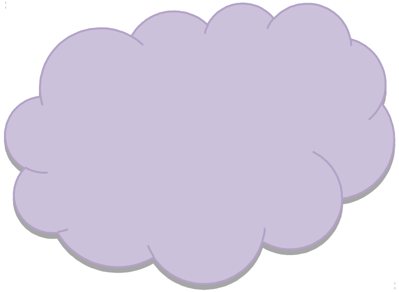
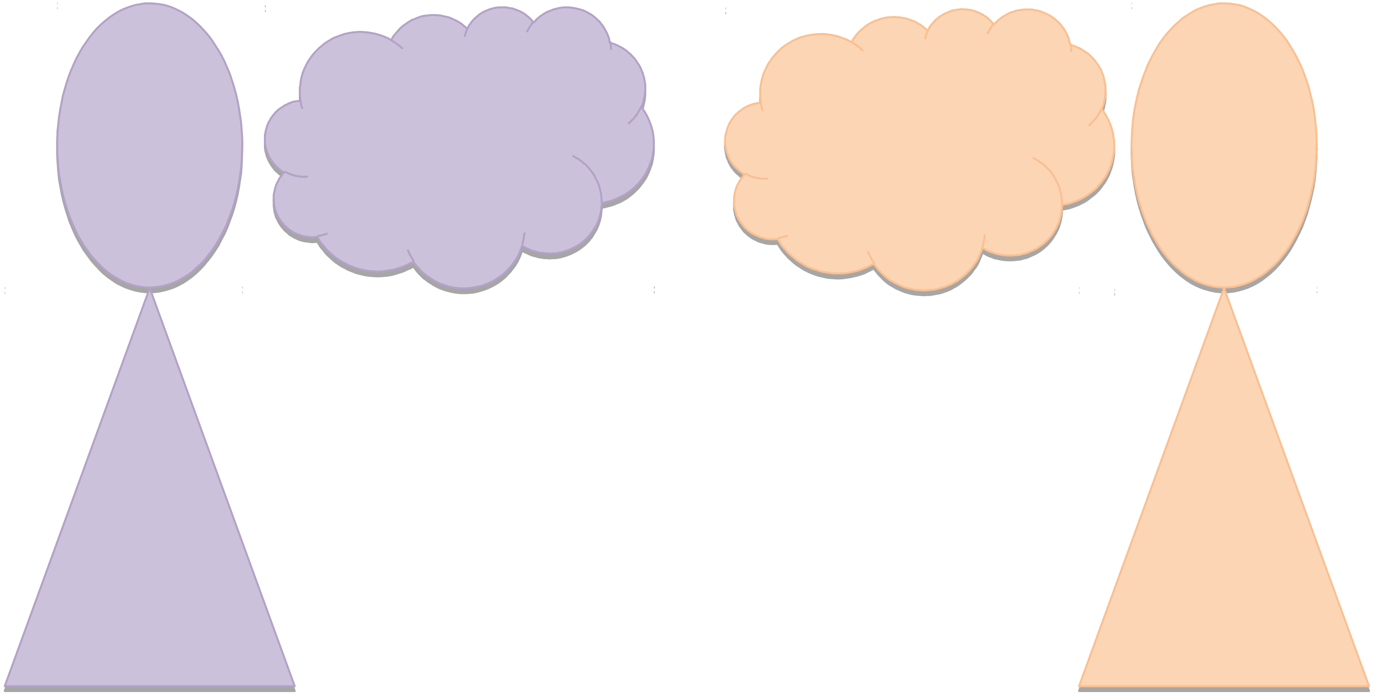


How Viruses Spread Through Breath

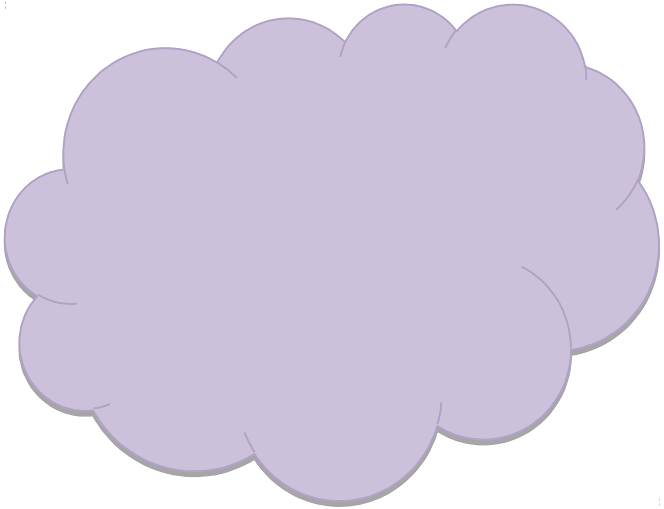
Current version available at orange-carb.org/virus

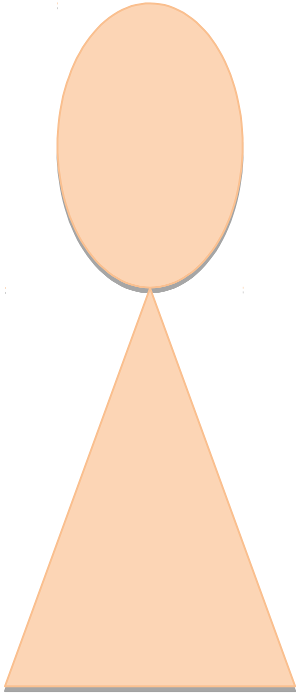
V.1.0.1, Schellinck, 2020-04-08

How could a virus spread during direct interactions?



How could a virus spread in the space where an infected person has been?

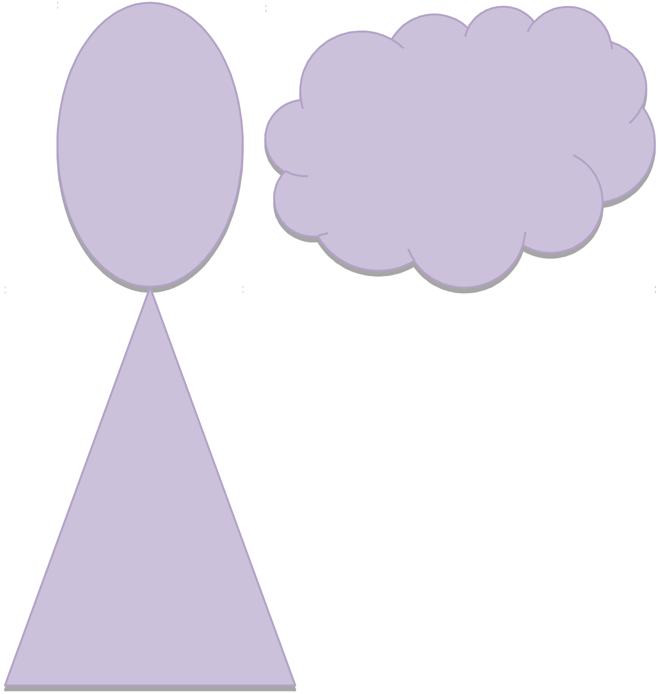




If we knew the answers to these questions, it might help us to better understand the advice we've been hearing,

about physical distancing, hand washing, and other precautions.

To answer these questions we need to know about several things:



How breath spreads out from a person

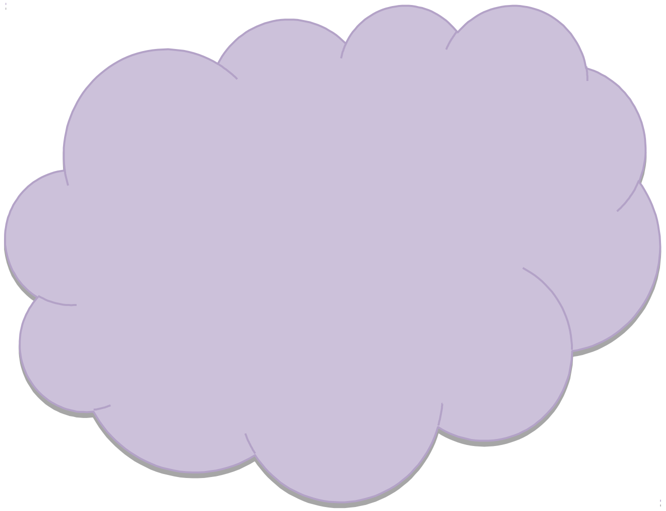
What the breath is like

How long the breath lasts in the air

How long a virus might live in the breath in the air

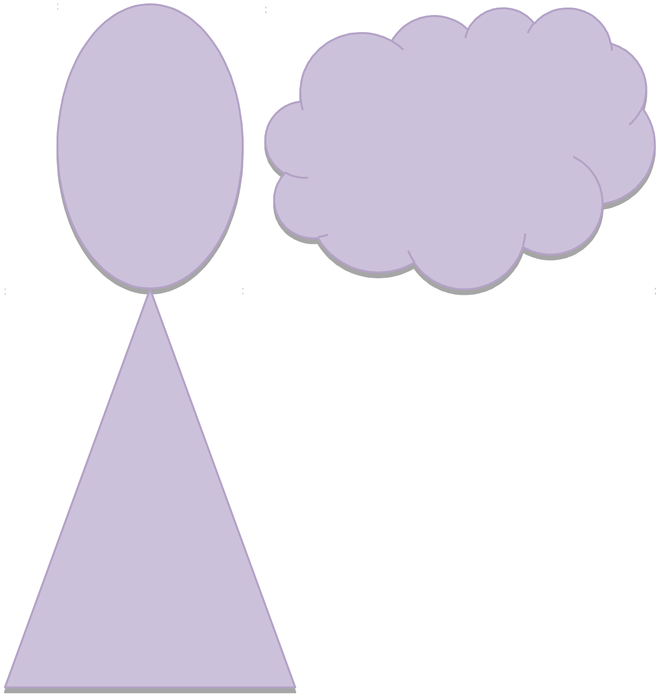
How much virus might live in the breath

How much virus is required to infect someone



HOW BREATH SPREADS OUT

How does the breath – the ‘breath cloud’ – spread out from a person?

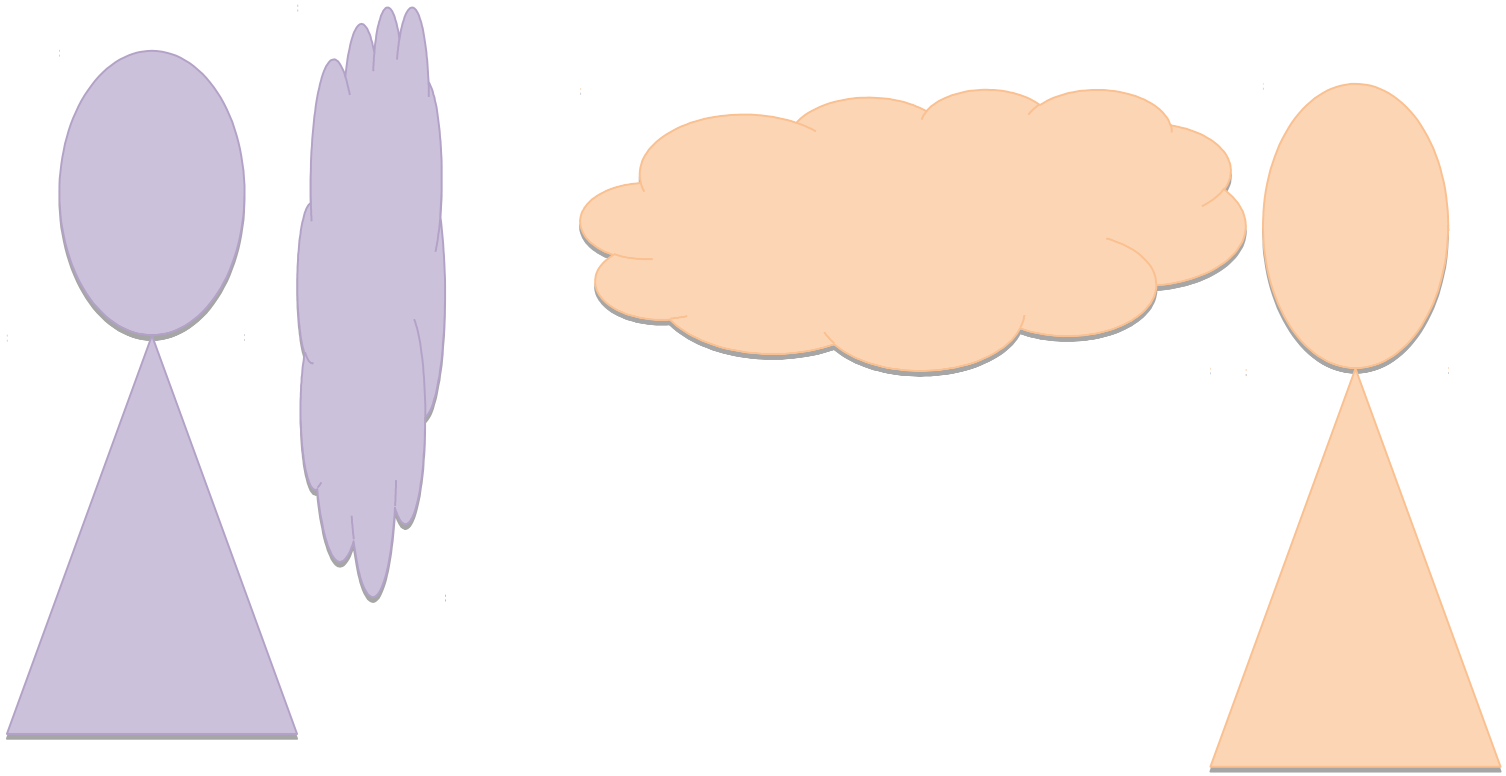


Two aspects:

Shape of ‘breath cloud’

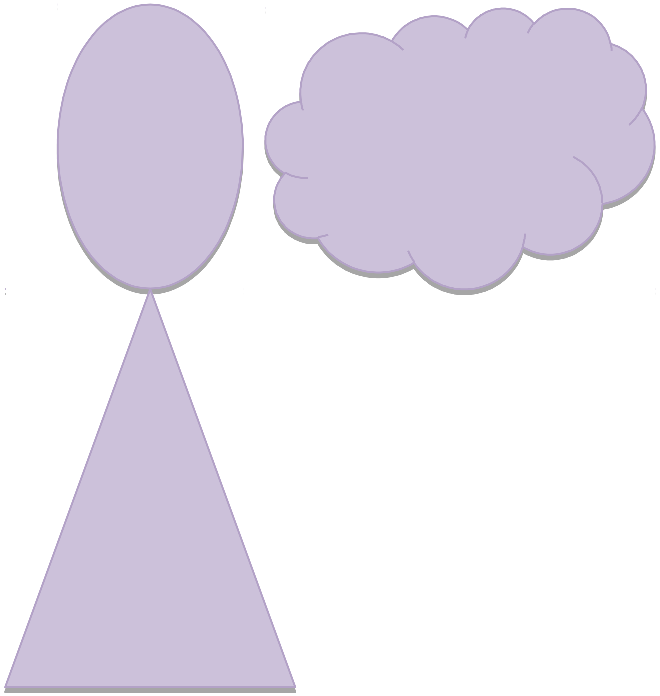
Direction of ‘breath cloud’

Are you talking, laughing, coughing, sneezing, covering your mouth?



These change the shape of the breath cloud.

Research Findings



Talking: Medium cloud (**typically** < 2 meters), many different shapes.

Coughing and sneezing: Long narrow cloud (**several meters**, estimates vary).

Covering mouth when coughing/sneezing: small cloud (typically < 2 meters), shape and size really depend on how you cover your mouth.

See references 1,2,3,4,7,14, 20,21 and 22 for articles and scientific papers with more detail.

Video: Breath clouds of two people talking (second half of video)

(click link below)

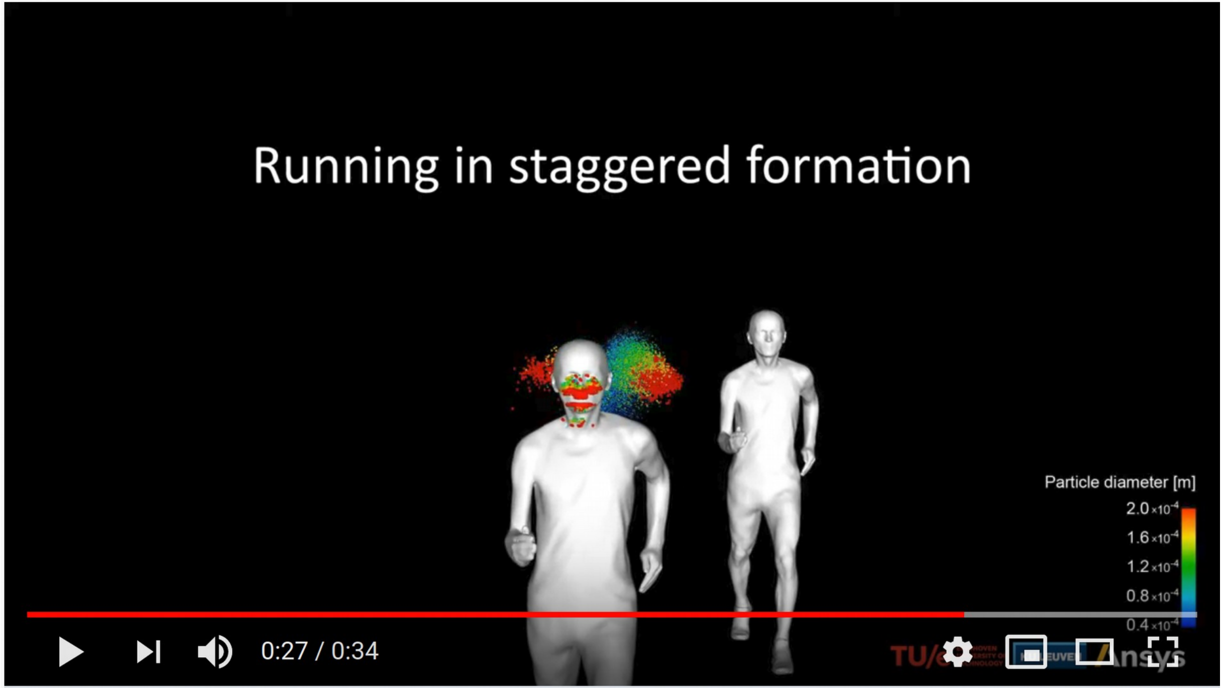
https://www.youtube.com/watch?v=gElHX1AIlOY

Video: Breath cloud of one person talking, coughing, covering mouth

(click link below)

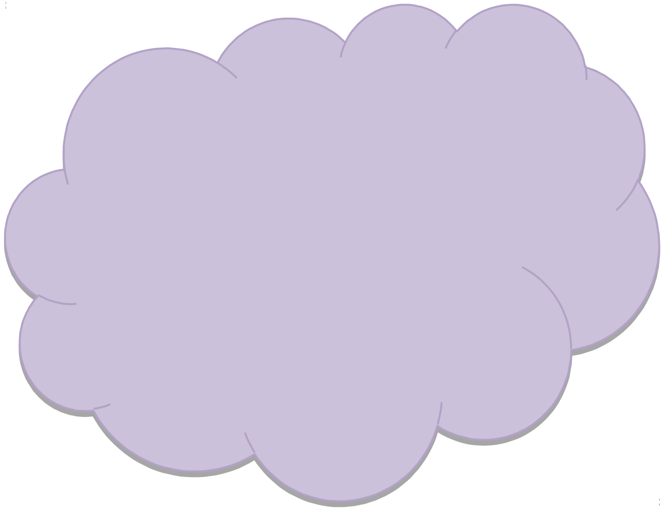
https://en.wikipedia.org/wiki/File:Qualitative-Real-Time-Schlieren-and-Shadowgraph-Imaging-of-Human-Exhaled-Airflows-An-Aid-to-Aerosol-pone.0021392.s001.ogv

Video: Simulation of breath cloud created when people exercise.



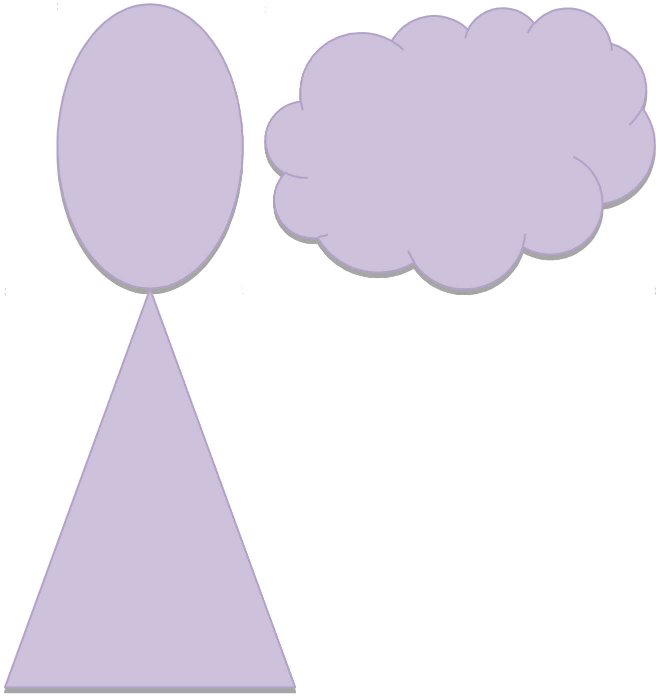
(click link below)

https://www.youtube.com/watch?v=99yx2wScgJA



WHAT THE BREATH CLOUD IS LIKE

What is the breath like?

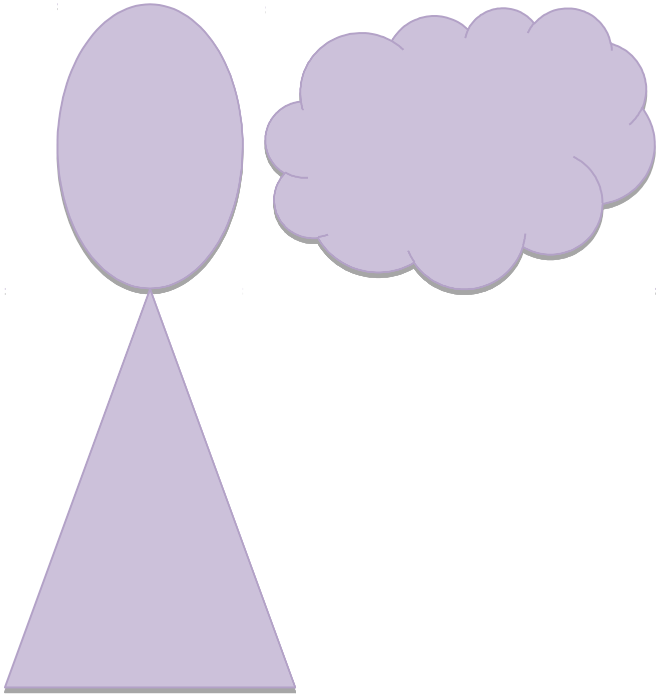


Two main aspects:

Amount of spit blobs in breath

Size of spit blobs in breath

Research Findings

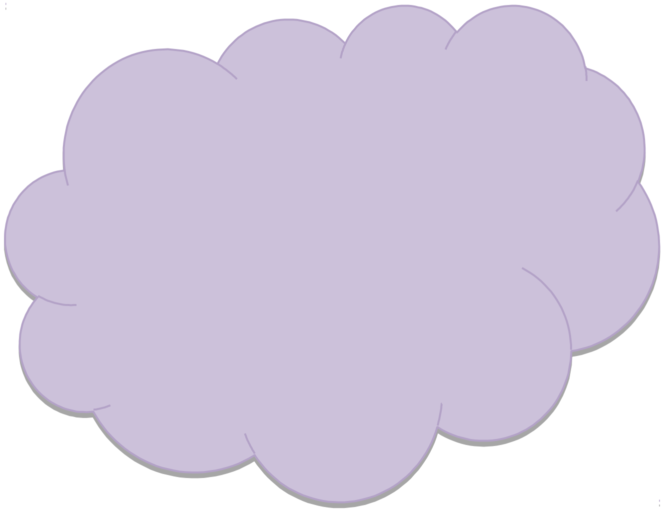


Talking: size of blobs varies from some very small (< 5 microns) up to to many medium (> 50 microns) and a few large.

Coughing and sneezing: Size of blobs varies from many very small (< 5 microns) to many medium and some very large (> 500 microns)

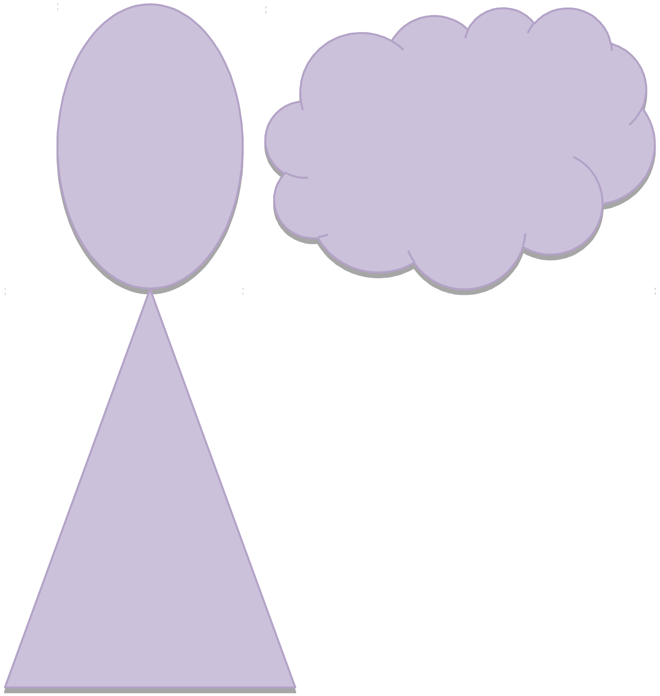
BUT lots of variability in size and number depending on the person!

See references 7,8, 14, 18, 19, 20 and 21 for articles and scientific papers with more detail.

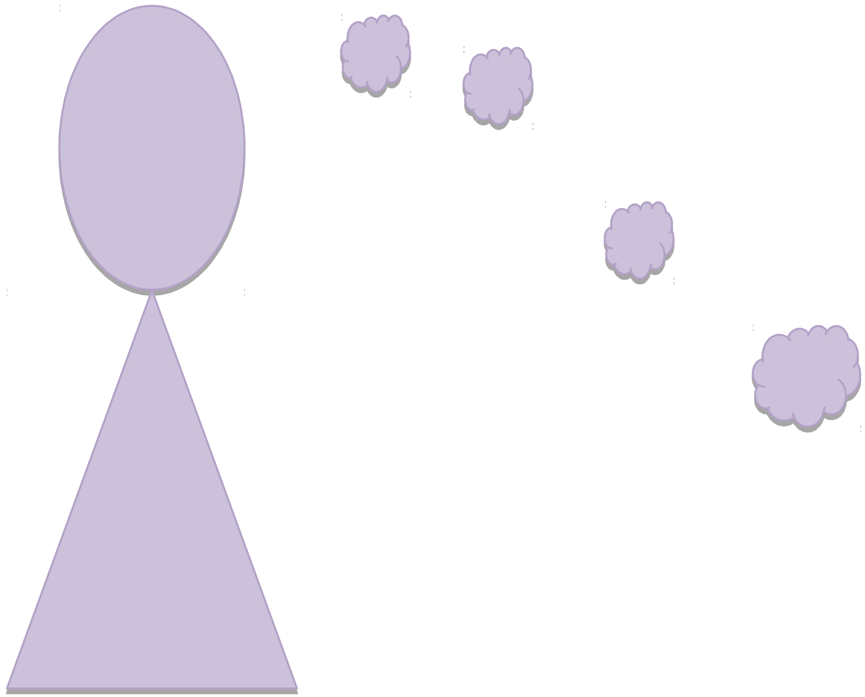


HOW LONG BREATH LASTS IN THE AIR

How long do the spit blobs in the cloud last in the air?



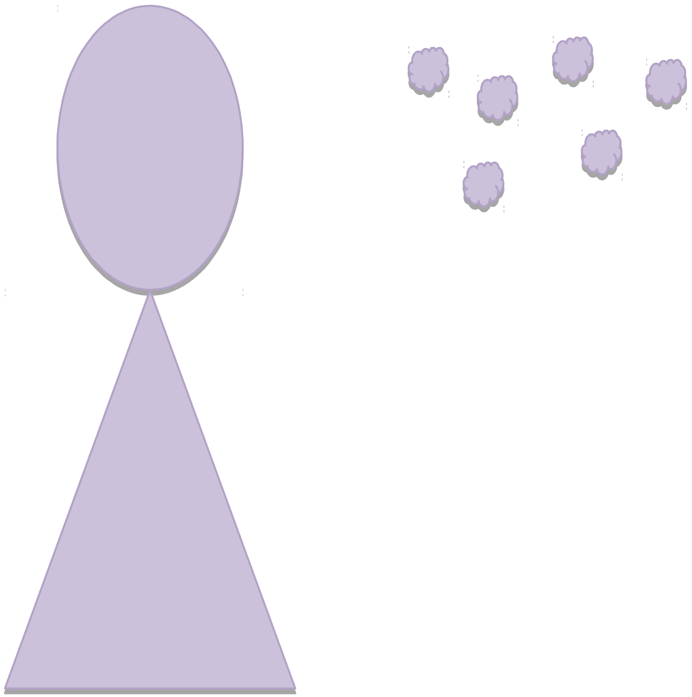
This depends on the size of the blobs.



Small, medium and large blobs (10 up to > 1000 microns) fall to the ground and other surfaces relatively quickly (< 15 minutes, probably).

The bigger they are, the faster they fall.

See references 2,7 and 8 for articles and scientific papers with more detail.

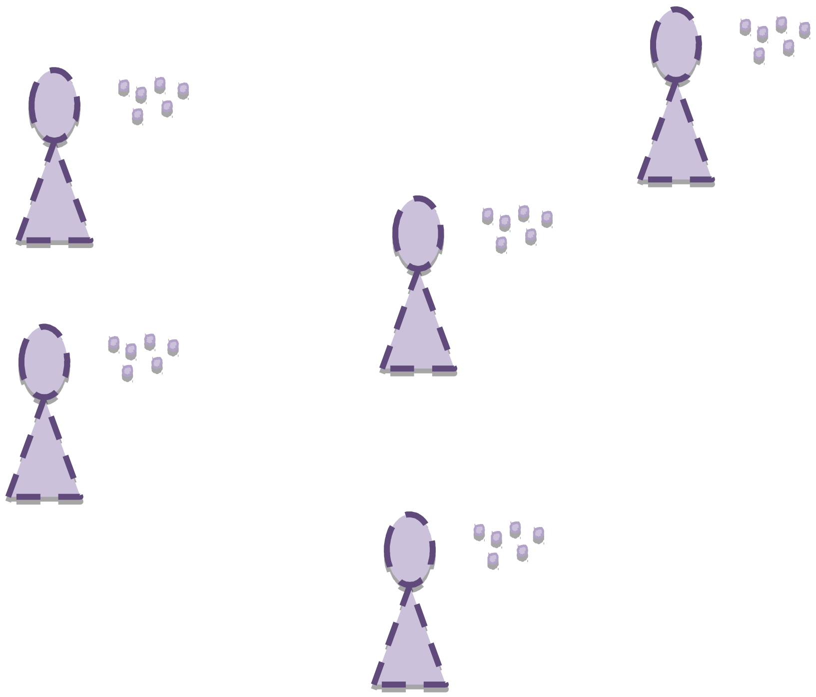


Very small blobs (< 10 microns) stay in the air for longer.

Dust particles of this size can stay in the air for 1 or more hours, depending on conditions.

People are still researching how this works for spit blobs.

See references 2, 7, 8 and 9 for articles and scientific papers with more detail.

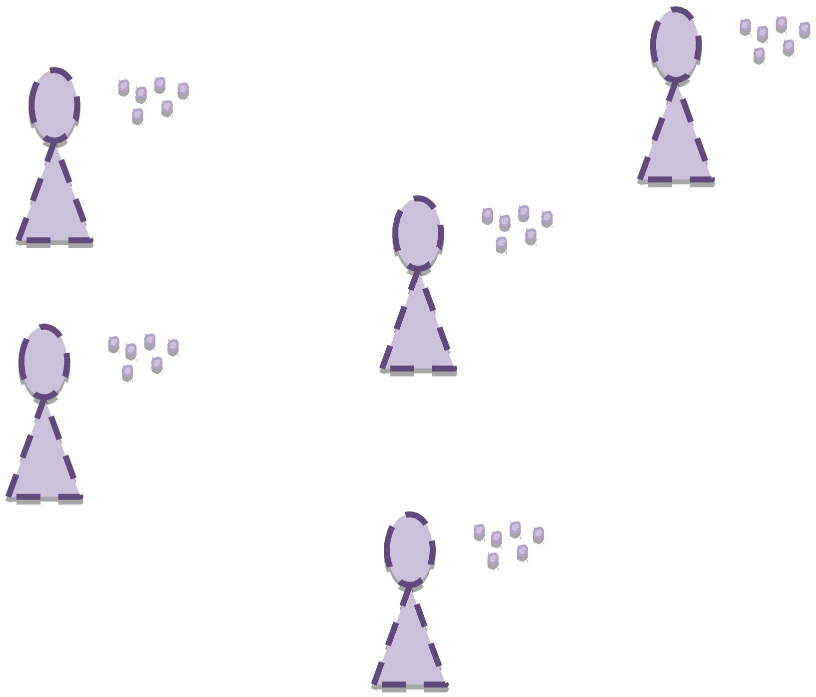


In **a few minutes** of **just talking**, a room full of **10 people** might produce:

about 7600 spit blobs of all different sizes, most of which would fall to the floor or other surfaces in a few minutes.

50 or more very small blobs that would float around for a while.

See Extra Slide 1 for the details of these calculations.



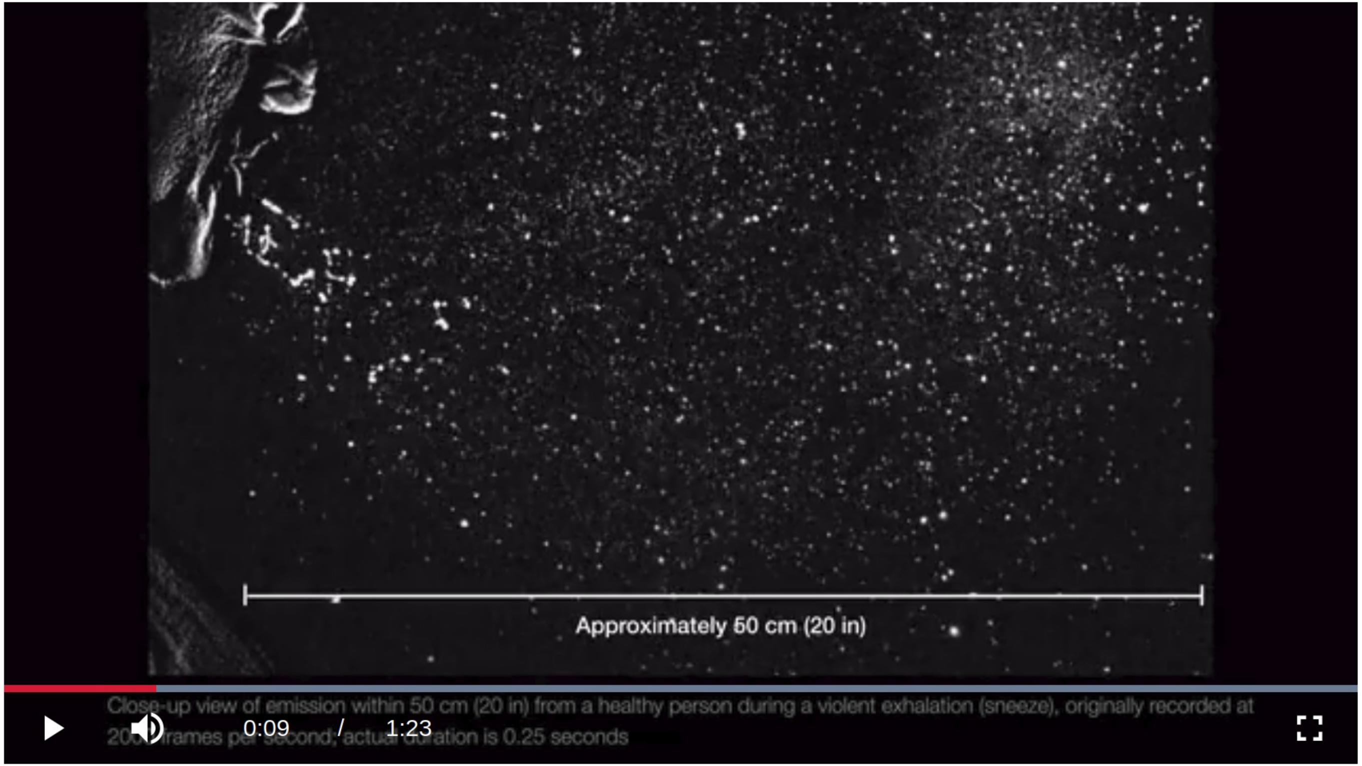
When people **cough or sneeze** the situation really **changes**.

It’s possible for **a single sneeze** to produce **> 100 000** spit blobs.

These spit blobs are of many different sizes, including **many more very small blobs** that could float in the air for some time and **more very large blobs**.

See references 19, 20, 21, 22 and 23 for articles and scientific papers with more detail.

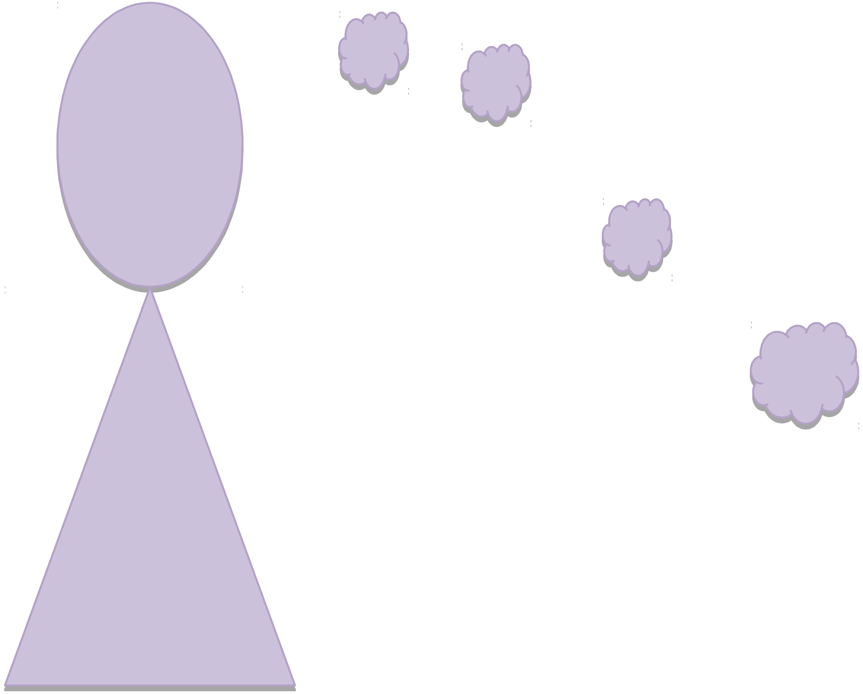
Video: Slow motion sneeze, showing spit blobs



(click link below)

https://edhub.ama-assn.org/jn-learning/video-player/18357411

VIRUS LIFE OUTSIDE OF THE BODY

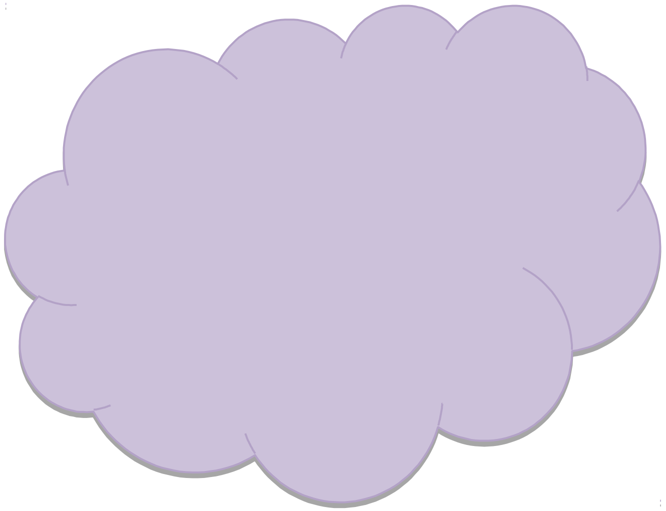


Current estimates are that the COVID-19 virus can stay alive for a while in spit blobs.

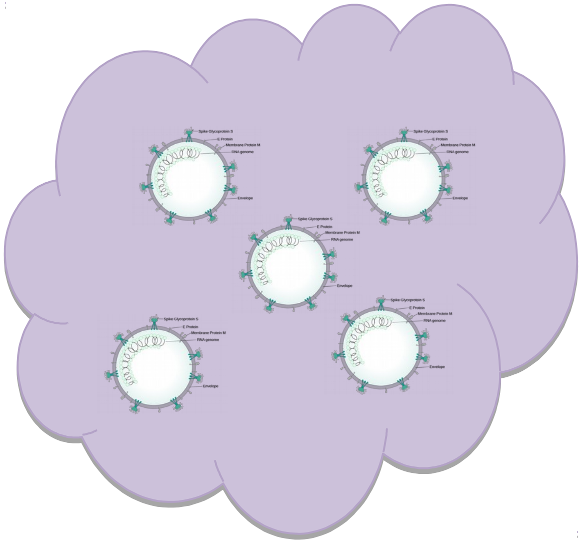
3 hours or more in spit blobs **in the air. Half the virus is dead after ~ 1.5 hours**.

Up to **3 days on some surfaces**. **Amount** of virus on surfaces also **decreases as time passes**.

See Extra Slide 2 for more information and reference 6 for a scientific paper with more details.



HOW MUCH VIRUS IN BREATH?



The size of a single COVID-19 virus is on the order of **0.1 microns** in diameter.

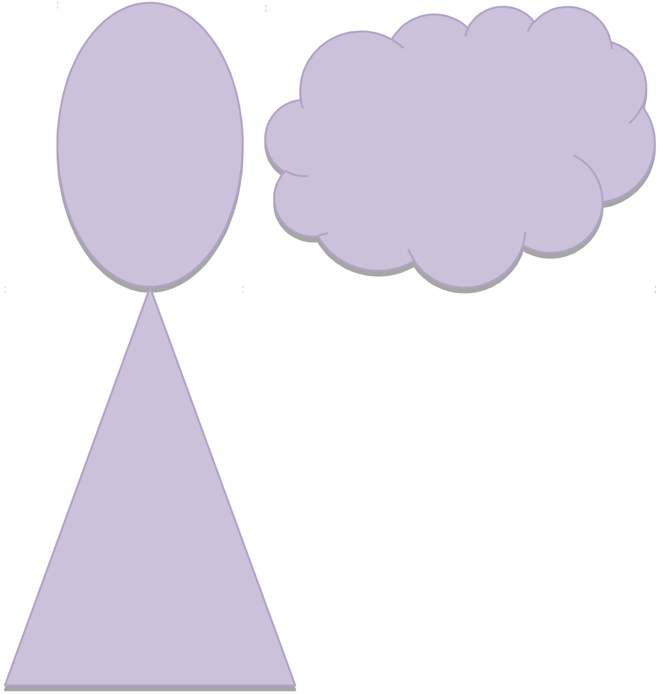
Most spit blobs range from 5 microns to > 500 microns in diameter.

If the viruses could fill up the blobs, there might be a lot of viruses in a blob, **but** viruses don’t take up all the space.

So how much virus is actually in spit blobs?

See references 15 and 16 for articles and scientific papers with more detail.

How much virus?



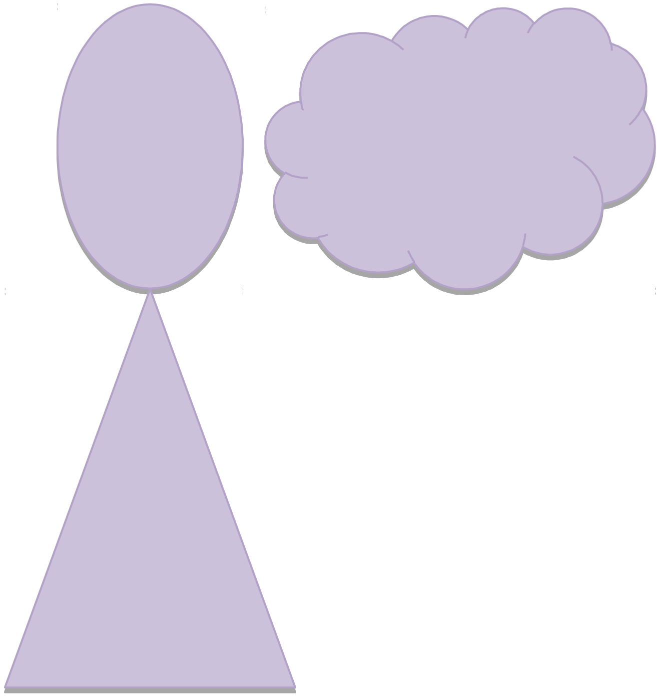
People with influenza might have **100 000 – 10 000 000 viruses per mL** of infected bodily fluid.

COVID-19 seems to be similar.

In the case of COVID-19, a drop of spit the size of **a typical drop of water** (0.05 ml) might have 5000 – 500 000 viruses in it.

See references 11 and 12 for articles and scientific papers with more detail.

How much virus?



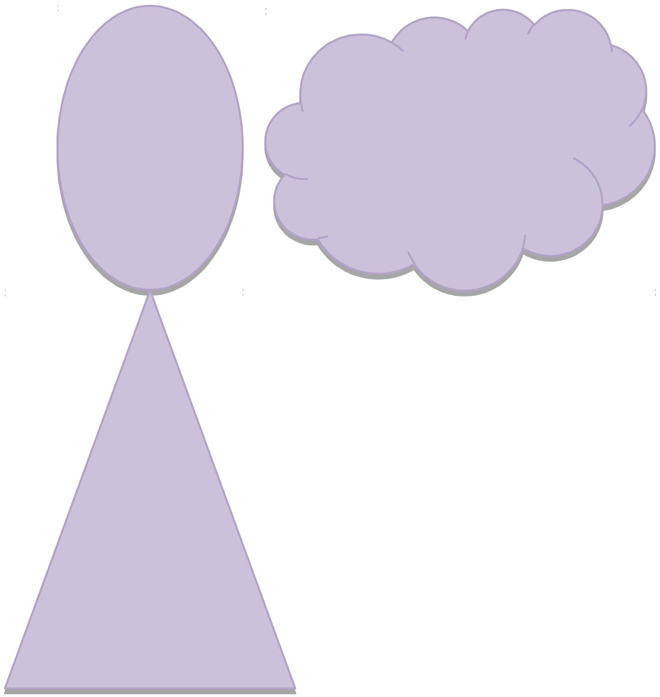
The spit blobs that come out of our mouth are typically **much much smaller** than a full drop of water.

The **largest spit blobs** that come out of our mouth (for example, **when we cough**) might be 1/100th the size of a typical drop of water.

How many COVID-19 viruses could be in these spit blobs?

See Extra Slide 3 for the details of these calculations.

How much virus?

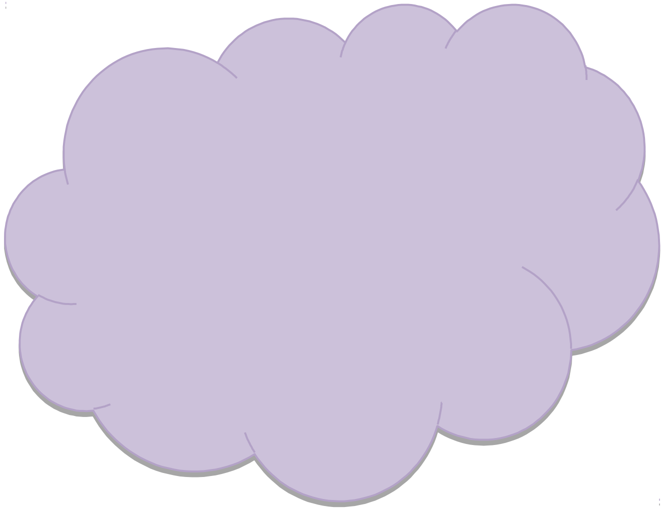


A **medium spit blob** (100 microns in diameter) from an infected person might contain **none - 5 viruses**.

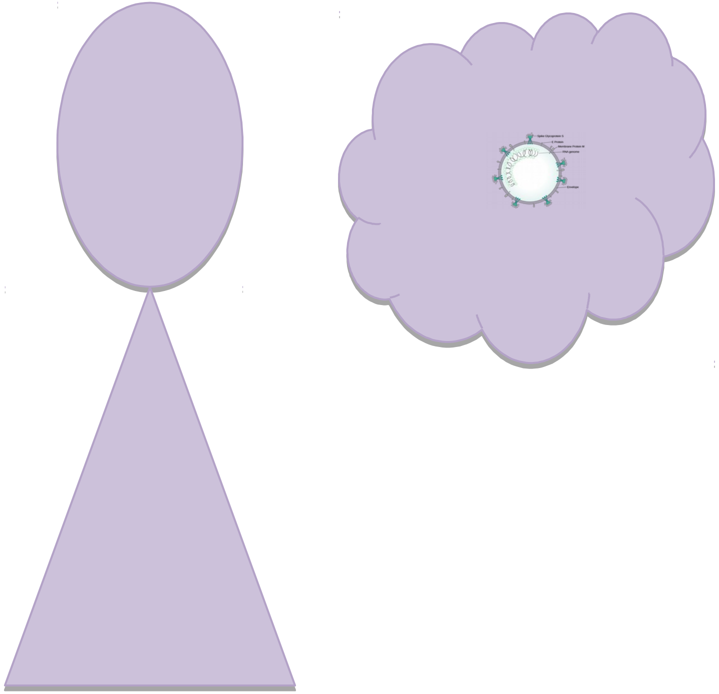
15 000 very small spit blobs (5 microns in diameter) might contain **none – 5 viruses**.

A very large spit blob (1000 microns in diameter) might contain **500 – 5000 viruses**.

See Extra Slides 4 and 5 for the details of these calculations.



HOW MUCH VIRUS TO INFECT SOMEONE?

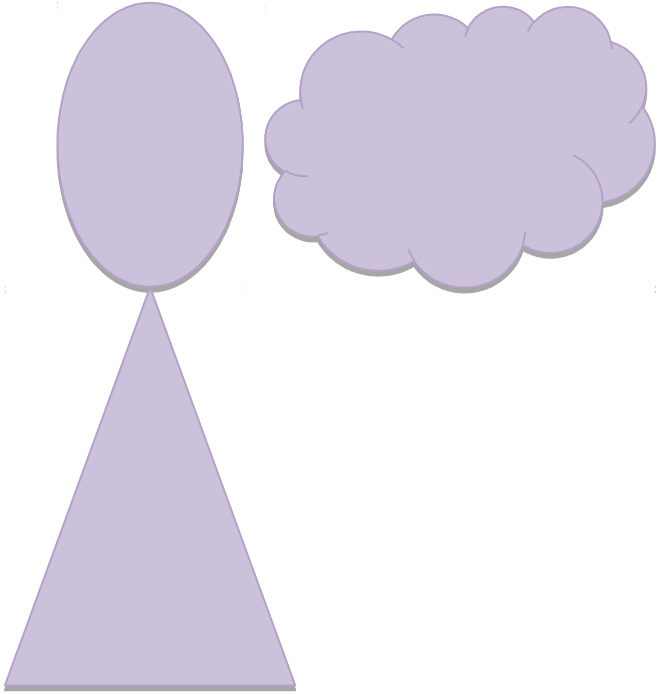


Except in very unusual cases, **a single virus** of a disease is not enough to infect someone.

But how many viruses are enough?

See reference 17 for an informal internet Q&A about single virus infection.

How much virus to infect someone?



There are many aspects involved:

Where the virus enters the body

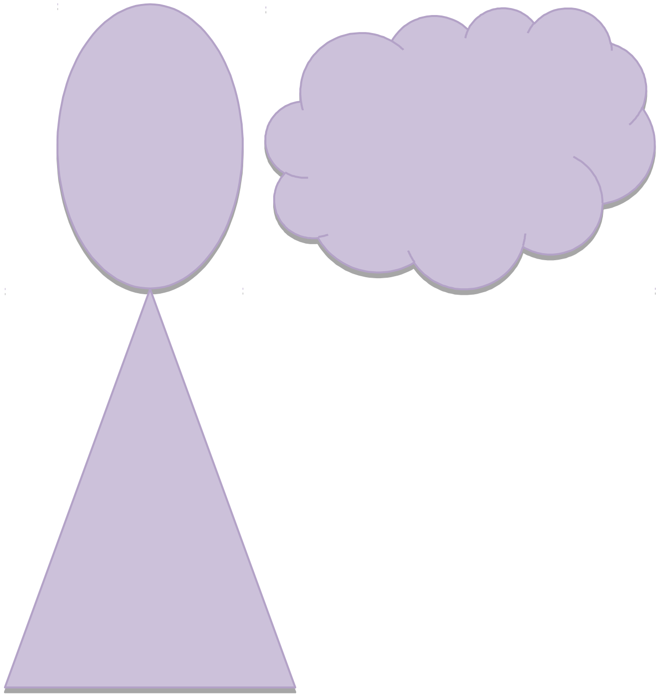
How the virus enters the body

The condition of the person’s body

What the virus is like

Maybe **other things** (like temperature)

How much virus to infect someone?

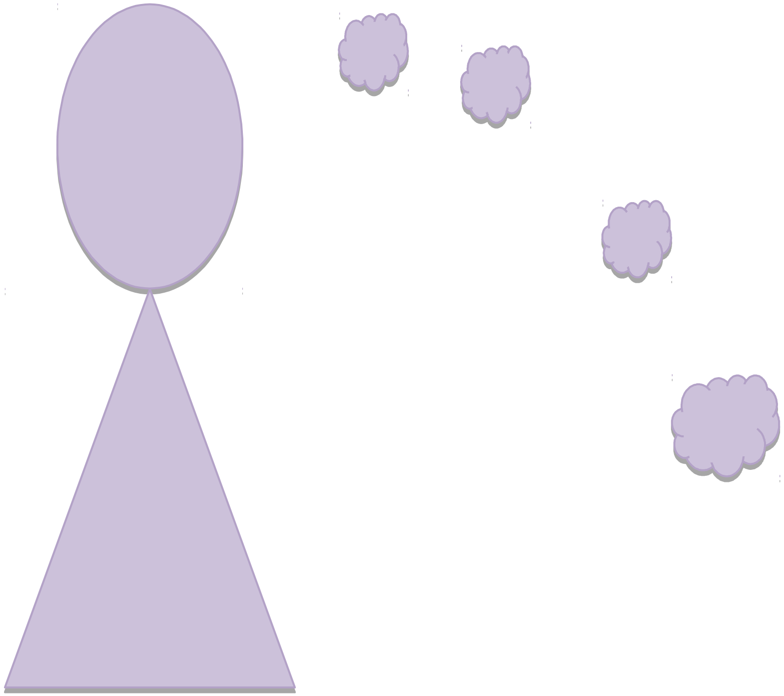


We still don’t know how many individual viruses a **specific person** would need to be exposed to in order to become infected with COVID-19.

It depends on many individual things.

This is probably why we are getting so much conflicting advice about what to do!

PUTTING THE PICTURE TOGETHER

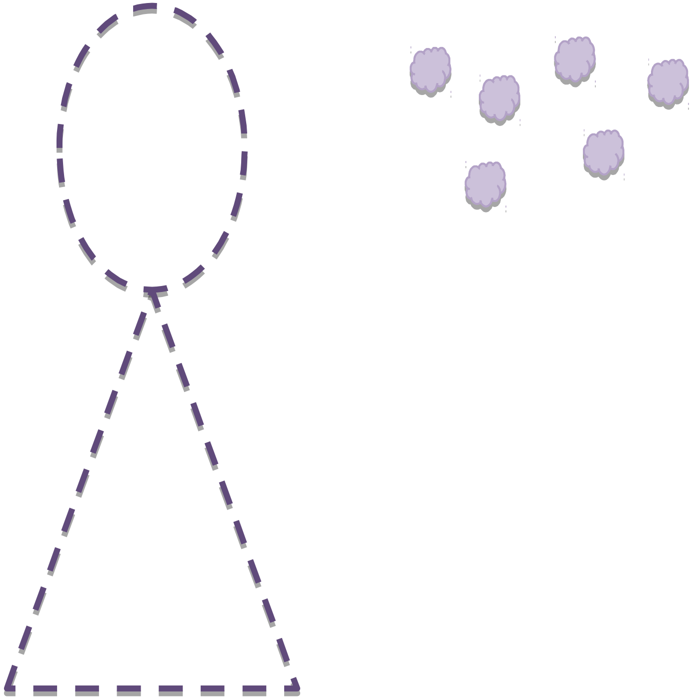


Most of the virus that leaves the body will fall to the ground and other surfaces relatively quickly.

The virus will fall within several meters of the person.

The virus can get on people’s hands **if they touch the surfaces** upon which spit blobs have landed.

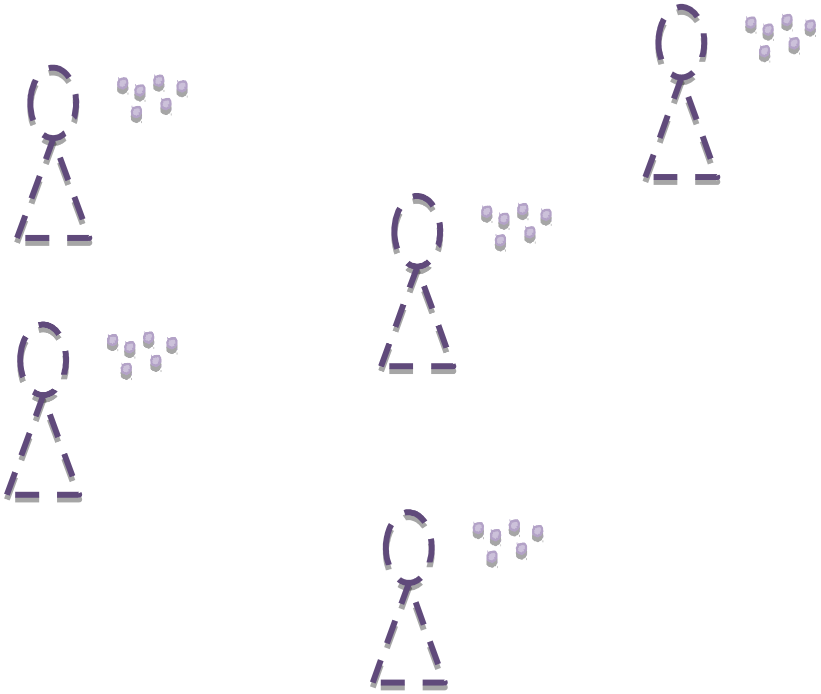
The virus might also land directly on someone’s mouth, nose and eyes.



A small amount of the living virus will come out in very small spit blobs when people breathe and talk. Many more will come out if they sneeze or cough.

These very small blobs can float around in the air with a bit of living virus in them for longer.

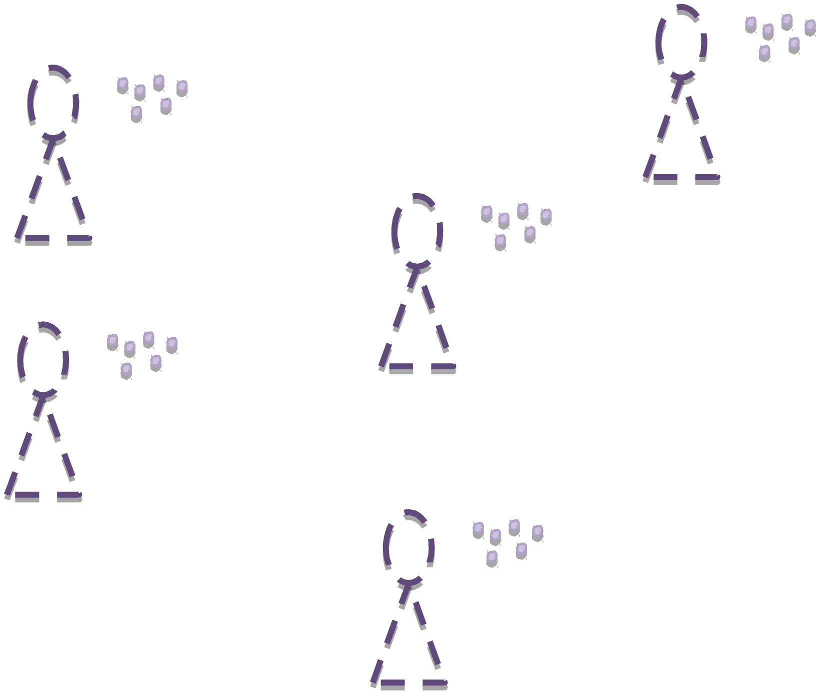
The amount of living virus in the very small blobs will get smaller and smaller over time.



In situations where there are many people in a space over time, many many spit blobs will be produced.

Most of these blobs will first go into the air and then fall onto surfaces after several minutes.

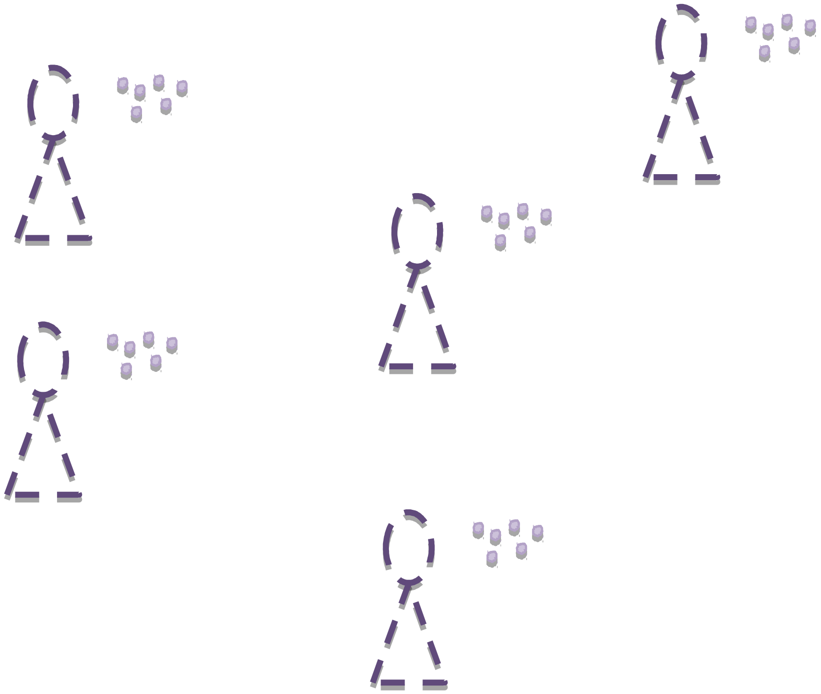
They will remain on the surfaces with some living virus in them for some time.



Some very small spit blobs will also float in the air, taking longer to settle.

The number of very small spit blobs in the air will rise over time.

Some of these very small spit blobs will also contain a small amount of virus.



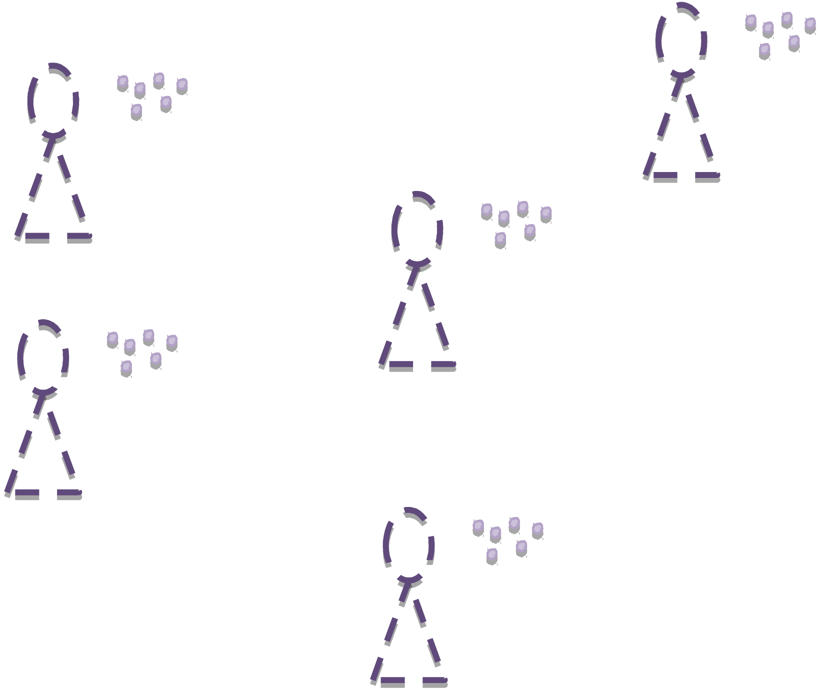
If 10 infected people **just talked (no coughing)** in a room for 30 minutes:

More than **100 000 spit blobs** could be produced that could contain up to roughly **2 million** living viruses across all blobs.

Most of these blobs would fall to surfaces, where the virus would live for a while.

A small bit of virus would float in the air for a while, too.

See Extra Slides 6 and 7 for the details of these calculations.

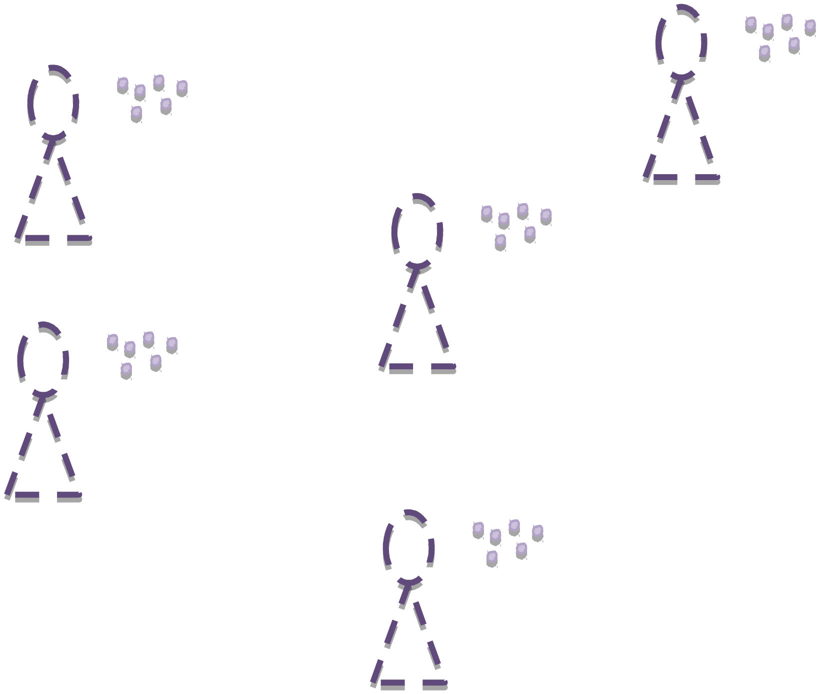


If those 10 people also **sneezed** and **coughed** sometimes, the picture **changes a lot**.

Research is ongoing, but it’s possible **a single sneeze or cough** might expel **> 200 000 viruses** into the air, inside **quite a bit of liquid**.

Many very small spit blobs (and some virus) from this sneeze or cough would continue to float in the air for some time.

See Extra Slide 8 for the details of these calculations.



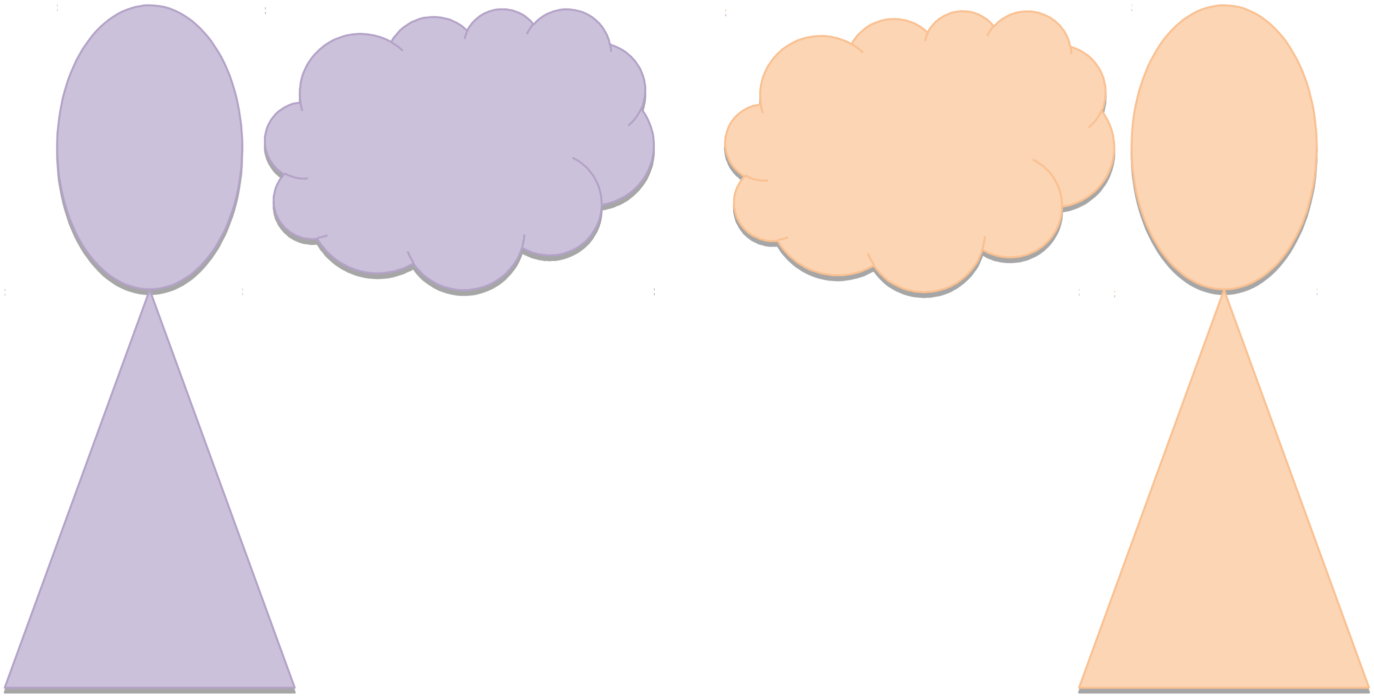
Would all of this be enough to infect the people in the room? Maybe not, but maybe.

At the very least, you can see why conferences would be a problem!

Importantly, washing with soap and water can destroy living viruses that land on surfaces and get picked up on hands.

See references 24 and 25 for articles and scientific papers with more detail.

All of this shows why physical distance, hand washing and avoiding groups helps limit spread.



Read on for more detailed references.

References - Page 1

Article ID: 1
Title: They Say Coronavirus Isn't Airborne—but It's Definitely Borne By Air
Publication Date: March 2020
Link: https://www.wired.com/story/they-say-coronavirus-isnt-airborne-but-its-definitely-borne-by-air/

Notes: This popular science article discusses the question of what it means for a virus to be airborne and notes that experts don't always agree on the definition. The article also highlights the research of Lydia Bourouiba, who has been doing in-depth investigation about breath cloud shape (see [2]). From the article "Whereas previous modeling might have suggested that 5-micron droplets can travel only a meter or two—as we've heard about the new coronavirus—her work suggests these same droplets can travel up to 8 meters when taking into account the gaseous form of a cough."

Article ID: 2
Publication Date: May 2016
Title: The snot-spattered experiments that show how far sneezes really spread
Link: https://www.nature.com/news/the-snot-spattered-experiments-that-show-how-far-sneezes-really-spread-1.19996

Notes: Nature popular science article on Lydia Bourouiba and her research on the fluid dynamics of breath clouds. Quote from article "Feeding her video evidence into her mathematical models, Bourouiba concluded that, thanks to the cloud dynamics, many of the larger droplets can travel up to 8 metres for a sneeze and 6 metres for a cough, depending on the environmental conditions, and stay suspended for up to 10 minutes — far enough and long enough to reach someone at the other end of a large room, not to mention the ceiling ventilation system."

References - Page 2

Article ID: 3
Publication Date: April 2013
Title: Airflow Dynamics of Human Jets: Sneezing and Breathing - Potential Sources of Infectious Aerosols
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3613375/

Notes: From abstract: " Real-time shadowgraph imaging was used to visualise and capture high-speed images of healthy volunteers sneezing and breathing (through the nose – nasally, and through the mouth - orally). Six volunteers, who were able to respond to the pepper sneeze stimulus, were recruited for the sneezing experiments (2 women: 27.5±6.36 years; 4 men: 29.25±10.53 years). The maximum visible distance over which the sneeze plumes (or puffs) travelled was 0.6 m, the maximum sneeze velocity derived from these measured distances was 4.5 m/s. The maximum 2-dimensional (2-D) area of dissemination of these sneezes was 0.2 m2. The corresponding derived parameter, the maximum 2-D area expansion rate of these sneezes was 2 m2/s. For nasal breathing, the maximum propagation distance and derived velocity were 0.6 m and 1.4 m/s, respectively. The maximum 2-D area of dissemination and derived expansion rate were 0.11 m2 and 0.16 m2/s, respectively. Similarly, for mouth breathing, the maximum propagation distance and derived velocity were 0.8 m and 1.3 m/s, respectively. The maximum 2-D area of dissemination and derived expansion rate were 0.18 m2 and 0.17 m2/s, respectively. Surprisingly, a comparison of the maximum exit velocities of sneezing reported here with those obtained from coughing (published previously) demonstrated that they are relatively similar, and not extremely high."

References – Page 3

Article ID: 4
Publication Date: March 2020 (date viewed)
Title: Shadowgraph Imaging of Human Exhaled Airflows: An Aid to Aerosol Infection Control
Link: https://www.youtube.com/watch?v=gElHX1AIIOY

Notes: Video from research study [3] showing individual breath cloud and then two people interacting while their breath cloud is visualized

Article ID: 5
Publication Date: March 2020 (date viewed)
Title: File:Qualitative-Real-Time-Schlieren-and-Shadowgraph-Imaging-of-Human-Exhaled-Airflows-An-Aid-to-Aerosol-pone.0021392.s001.ogv
Link:
https://en.wikipedia.org/wiki/File:Qualitative-Real-Time-Schlieren-and-Shadowgraph-Imaging-of-Human-Exhaled-Airflows-An-Aid-to-Aerosol-pone.0021392.s001.ogv

Notes: Video showing a person's breath cloud while breathing, coughing, etc. - same as first part of video above, but with some additional captioning and notes.

References – Page 4

Article ID: 6
Publication Date: March 2020
Title: Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1
Link: https://www.nejm.org/doi/10.1056/NEJMc2004973

Notes: From the letter: "SARS-CoV-2 remained viable in aerosols throughout the duration of our experiment (3 hours), with a reduction in infectious titer from 10^3.5 to 10^2.7 TCID50 per liter of air. This reduction was similar to that observed with SARS-CoV-1, from 10^4.3 to 10^3.5 TCID50 per milliliter (Figure 1A).

SARS-CoV-2 was more stable on plastic and stainless steel than on copper and cardboard, and viable virus was detected up to 72 hours after application to these surfaces (Figure 1A), although the virus titer was greatly reduced (from 10^3.7 to 10^0.6 TCID50 per milliliter of medium after 72 hours on plastic and from 10^3.7 to 10^0.6 TCID50 per milliliter after 48 hours on stainless steel). The stability kinetics of SARS-CoV-1 were similar (from 10^3.4 to 10^0.7 TCID50 per milliliter after 72 hours on plastic and from 10^3.6 to 10^0.6 TCID50 per milliliter after 48 hours on stainless steel). On copper, no viable SARS-CoV-2 was measured after 4 hours and no viable SARS-CoV-1 was measured after 8 hours. On cardboard, no viable SARS-CoV-2 was measured after 24 hours and no viable SARS-CoV-1 was measured after 8 hours (Figure 1A).

Both viruses had an exponential decay in virus titer across all experimental conditions, as indicated by a linear decrease in the log10TCID50 per liter of air or milliliter of medium over time (Figure 1B)."

References – Page 5

Article ID: 7
Publication Date: December 2009
Title: Exhaled droplets due to talking and coughing
Link:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2843952/

Notes: This open source paper provides very detailed data on the breath cloud properties and behaviours of a small sample of people. It is a major reference used to make the calculations in the deck. In particular, Table 2 of this paper was used for estimates of number of droplettes of different sizes being produced under varying circumstances.

Article ID: 8
Publication Date: 2009
Title: Natural Ventilation for Infection Control in Health-Care Settings. Annex C Respiratory droplets
Link: https://www.ncbi.nlm.nih.gov/books/NBK143281/

Notes: From the article: "Both these naturally and artificially generated droplets are likely to vary in both size and content. Droplets >5 μm tend to remain trapped in the upper respiratory tract (oropharynx — nose and throat areas), whereas droplets ≤5 μm have the potential to be inhaled into the lower respiratory tract (the bronchi and alveoli in the lungs).

Currently, the term droplet is often taken to refer to droplets >5 μm in diameter that fall rapidly to the ground under gravity, and therefore are transmitted only over a limited distance (e.g. ≤1 m). In contrast, the term droplet nuclei refers to droplets ≤5 μm in diameter that can remain suspended in air for significant periods of time, allowing them to be transmitted over distances >1 m (Stetzenbach, Buttner & Cruz, 2004; Wong & Leung, 2004)."

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Article ID: 9
Publication Date: Unknown
Title: Generation and Behavior of Airborne Particles (Aerosols)
Link: https://www.cdc.gov/niosh/topics/aerosols/pdfs/Aerosol_101.pdf

Notes: This presentation provides numerous details and values related to small airborn particle behaviour, movement and spread. Values were used in calculations for breath cloud scenarios.

Article ID: 10
Publication Date: February 2011
Title: A review of mathematical models of influenza A infections within a host or cell culture: lessons learned and challenges ahead
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3317582/

Notes: From abstract: "Most mathematical models used to study the dynamics of influenza A have thus far focused on the between-host population level, with the aim to inform public health decisions regarding issues such as drug and social distancing intervention strategies, antiviral stockpiling or vaccine distribution. Here, we investigate mathematical modeling of influenza infection spread at a different scale; namely that occurring within an individual host or a cell culture."

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Article ID: 11
Publication Date: March 2020
Title: Improved molecular diagnosis of COVID-19 by the novel, highly sensitive and specific COVID-19-RdRp/Hel real-time reverse transcription-polymerase chain reaction assay validated in vitro and with clinical specimens.
Link: https://www.ncbi.nlm.nih.gov/pubmed/32132196

Notes: From abstract: "Among 273 specimens from 15 patients with laboratory-confirmed COVID-19 in Hong Kong, 77 (28.2%) were positive by both the COVID-19-RdRp/Hel and RdRp-P2 assays. The COVID-19-RdRp/Hel assay was positive for an additional 42 RdRd-P2-negative specimens [119/273 (43.6%) vs 77/273 (28.2%), P<0.001], including 29/120 (24.2%) respiratory tract specimens and 13/153 (8.5%) non-respiratory tract specimens. The mean viral load of these specimens was 3.21×104 RNA copies/ml (range, 2.21×102 to 4.71×105 RNA copies/ml)"

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Article ID: 12
Publication Date: February 2020
Title: Viral load of SARS-CoV-2 in clinical samples
Link: https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30113-4/fulltext

Notes: From abstract: "Serial samples (throat swabs, sputum, urine, and stool) from two patients in Beijing were collected daily after their hospitalisation (patient 1, days 3–12 post-onset; patient 2, days 4–15 post-onset). These samples were examined by an N-gene-specific quantitative RT-PCR assay, as described elsewhere.3
The viral loads in throat swab and sputum samples peaked at around 5–6 days after symptom onset, ranging from around 10^4 to 10^7 copies per mL during this time (figure A, B). This pattern of changes in viral load is distinct from the one observed in patients with SARS, which normally peaked at around 10 days after onset.4
Sputum samples generally showed higher viral loads than throat swab samples. No viral RNA was detected in urine or stool samples from these two patients."

Article ID: 13
Publication Date: March 2020 (
Title: Viral load – converting log values to numbers
Link: http://i-base.info/qa/factsheets/viral-load-converting-log-values-to-numbers

Notes: A useful fact sheet explaining how to interpret viral load measurements.

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Article ID: 14
Publication Date: March 2020
Title: Six-foot rule to protect against coronavirus may not be enough, MIT professor says
Link:
https://www.bostonglobe.com/2020/03/31/nation/six-foot-rule-protect-against-coronavirus-is-questionable-mit-professor-says/

Notes: Boston Globe article that provides an update on Lydia Bourouiba's research, as it may apply to coronavirus questions.

Article ID: 15
Publication Date: April 2020
Title: Severe acute respiratory syndrome coronavirus 2
Link: https://en.wikipedia.org/wiki/Severe_acute_respiratory_syndrome_coronavirus_2

Notes: Article used for information on size of SARS-CoV-19 virus. From the article: "Each SARS-CoV-2 virion is approximately 50–200 nanometres in diameter."

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Article ID: 16
Publication Date: March 2020
Title: Coronavirus
Link: https://www.britannica.com/science/coronavirus-virus-group

Notes: Article used for information on typical size of coronavirus. From the article: "Coronavirus, any virus belonging to the family Coronaviridae. Coronaviruses have enveloped virions (virus particles) that measure approximately 120 nm (1 nm = 10−9 metre) in diameter."

Article ID: 17
Publication Date: November 2011
Title: How many individual virus are needed to start an infection? Will 1 flu virus be enough to make you sick or do you need many more than that?
Link:
https://www.quora.com/How-many-individual-virus-are-needed-to-start-an-infection-Will-1-flu-virus-be-enough-to-make-you-sick-or-do-you-need-many-more-than-that?share=1

Notes: I couldn't find any journal articles that directly addressed this question, probably because it's more a of a popular science question. This article isn't the greatest of references, but I think the first reply given to the question is fairly credible. Quoting the reply: "A single viable viral particle, bacterial cell/spore or fungal cell/spore have an nearly negligible chance of causing disease in any kind of host, even an immune-compromised host."

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Article ID: 18
Publication Date: June 2009
Title: The Gross Science of a Cough and a Sneeze
Link: https://www.livescience.com/3686-gross-science-cough-sneeze.html

Notes: A popular science article with an estimate of how much virus is released by a single sneeze. Quote from article: “If a person is sick, the droplets in a single cough may contain as many as two hundred million individual virus particles.” Unfortunately, no academic source for this number is provided.

Article ID: 19
Publication Date: Nov. 2013
Title: Characterizations of particle size distribution of the droplets exhaled by sneeze
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3785820/

Notes: A journal article examining particle sizes of sneezes. Total volume of liquid produced was not measured and counts of droplets are not given, only percentages of the different sizes of droplets. This article is relatively consistent size-wise with reference [7], but not consistent with reference [20]

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Article ID: 20
Publication Date: Dec. 2015
Title: Quantity and Size Distribution of Cough-Generated Aerosol Particles Produced by Influenza Patients During and After Illness
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4676262/

Notes: A journal article looking very specifically at very small particles produced by coughts and sneezes. The results of this study are very different from the results obtained by references [7] and [19]. In contrast to those references, this one suggests that very large numbers of droplets are produced, and many of these droplets are very small. This could be due to the use of measuring equipment specifically designed to measure very small droplets. This is an important difference, relative to [7] and [19] because it suggests that multiple orders of magnitudes of more droplets are aerosolized. At the same time, the density of virus released in these particles could still be small, given their size and the expected viral density. From the article: “The average number of particles expelled per cough varied widely from patient to patient, ranging from 900 to 302,200 particles/cough while subjects had influenza and 1100 to 308,600 particles/cough after recovery. “

Article ID: 21
Publication Date: March 2020
Title: Respiratory Pathogen Emission Dynamics
Link: https://edhub.ama-assn.org/jn-learning/video-player/18357411

Notes: A video showing sneeze breath clouds.

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Article ID: 22
Publication Date: October 2016
Title: Visualization ofsneeze ejecta: steps of fluid fragmentation leading to respiratory droplets
Link: https://math.mit.edu/~bush/wordpress/wp-content/uploads/2016/02/Sneeze-2016.pdf

Notes: Detailed but qualitative paper by a number of researchers, including Lydia Bourouiba, the researcher mentioned in [1] and [2] and [14] on the fluid dynamics of sneezing. Lots of interesting detail. This is consistent with a number of papers in that the total quantity of fluids produced is not measured. Perhaps this is difficult to do, or just not that interesting to researchers in this area.

Article ID: 23
Publication Date: March 2020
Title: Turbulent Gas Clouds and Respiratory Pathogen EmissionsPotential Implications for Reducing Transmission of COVID-19
Link: https://jamanetwork.com/journals/jama/fullarticle/2763852

Notes: A short paper by Lydia Bourouiba, linking her existing research to the current pandemic, and detailing possible precautions that should be taken by health care workers, based on her research.

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Article ID: 24
Publication Date: February 2011
Title: Efficacy of Soap and Water and Alcohol-Based Hand-Rub Preparations against Live H1N1 Influenza Virus on the Hands of Human Volunteers
Link: https://academic.oup.com/cid/article/48/3/285/304169

Notes: HH is hand-hygene. From the article: "Marked antiviral efficacy was noted for all 4 HH protocols, on the basis of culture results (14 of 14 had no culturable H1N1; $P<.002$) and PCR results ($P<.001$; cycle threshold value range, 33.3–39.4), with SW statistically superior ($P<.001$) to all 3 alcohol-based hand rubs, although the actual difference was only 1–100 virus copies/μL. There was minimal reduction in H1N1 after 60 min without HH."

Article ID: 25
Publication Date: January 2011
Title: The Effect of Handwashing with Water or Soap on Bacterial Contamination of Hands
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3037063/

Notes: From the article: "Bacteria of potential faecal origin (mostly Enterococcus and Enterobacter spp.) were found after no handwashing in 44% of samples. Handwashing with water alone reduced the presence of bacteria to 23% ($p < 0.001$). Handwashing with plain soap and water reduced the presence of bacteria to 8% (comparison of both handwashing arms: $p < 0.001$). The effect did not appear to depend on the bacteria species."

Extra Slide 1

Question: How many very small spit blobs would be produced by a person, on average, during a few minutes of talking?

Reference [7] studied people slowly counting to 100 out loud. Assumption - this would take a few minutes.

A person produced, on average, 760 spit blobs during this time.

So 10 people would produce 7 600 blobs.

The same amount of talking also produced 4.28 blobs under 10 microns on average.

To be conservative, round up to 5 very small blobs on average per person. 10 people would produce 50 very small blobs.

Extra Slide 2

Question: How long does the virus live outside of the body?

Reference [6] provides information on how long the virus lives outside the body, in an experimental setting.

The virus starts to die when it leaves the body, so the amount of living virus in any given spot (e.g. in a spit blob sitting in a surface) decreases over time.

Plastic: viable virus was found up to 72 hours. Almost all virus was gone at this point.
Stainless steel: viable was found up to 72 hours. Almost all virus was gone at this point.
Copper: viable virus not found after 4 hours.
Cardboard: viable virus not found after 24 hours.

Extra Slide 3

Question: How big is a very large spit blob, relative to a drop of water?

Estimates vary, but a typical drop of water is roughly 0.05 ml.

Blobs of spit in breath clouds are rarely larger than 1000 microns in diameter, based on reference [7].

A large spit blob of 1000 microns in diameter has a volume of 4/3 * PI * (1000/2)^3
= 523 598 776 cubic microns.

1 ml = 10^12 cubic microns. A large spit blob = 523 598 776/10^12 = 0.0005 ml

One drop of water is 0.05 ml, so one very large spit blob is blob is 1/100th (0.0005/0.05) of a drop of water.

Extra Slide 4

Question: How many viruses are in a medium spit blob 100 microns in diameter?

References [11] and [12] suggest between 10^4 and 10^7 viruses/ml of infected fluid. Reference [12] says there's typically 10^6 viruses/ml of infected spit blob.

1 ml = 10^12 cubic microns, so there will be 10^6 viruses/10^12 cubic microns
= 10^-6 viruses/cubic micron.

A medium spit blob of 100 microns in diameter has a volume of 4/3 * PI * (100/2)^3
= 523599 cubic microns.

523599 cubic microns * 10^-6 viruses/cubic micron = 0.52 viruses/medium spit blob ~= 1 virus/medium spit blob. And since 10^6 (typical from [12]) to 10^7 (maximum in [11&12]) is a factor of 10, this estimate might also go up by a factor of 10 giving a maximum of 5 viruses per medium sized blob.

Extra Slide 5

Question: How many viruses in a very small spit blob 5 microns in diameter?

References [11] and [12] suggests typically 10^-6 viruses/cubic micron (see Extra Slide 3 for more detail).

A very small spit blob of 5 microns in diameter has a volume of 4/3 * PI * (5/2)^3
= 66 cubic microns.

66 cubic microns * 10^-6 viruses/cubic micron = 66 * 10^-6 viruses/very small spit blob.

66 viruses / 1 000 000 very small spit blobs = 1 virus / 15151.5 very small spit blobs

~ 1 virus per 15 000 very small spit blobs. Or, if we consider the upper value for viral load in reference [12], ~ 10 virus per 15 000 very small spit blobs

Extra Slide 6

Question: How many spit blobs would be produced if 10 people talked in a room for 30 minutes?

According to reference [7], one person produces an average of 760 spit blobs after talking for a few minutes (counting out loud to 100 slowly and clearly).

10 people would produce 7 600 spit blobs in the same period of time.

If we assume that it takes 3 minutes to count out loud to 100, then these people would produce 76 000 spit blobs in 30 minutes. If we assume that counting out loud to 100 takes 2 minutes, they would produce 114 000 spit blobs in 30 minutes.

So round it to an even 100 000 spit blobs.

Extra Slide 7

Question: How many viruses would be contained within the spit blobs produced by 10 people talked in a room for 30 minutes?

Based on extra slide 6, people would produce approximately 100 000 spit blobs in this time.

Based on reference [6], 60% (60 000) will be between 50 and 200 microns in diameter. 37% (37 000) will be smaller, and 3% (3 000) will be larger.

For the sake of this rough calculation, we'll assume that medium droplets typically have 5 viruses in them, small droplets typically have 5 viruses in 15 000 droplets, and larger viruses typically have 500 viruses in them.

60 000 * 5 + (37 000 / 15 000) * 5 + 3 000 * 500 = 1 800 123 ~ 2 000 000

Extra Slide 8

Question: How many viruses are released when someone coughs or sneezes?

I could find very little hard data on this exact question. It appears to be an ongoing area of research.

Reference [18], a popular science article, states 200 000 000 viruses per sneeze.

Reference [7] attempted to weight the amount of liquid released during coughing, but encountered methodological difficulties. Nonetheless, the estimate is on the order of 10 mg.

Assuming the density of spit blobs is roughly the same as water, this would be = 10 ml of liquid. According to reference [12], viral load is between 10^4 and 10^7 viruses/ml.

In this case, one cough would produce between 10^5 and 10^8 viruses. We might assume, from [20], that sneezes would be roughly comparable. This is roughly consistent with [18].