# CoronaViral Calculations

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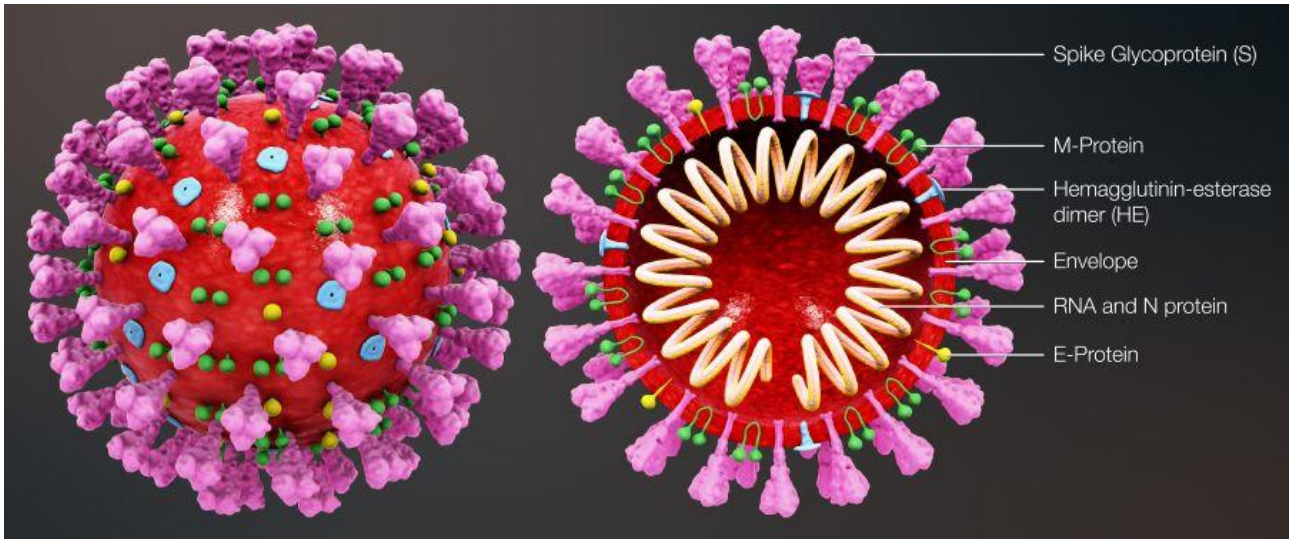
This document is a collection of ***data I found online*** (***DIFO***) and ***data I calculated approximately*** (***DICA***) based on DIFO. Since DIFO is always questionable and I have no medical degrees, the DICA presented below is also neither credible nor fit for any purpose.

## 1. Structure of Coronavirus

Coronavirus has a spherical shape with spikes on its surface.




## 2. Mass of Coronavirus

I could not find a direct report of the average weight of a single coronavirus, therefore I calculated an estimate based on DIFO for 3 other viruses.

| Virus | DIFO | Assumptions for DICA |
|---|---|---|
| **Corona** | Average diameter: 125 $nm$<br>Diameter of envelope: 85 $nm$<br>Length of spikes: 20 $nm$ | Shape is assumed to be a **sphere** with a 90 $nm$ diameter. |
| **Vaccinia** | Dimensions: $360 \times 270 \times 250\ nm$<br>Mass: $\sim 5 - 10 \times 10^{-18}\ kg$ | Shape is assumed to be an **ellipsoid** fitting inside a rectangular prism with the given dimensions. Mass is assumed to be $7.5 \times 10^{-18}\ kg$. |
| **Tobacco Mosaic** | Rod-like appearance:<br>300 $nm$ length and 18 $nm$ diameter<br>Mass: $6.8 \times 10^{-20}\ kg$ | Shape is assumed to be a **cylinder** with the given dimensions. Mass is used as given. |
| **Brome Mosaic** | Length: 28 $nm$<br>Mass: $7.6 \times 10^{-21}\ kg$ | Shape is assumed to be a **sphere** with the given length specifying the diameter. Mass is used as given. |

The calculations below involve approximating the densities of the 3 viruses with known volume and mass information, averaging them to get a ***mean viral density***, and calculating the mass of coronavirus based on this mean density.

***Vaccinia Virus*:**

$\{l, w, h\} = \{360\ nm, 270\ nm, 250\ nm\} = \{36 \times 10^{-6}\ cm, 27 \times 10^{-6}\ cm, 25 \times 10^{-6}\ cm\}$

$V = \frac{4}{3}\pi r_1 r_2 r_3 = 12723 \times 10^{-18}\ cm^3$

$m = 7.5 \times 10^{-18}\ kg = 7.5 \times 10^{-15}\ g$

$\rho = \frac{m}{V} = \frac{7.5 \times 10^{-15}\ g}{12723 \times 10^{-18}\ cm^3} = 0.5895\ g/cm^3$

***Tobacco Mosaic Virus*:**

$\{l, d\} = \{300\ nm, 18\ nm\} = \{3 \times 10^{-5}\ cm, 18 \times 10^{-7}\ cm\}$

$V = \pi r^2 l = 763.4 \times 10^{-19}\ cm^3$

$m = 6.8 \times 10^{-20}\ kg = 6.8 \times 10^{-17}\ g$

$\rho = \frac{m}{V} = \frac{6.8 \times 10^{-17}\ g}{763.4 \times 10^{-19}\ cm^3} = 0.8908\ g/cm^3$

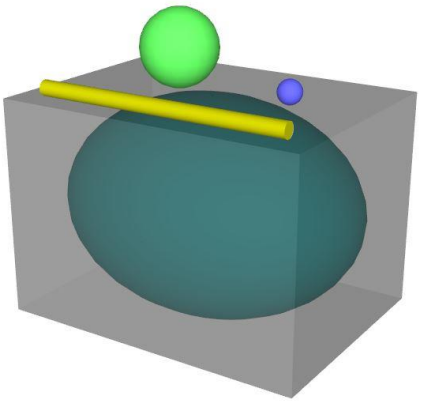
***Brome Mosaic Virus*:**

$d = 28\ nm = 28 \times 10^{-7}\ cm$

$V = \frac{4}{3}\pi r^3 = 11494 \times 10^{-21}\ cm^3$

$m = 7.6 \times 10^{-21}\ kg = 7.6 \times 10^{-18}\ g$

$\rho = \frac{m}{V} = \frac{7.6 \times 10^{-18}\ g}{11494 \times 10^{-21}\ cm^3} = 0.6612\ g/cm^3$



Shape assumptions for viruses.
Drawn to scale with respect to each other.

***Mean Viral Density*:**

$$\bar{\rho}_v = \frac{0.5895 + 0.8908 + 0.6612}{3} = 0.7138\ g/cm^3$$

***Coronavirus*:**

$d = 90\ nm = 90 \times 10^{-7}\ cm = 9 \times 10^{-6}\ cm$

$V = \frac{4}{3}\pi r^3 = 381.7 \times 10^{-18}\ cm^3$

$$\tilde{m} = V \times \bar{\rho}_v = 272.46 \times 10^{-18}\ g = 272.46 \times 10^{-21}\ kg$$

Volumes and masses of viruses in terms (units) of **Brome Mosaic Virus** are noted below:

| Virus | Volume in Brome Mosaic | Mass in Brome Mosaic |
|---|---|---|
| **Tobacco Mosaic** | 6.64 $V_{BM}$ | 8.95 $m_{BM}$ |
| **Corona** | 33.21 $V_{BM}$ | 35.85 $m_{BM}$ |
| **Vaccinia** | 1106.93 $V_{BM}$ | 986.84 $m_{BM}$ |

### 3. One Gram of Coronaviruses

$$Count = N_g = \frac{1\ g}{272.46 \times 10^{-18}\ g} = 0.00367 \times 10^{18} = 3.67 \times 10^{15}$$

$$Volume = V_g = N \times V = \frac{381.7 \times 10^{-18}\ cm^3}{272.46 \times 10^{-18}} = 1.4\ cm^3$$

### 4. Total Number, Volume and Mass of Coronaviruses on Earth

The list of relevant (and also some interesting) DIFO is as follows:

1. As of Friday, July 10, 2020, according to Johns Hopkins University Covid-19 data, there are 5,105,214 (~$5.1 \times 10^6$) active cases worldwide.
2. If all the $10^{31}$ viruses on earth were laid end to end, they would stretch for 100 million light years.
3. If you piled up all the viruses—more than $10^{30}$ of them—in one place, they would be the size of a small mountain.
4. If you gathered all the viruses in all the humans in the world, they would fill about ten oil drums.
5. Across all the people in the world, there probably exists about a spoonful worth of HIV[1].
6. The typical healthy human body contains about $3 \times 10^{12}$ viruses.
7. 1 virus-infected cell can produce 100s to 1000s of viruses.
8. Burst size of MHV (Murine Herpes Virus, a model $\beta$-coronavirus on which much laboratory research has been conducted) is ~$10^3$ virions.
9. If you get sick with the flu, every infected cell in your airway produces about 10000 new viruses.
10. The total number of flu viruses in your body can rise to 100 trillion ($100 \times 10^{12}$) within a few days.
11. The human body consists of some 37.2 trillion ($37.2 \times 10^{12}$) cells.
12. Coronavirus host cells per person[2]:
    a. Type I and II pneumocytes: ~$10^{11}$ cells
    b. Alveolar macrophage: ~$10^{10}$ cells
    c. Mucous cells in nasal cavity: ~$10^9$ cells
    d. Host cell volume: ~$10^3\ \mu m^3 = 10^3\ fL = 10^{-12}\ L = 10^{-9}\ cm^3$

$$\sum cells = 111 \times 10^9$$

$$\sum volume = 111\ cm^3$$

Now, let us work backwards first to establish some baseline: Assume that there is a total of 1 gram of coronaviruses on earth that are equally distributed among all active cases, and there are no other coronaviruses elsewhere in the world. In this case every active person has about 720 million coronaviruses in their bodies:

$$N_{person} = \frac{N_g}{5.1 \times 10^6} = \frac{3.67 \times 10^{15}}{5.1 \times 10^6} = 7.196 \times 10^8 = 719.6 \times 10^6$$

This number is significantly lower than DIFO number 10 in the above list. Therefore, let us work forwards next, and assume that every active person has $10^{14}$ coronaviruses in their bodies. In this case:

$$N_{total} = 5.1 \times 10^6 \times 10^{14} = 5.1 \times 10^{20}$$

$$V_{total} = N_{total} \times V = 5.1 \times 10^{20} \times 381.7 \times 10^{-18} = 194667\ cm^3 \cong 195\ L$$

$$M_{total} = N_{total} \times \tilde{m} = 5.1 \times 10^{20} \times 272.46 \times 10^{-18} = 138955\ g \cong 139\ kg$$

Those numbers do not seem to agree with DIFO numbers 4 and 5 in the list above. Therefore, we will just end up with overly conservative boundaries for the DICA in this section.

[1] https://what-if.xkcd.com/80/

[2] https://raw.githubusercontent.com/milo-lab/SARS-CoV-2/master/versions/SARS-CoV-2_BTN.pdf