available to its associates to help **differentiate the symptoms of COVID-19, flu or cold.**

The **RFEF Medical Services** in collaboration with experts in epidemiology, virology, immunology and data analysis have developed this tool, but remember that **the results are not a diagnostic test, but only an orientation.**

In collaboration with

**DATA FOR HOPE****CLOUD DISTRICT**

14:48



Check your symptoms for:

COLD

**FLU**

COVID

It only takes 2 minutes

Start

[Link to health information](#)