Jose-Luis Jimenez @jljcolorado
8 May • 102 tweets • jljcolorado/status/1391111720526024708

1/ TIME FOR SOME AIRBORNE + DROPLET HISTORY

Now that @WHO and @CDCgov have finally accepted *after a year of denial and delays* that airborne transmission is a major mode for COVID-19, it is time to review the history to try to understand why this response was so poor.

2/ Remember, the evidence is overwhelming that airborne transmission (1 to 1 in close proximity, and 1 to many in shared room air = superspreading) is the dominant mode of transmission.

> **Jose-Luis Jimenez**
> @jljcolorado
>
> 1/ TEN SCIENTIFIC REASONS IN SUPPORT OF AIRBORNE TRANSMISSION OF SARS-CoV-2
>
> Peer-reviewed publication in @TheLancet
>
> An honor to have collaborated in multidisciplinary team across medicine, infectious diseases, epidemiology, aerosol science, sociology
>
> 
> Ten scientific reasons in support of airborne transmission ...
> Heneghan and colleagues' systematic review, funded by WHO, published in March, 2021, as a preprint, states: "The...
> thelancet.com
>
> 11:43 PM · Apr 17, 2021
>
> 3.2K See the latest COVID-19 information on Twitter

3/ And probably we are being charitable by saying only "dominant." Can't find any real evidence that airborne is not 99%. Airborne can explain all the epidemiological patterns, while large droplets and fomites can't, and they are pathetically lacking ev.

> **Jose-Luis Jimenez**
> @jljcolorado
>
> Serious question: do we have any evidence to suggest that airborne is not ~100% of SARS-CoV-2 transmission?
>
> Plausibly there are likely small contributions from droplets (if someone coughs on someone's face) or surfaces (rare cases)

someone coughs on someone's face) or surfaces (rare cases).

But is there evidence? Pls include in replies

2:42 AM · May 7, 2021

725 See the latest COVID-19 information on Twitter

4/ @zeynep published an outstanding article yesterday in the @nytimes where she explains the context, the implications, and some of the history.

I wanted to give some more historical detail, without the word limits that she faced in @nytimes.

Opinion | Why Did It Take So Long to Accept the Facts About Covid?

The importance of airborne transmission in the pandemic was clear long before the World Health Organization finally began to acknowledge it.

https://www.nytimes.com/2021/05/07/opinion/coronavirus-airborne-transmission.html

5/ Why does this matter? bc we still face resistance. We have seen how @WHO and others do the changes too quietly, and they don't communicate how the mitigations need to change. And in many countries they report that mssg doesn't arrive, still focusing on disinfection + plexiglas

6/ We have written an article on history. Started by trying to figure out where 5 micron error for droplet / aerosol boundary came from, since physics tells us it is ~100 um. E.g. see this video of 50 micron particles, ain't falling to the ground quickly:

Ryan Davis
@MicroLevitator

Much discussion lately in aerosol/disease transmission communities about the "5 micron cutoff" where droplets supposedly fall to ground w/in 1-2 m. @JIjcolorado and @linseymarr has suggested ~50 microns.

Here's some video evidence for that. 50 micron droplets wafting in lab...

12:16 AM · Jul 16, 2020

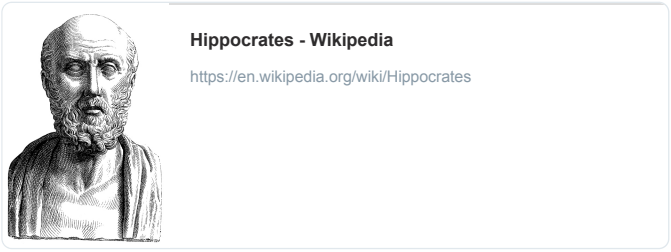
391 13 Copy link to Tweet

7/ But as we investigated the origins of the 5 micron error, we learned a lot more about the history of infectious disease transmission, which is the root of the resistance and delays of @WHO and @CDCGov. As we'll see, the creation of the @CDCgov is deeply embedded in the errors!

8/ Our preprint on the history can be read here. Written by @katierandall, @EThomasEwing, @linseymarr, Lydia Bourouiba and yours truly.

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3829873

9/ We need to go back to the origins of theories about the transmission of diseases. Hippocrates (



) in ancient Greece proposed that diseases were transmitted through the air.

[I think doctors still do the Hippocratic Oath:

]

The Hippocratic text "On the Nature of Man" reads:

"Whenever many men are attacked by one disease at the same time, the cause should be assigned to that which is most common, and which we all use most. This it is which we breathe in."

Nature of Man: Chapter IX
departure in spring. Whenever a disease passes these limits, you may know that it will last a year. The physician too must treat diseases with the conviction that each of them is powerful in the body…

https://www.loebclassics.com/view/hippocrates_cos-nature_man/1931/pb_LCL150.25.…

11/ Throughout much of human history, belief persisted that diseases were transported through the air. Coming from putrid matter, traveling long distances (e.g. a person infected by the flu in Boston could infect someone in UK)

This was miasma theory:

Miasma theory - Wikipedia

https://en.wikipedia.org/wiki/Miasma_theory

12/ The idea of person-to-person transmission, which now seems obvious (e.g. we get COVID-19, the flu, or tuberculosis from another person) wasn't seriously considered till Italian physician Girolamo Fracastoro proposed it in 1546:

Girolamo Fracastoro - Wikipedia

https://en.wikipedia.org/wiki/Girolamo_Fracastoro

13/ The debate ensued for centuries between the miasmatists and the contagionists.

https://oyc.yale.edu/history/hist-234/lecture-13

14/ A middle ground was devised, "Contingent Contagionism"

https://en.wikipedia.org/wiki/Contingent_contagionism

15/ CC was "a qualified way of rejecting application of term "contagious disease" for a particular infection. E.g. it could be stated that cholera, or typhus, was not contagious in a "healthy atmosphere", but might be contagious in an "impure atmosphere"

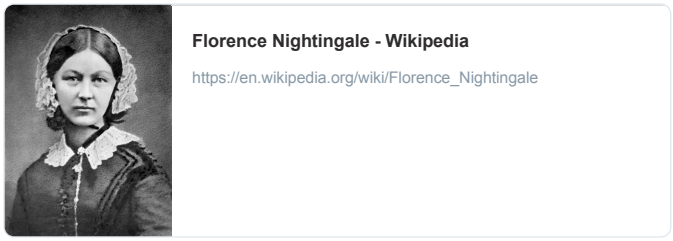
https://en.wikipedia.org/wiki/Contingent_contagionism

16/ Eerie how that applies to COVID-19. Highly contagious under some low ventilation conditions, much less so under well ventilated or outdoor conditions.

E.g. our preprint, where we reproduce indoor superspreading quantitatively with an airborne model:

17/ Florence Nightingale was a contingent contagionist.

During the Crimean war in the 1850s, she greatly reduced infection rates with social distance & ventilation.



18/ In 1854, there is a cholera epidemic in London. The public health established believed it to be caused by a miasma (bad air).

John Snow (

https://en.wikipedia.org/wiki/John_Snow

) shows that it is transmitted through water!

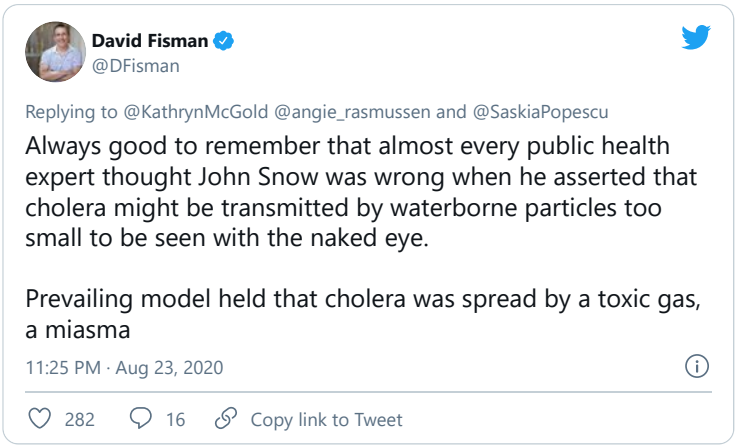
19/ The establishment didn't take it kindly, and refused to accept contaminated water as the explanation.

The Board of Health issued a report that said, “we see no reason to adopt this belief” and shrugged off Snow’s evidence as mere “suggestions.”

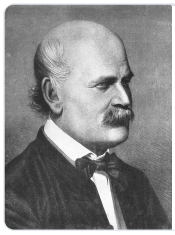
https://www.ph.ucla.edu/epi/snow/snowcricketarticle.html

20/ @DFisman explained in this brilliant thread why the establishment was so keen on rejecting water as the source of cholera: they had a lot to lose, including their prestige by admitting they had been so wrong.

Snow was outsider & could afford fight



21/ Ignaz Semmelweis was another pioneer of disease transmission (

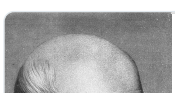


Ignaz Semmelweis - Wikipedia

https://en.wikipedia.org/wiki/Ignaz_Semmelweis

). In 1847, he figured out that handwashing greatly reduced deaths by childbed fever in a maternity clinic:

22/ These are some of Semmelweis' data (

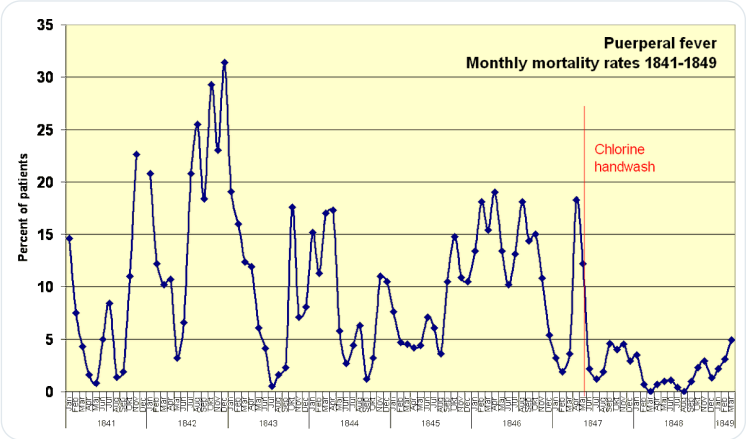


Ignaz Semmelweis - Wikipedia

https://en.wikipedia.org/wiki/Ignaz_Semmelweis

):

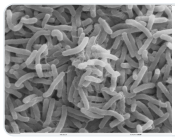
I'd call that pretty convincing and certainly worth a serious look.



23/ But Semmelweis's was largely ignored, rejected, or ridiculed. He was dismissed from hospital for political reasons and harassed by medical community in Vienna, being eventually forced to move to Budapest.

After some years broke down, was interned & beated, died of infection

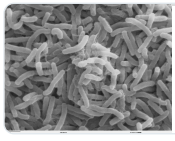
24/ In the 2nd half of the 19th Century, Pasteur and Koch demonstrate the germ theory of disease:



Germ theory of disease - Wikipedia

https://en.wikipedia.org/wiki/Germ_theory_of_disease

25/ Germ theory is not accepted overnight: "By the end 1880s, miasma theory was struggling to compete. Viruses were initially discovered in the 1890s. Eventually, a "golden era" ensued, with identification of the actual organisms that cause many diseases.



Germ theory of disease - Wikipedia

https://en.wikipedia.org/wiki/Germ_theory_of_disease

26/ In the 1990s Carl Flugge in Germany sets out to disprove the then dominant theory, that tuberculosis is transmitted when the dry sputum of the sick goes back

into the air.

27/ Flugge thought that it was not the dried secretions from the sick that went back to infect, but rather the fresh secretions were leading to infection before reaching the ground.

We explain this in paper (Lydia B. read the original papers in German)

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3829873

28/ Although it has been attributed to him (e.g. erroneously in Wikipedia:

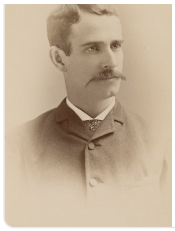
), he didn't push "Flugge's droplets" that fell to ground.

They waited 5 hours for droplets AND aerosols to settle from the air!!

29/ In 1905 a speaker at the pulpit of the expansive UK House of Commons gargled with a broth culture of B. prodigiosus before reciting Shakespeare passages in a loud voice to the empty room...

30/ ... although growth colonies were more numerous in plates near the speaker, cultures were apparent on plates over 21 m away.

31/ So we get to the critical point in the history, the work of prominent American epidemiologist Charles V. Chapin. He was very successful, in 1927 the President of American Public Health Association.



Charles V. Chapin - Wikipedia

https://en.wikipedia.org/wiki/Charles_V._Chapin

32/ Chapin was enormously influential for along time, till today. He was described in 1967 as "the greatest American epidemiologist" by Alexander Langmuir, the first a long-time director (1949-1969) of the epidemiology branch of the @CDCgov

Sorry, have to take a break to take kid to soccer. Just a I was getting to the most interesting part of the history. I'll continue in a couple of hours

34/ OK, back from soccer. Kid's team lost 2-8 and he and his best friend got hit on the face with the ball (they are 7), but they had a great time.

Let's redo the last tweet on Chapin since I made some mistakes by hurrying.

Also typo on tweet #26, Flugge worked in 1890s

35/ Chapin was enormously influential for a long time, (till today really). He was described in 1967 as "the greatest American epidemiologist" by Alexander Langmuir (https://academic.oup.com/aje/article/144/Supplement_8/S39/110304), the first and long-time director (1949-1969) of the epidemiology branch of the @CDCgov

36/ Chapin is working when miasma theory of phantasmagorical disease transmission through the air is still in the public's mind. Not so long after germ theory has been accepted.

It is a fluid time. He studies the evidence of transmission of different diseases.

37/ In 1910 he published his seminal book "The Sources and Modes of Infection."

Free on the web, and extraordinarily interesting for anyone who digs this history.

The Sources and Modes of Infection by Charles Value Chapin - Books …

The Sources and Modes of Infection - Ebook written by Charles Value Chapin. Read this book using Google Play Books app on your PC, android, iOS devices. Download for offline reading, highlight, bookm…

https://play.google.com/store/books/details?id=8bJCAAAAIAAJ&rdid=book-8bJCAAAA…

38/ Chapin conceptualized "contact infection". Germs don't come from the environment, they come from other people through direct contact or close proximity.

Starts the book by arguing against the first idea:

CHAPTER I.

LIFE OF DISEASE GERMS OUTSIDE OF THE BODY

Former Theories. — From time immemorial miasms, malarias, vapors and emanations, gaseous or otherwise, have been believed to be the frequent cause of disease. These miasms were thought to arise from stagnant marshes, decaying vegetation, putrid animal matter, and indeed filth of every kind. This belief in the extra-corporal origin of disease reached its widest acceptance about the middle of the nineteenth century. The rise of the germ theory greatly strengthened it. The discovery of bacteria and of their wide distribution and almost universal growth in dead organic substances, and the theory that these bacteria were the real cause of disease, led men to look for the source of disease outside of the body, and chiefly in dead animal and vegetable matter. With the passing of the germ theory as

39/ In the book he argues that since germs begin to die or lose their virulence outside of the body, the closer we are to others, the greater the chance of infection.

"Contact infection is more important than by fomites or by air"

Contact Chief Mode of Infection. — Since it is true that pathogenic organisms begin to die or lose their virulence when thrown off from the body, we are forced to conclude that the closer the relationship in time and space with the bearers of the germs, the greater the chance of infection. Now that the number of unknown foci of infection and the opportunities for direct transfer of secretions have been demonstrated, the deduction is certainly permissible that contact infection is more important than the more indirect infection by fomites or by air.

40/ There are many opportunities for "transfer or secretions" between people during close contact, including from asymptomatic cases.

Like "typhoid Mary," (

Mary Mallon - Wikipedia

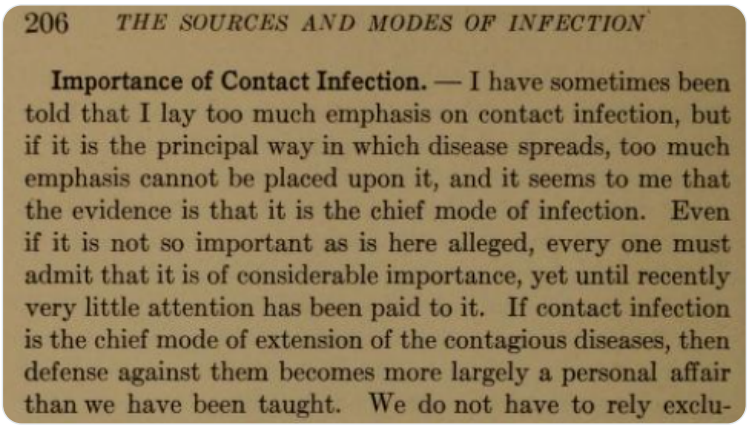
https://en.wikipedia.org/wiki/Mary_Mallon

) an asymptomatic cook who infected 53 people with typhoid fever in 1907.

Chapin of course aware.

41/ Chapin believes that contact infection is the main mode of transmission of many diseases. But like any new theory, he encounters resistance: "I have sometimes been told I lay too much emphasis on contact infection."

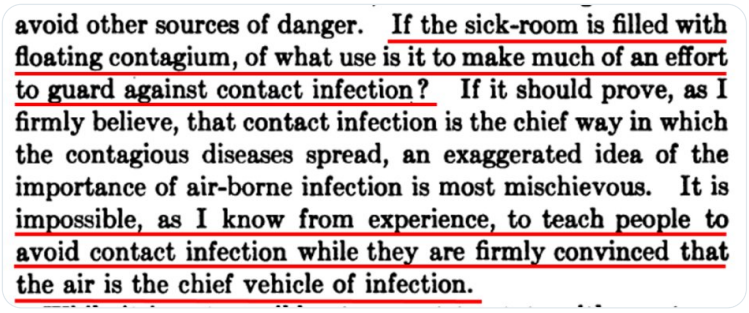
"Until recently very little attention has been paid to it"



206 THE SOURCES AND MODES OF INFECTION

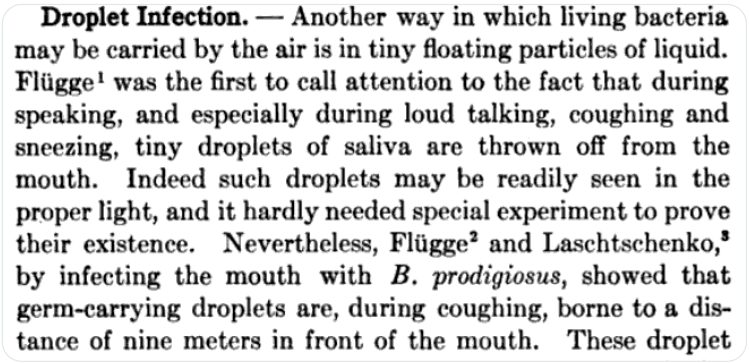
Importance of Contact Infection. — I have sometimes been told that I lay too much emphasis on contact infection, but if it is the principal way in which disease spreads, too much emphasis cannot be placed upon it, and it seems to me that the evidence is that it is the chief mode of infection. Even if it is not so important as is here alleged, every one must admit that it is of considerable importance, yet until recently very little attention has been paid to it. If contact infection is the chief mode of extension of the contagious diseases, then defense against them becomes more largely a personal affair than we have been taught. We do not have to rely exclu-

42/ Chapin also reviews the possibility of airborne infection. As he admits at the end of that chapter, the belief on airborne infection is the main obstacle he is encountering to promote his ideas of the importance of contact infection:



avoid other sources of danger. If the sick-room is filled with floating contagium, of what use is it to make much of an effort to guard against contact infection? If it should prove, as I firmly believe, that contact infection is the chief way in which the contagious diseases spread, an exaggerated idea of the importance of air-borne infection is most mischievous. It is impossible, as I know from experience, to teach people to avoid contact infection while they are firmly convinced that the air is the chief vehicle of infection.

43/ Chapin is aware of the work of Flugge (tweets 26-28). Tiny droplets that can be seen in the proper light. That on a bad cough can reach 9 meters.



Droplet Infection. — Another way in which living bacteria may be carried by the air is in tiny floating particles of liquid. Flügge[1] was the first to call attention to the fact that during speaking, and especially during loud talking, coughing and sneezing, tiny droplets of saliva are thrown off from the mouth. Indeed such droplets may be readily seen in the proper light, and it hardly needed special experiment to prove their existence. Nevertheless, Flügge[2] and Laschtschenko,[3] by infecting the mouth with *B. prodigiosus*, showed that germ-carrying droplets are, during coughing, borne to a distance of nine meters in front of the mouth. These droplet

44/ Chapin is also aware of the work of Flugge and at the UK the House of Commons showing transport of germs for considerable distances and floating for hours (tweets 28-30).

Amount of Droplet Infection. — Since it has been shown by Flügge that droplets from speaking may float for from five to six hours, and be transported by air currents of only one mm. per second, it is not surprising that they should be carried such distances. Nor is it surprising that Hutchinson[1] was able to prove that a fine spray of a culture of *B. prodigiosus* was carried fifty-five meters along a corridor, and up two flights of stairs, and also a considerable distance out of doors. Others have shown that the bacteria of the mouth may be carried by the air during speaking over a large room or hall.[2] Leon[3] showed that in speaking three hundred words 250,000 bacteria were thrown off from the mouth, and Ziesché[4] found over 20,000 tubercle bacilli on a plate 324 sq. cm. exposed for half an hour. But it has further been shown by Kirstein[5] and Königer[6] and Laschtschenko[7] that the size of the droplets and the distance they can be carried depend to a large extent upon whether the liquid is thin and watery or a thick mucus. Hence we should expect that droplets of thick sputum would not be carried nearly so far as droplets of more liquid saliva, and according to Goldie[8] droplets of the saliva rarely carry bacilli but only the droplets of sputum.

45/ C. concludes that the evidence for transmission through the air is overall weak, and that contact and spray-borne infection is a better explanation of the observed patterns.

He was especially fighting airborne transmission over v. long distances, nearly impossible to avoid

Conclusions. — After the foregoing survey of the subject we are, I think, justified in the following conclusions:

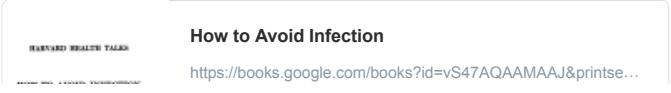
1. The theory of the aerial transmission of disease was developed as the most reasonable way of explaining the phenomena of infection.
2. Contact infection with carriers and missed cases affords a better explanation of the phenomena.
3. The best medical thought has been steadily restricting the supposed sphere of aerial transmission.
4. Only a few authorities now assert that disease is carried by the atmosphere outside of dwellings, and this assertion is made only in regard to smallpox.
5. Bacteriology teaches that former ideas in regard to the manner in which diseases may be air-borne are entirely erroneous; that most diseases are not likely to be dust-borne, and they are spray-borne only for two or three feet, a phenomenon which after all resembles contact infection more than it does aerial infection as ordinarily understood. Tuberculosis is more likely to be air-borne than is any other common disease.
6. Surgeons at first developed aseptic surgery on the theory that air infection was of the highest importance. They have gradually learned to pay less attention to it, until at present some of the best surgeons consider it a negligible factor.
7. Animal experimentation indicates that tuberculosis and anthrax may be air-borne, and that plague and some other diseases are not.
8. Pathology has not determined, as is sometimes alleged, that even pulmonary consumption is an air-borne disease.
9. There is no good clinical evidence that the common diseases are air-borne.

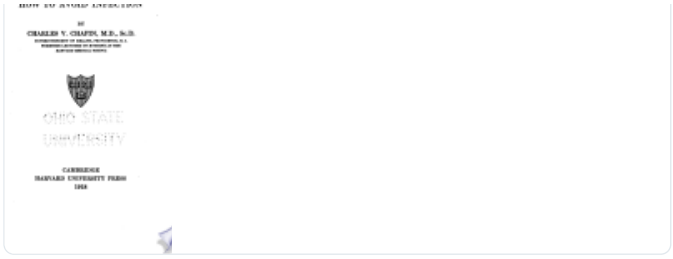
46/ And we get to the key point: there is not a lot of evidence of airborne, & it is getting on the way of contact.

Therefore "we are warranted in discarding [airborne]. It will be a great relief to most persons to be freed from the specter of infected air... since Hippocrates"

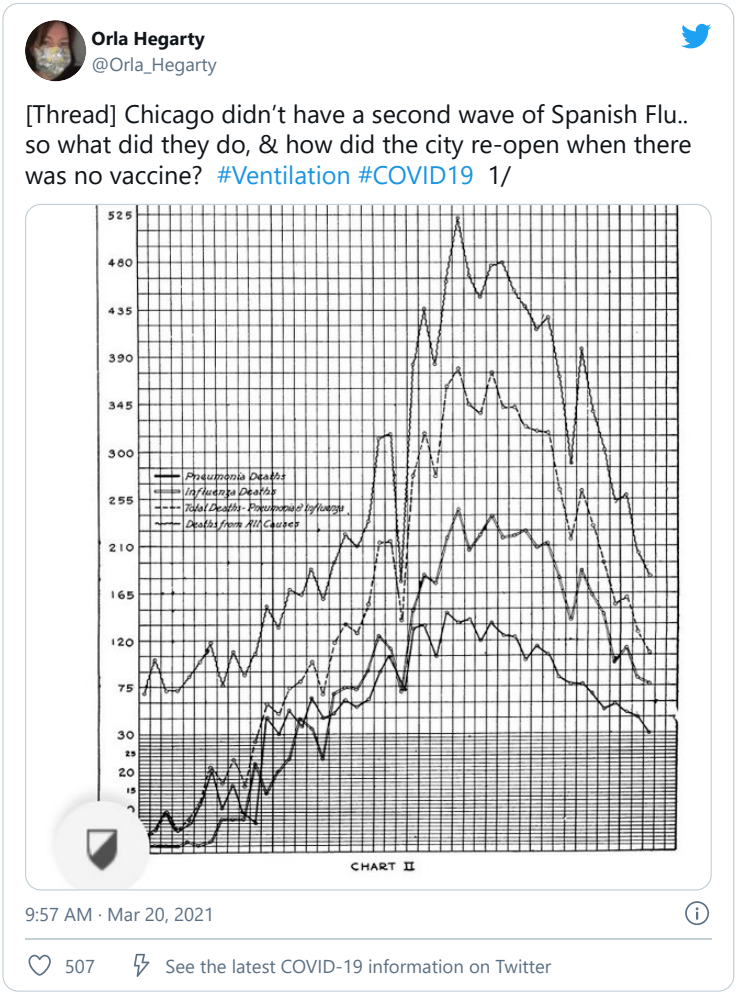
tance of infection by air are unwarranted. Without denying the possibility of such infection, it may be fairly affirmed that there is no evidence that it is an appreciable factor in the maintenance of most of our common contagious diseases. We are warranted, then, in discarding it as a working hypothesis and devoting our chief attention to the prevention of contact infection. It will be a great relief to most persons to be freed from the specter of infected air, a specter which has pursued the race from the time of Hippocrates, and we may rest assured that if people can as a consequence be better taught to practice strict personal cleanliness, they will

47/ To learn more about Chapin's views, this short book is the transcript of a talk he gave at Harvard in 1917:





48/ The 1918 "Spanish Flu" happens the next year. There is evidence that ventilation and outdoor air work, that point to airborne transmission.



49/ Still, Chapin's ideas are widely accepted over the next 2 decades and become firmly established.

In the 1930s, William Wells (Harvard Prof.) & wife Milfred Wells start applying more modern methods to the investigation of airborne transmission.

In particular TB & measles.

50/ Wells is the first person to study what is the size of sprayborne droplets vs. airborne aerosols.

Conceptualizes it as sprayborne droplets fall before they dry, while aerosols dry

before they fall (thus "droplet nuclei".

https://academic.oup.com/aje/article-abstract/20/3/611/280025?redirectedFrom=PDF

51/ Figures out that droplets are larger than ~100 microns, and aerosols smaller.

"A raindrop 2 mm in diameter can fall miles without completely evaporating under conditions which would cause a 0.2 mm droplet to evaporate before it had fallen from the height of a man"

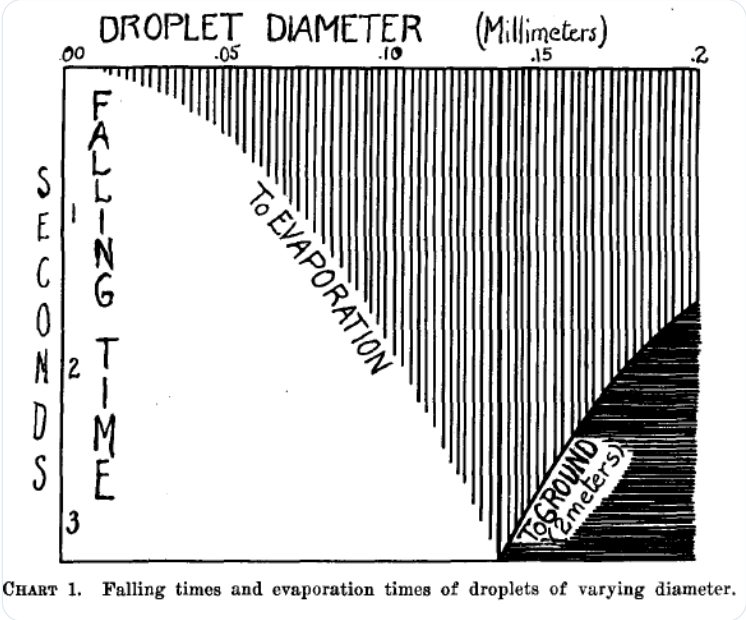


CHART 1. Falling times and evaporation times of droplets of varying diameter.

52/ The Wells encounter a lot of resistance. They are accused of "trying to bring back miasmas"

https://en.wikipedia.org/wiki/William_F._Wells

53/ Chapin had fought for his ideas. He knew of course of the difficulties that Semmelweis or Snow had had to get their theories accepted.

But he was better positioned & was spectacularly successful. Ease of infection in close proximity was understood as PROOF of spray droplets

54/ Measles was thought to be a droplet fomite disease. At the time of Wells, and as late as 1985, because of ease of transmission in close proximity (== sprayborne droplets per Chapin) and cases of lack of infection with shared air.

Wells thinks it is airborne.

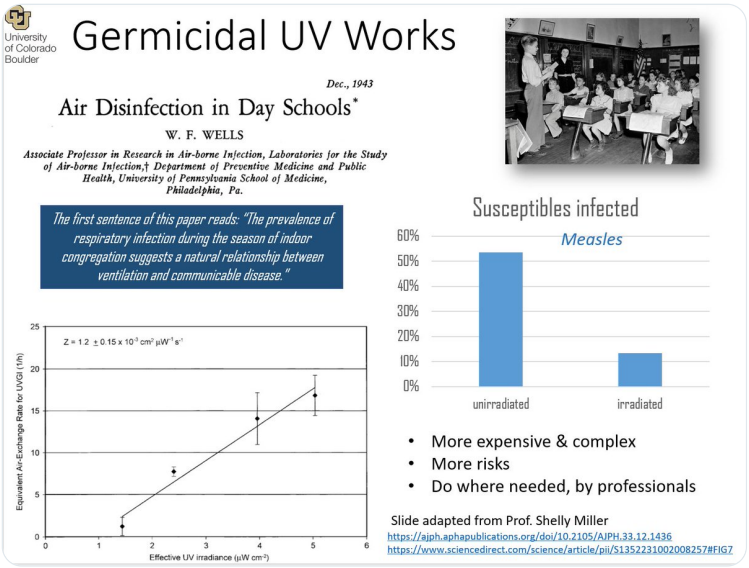
Measles (1985)

75%.[1] Most public health authorities believe that the primary mode of transmission is by large respiratory droplets which remain suspended in air for short time intervals.[2] Successful transmission in this manner requires close contact between susceptible individuals and a source patient, usually within 1 m (3 ft). Data supporting respiratory droplet spread come from studies conducted in the early 20th century.[3] Following hospitalization of 182 patients with measles at two hospitals, only one secondary case of measles occurred. Transmission was limited despite free circulation of air in both hospitals, presumably because measures were taken to prevent direct contact between patients with measles and others who were susceptible.

55/ Wells has some initial success showing that UV lights installed in the ceiling of classrooms greatly reduced measles infection.

The American Journal of Public Health (AJPH) from the American Publ…
American Journal of Public Health (AJPH) from the American Public Health Association (APHA)

https://ajph.aphapublications.org/doi/10.2105/AJPH.33.12.1436



56/ However, subsequent attempts give mixed results.

In retrospect, clear why:

- In school where UV worked the kids where only together indoors in the school, not otherwise

- In later schools they shared other indoor spaces for hours, such as school buses. Got infected there.

57/ In the 1945 article in the predecessor journal of @ScienceMagazine, Wells laments how our societies have invested and been successful on eliminating infections through drinking water and through food.

But air infection is denied, so no action taken

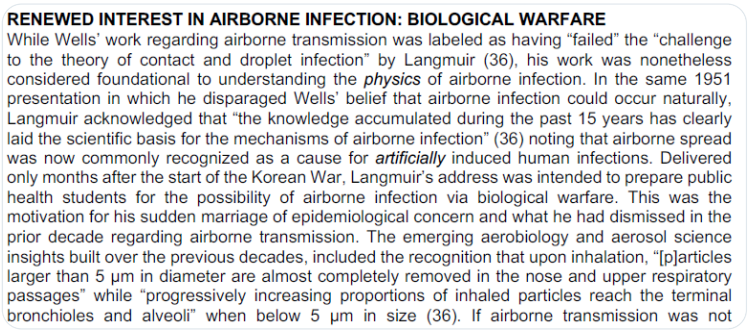
58/ In 1951, Alexander Langmuir (first and longtime director of epidemiology branch of @CDCgov) states:

"It remains to be proved that airborne infection is an important mode of spread of

naturally occurring disease”

59/ However, Langmuir has renewed interest on the physics of airborne infection, because of biological warfare. Natural diseases don't seem to be airborne, but Langmuir reaches the conclusion that weapons of airborne disease can be created.

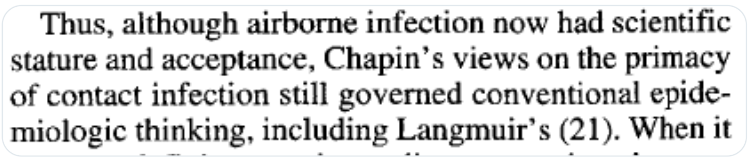
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3829873


RENEWED INTEREST IN AIRBORNE INFECTION: BIOLOGICAL WARFARE
While Wells' work regarding airborne transmission was labeled as having “failed” the “challenge to the theory of contact and droplet infection” by Langmuir (36), his work was nonetheless considered foundational to understanding the ***physics*** of airborne infection. In the same 1951 presentation in which he disparaged Wells' belief that airborne infection could occur naturally, Langmuir acknowledged that “the knowledge accumulated during the past 15 years has clearly laid the scientific basis for the mechanisms of airborne infection” (36) noting that airborne spread was now commonly recognized as a cause for ***artificially*** induced human infections. Delivered only months after the start of the Korean War, Langmuir's address was intended to prepare public health students for the possibility of airborne infection via biological warfare. This was the motivation for his sudden marriage of epidemiological concern and what he had dismissed in the prior decade regarding airborne transmission. The emerging aerobiology and aerosol science insights built over the previous decades, included the recognition that upon inhalation, “[p]articles larger than 5 μm in diameter are almost completely removed in the nose and upper respiratory passages” while “progressively increasing proportions of inhaled particles reach the terminal bronchioles and alveoli” when below 5 μm in size (36). If airborne transmission was not

60/ Langmuir has a key problem when trying to investigate airborne infection.

He views the world through the lens of Chapin's theories. He had called Chapin the greatest American epidemiologist, and as late as 1980 Chapin's views were still dominant:

https://academic.oup.com/aje/article/144/Supplement_8/S39/110304


Thus, although airborne infection now had scientific stature and acceptance, Chapin's views on the primacy of contact infection still governed conventional epidemiologic thinking, including Langmuir's (21). When it

61/ It is apparent reading this article on Langmuir and his investigation of airborne transmission that he had the wrong Chapin-influenced mental model.

They equated transmission in close proximity with droplets only.

https://academic.oup.com/aje/article/144/Supplement_8/S39/110304

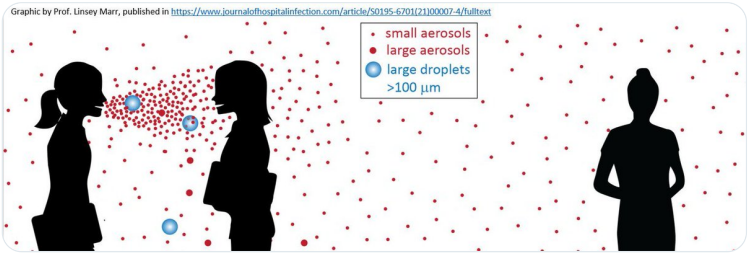
62/ And they ignored the concept of dilution!! They assumed that airborne infection would STAY THE SAME if distance increased.

https://academic.oup.com/aje/article/144/Supplement_8/S39/110304

Persisting questions about airborne spread led Langmuir to undertake some intervention studies that evaluated several environmental measures directed toward reducing transmission. One such study (10) evaluated double bunking without concomitant crowding. If droplet spread were important, then double bunking, with more space between bunks, should decrease close contact, and illness should decrease. However, if spread were airborne, there should be no change in the illness rate since the number of cubic feet of air per person within the barracks remained unchanged. During an epidemic of acute respiratory disease, the weekly incidence rate per 1,000 persons in the double-bunked group was substantially less than the control group—11.2 versus 19.6—thus substantiating the role of droplet spread. The same appeared to be true for primary atypical pneumonia.

63/ But that is not how the world works. Distance reduces droplets, but it also reduces how much exhaled air from others is inhaled (think cigarette smoke).

I have this image as my Twitter banner because @WHO & @CDCgov have been making this very error TILL THIS WEEK!!



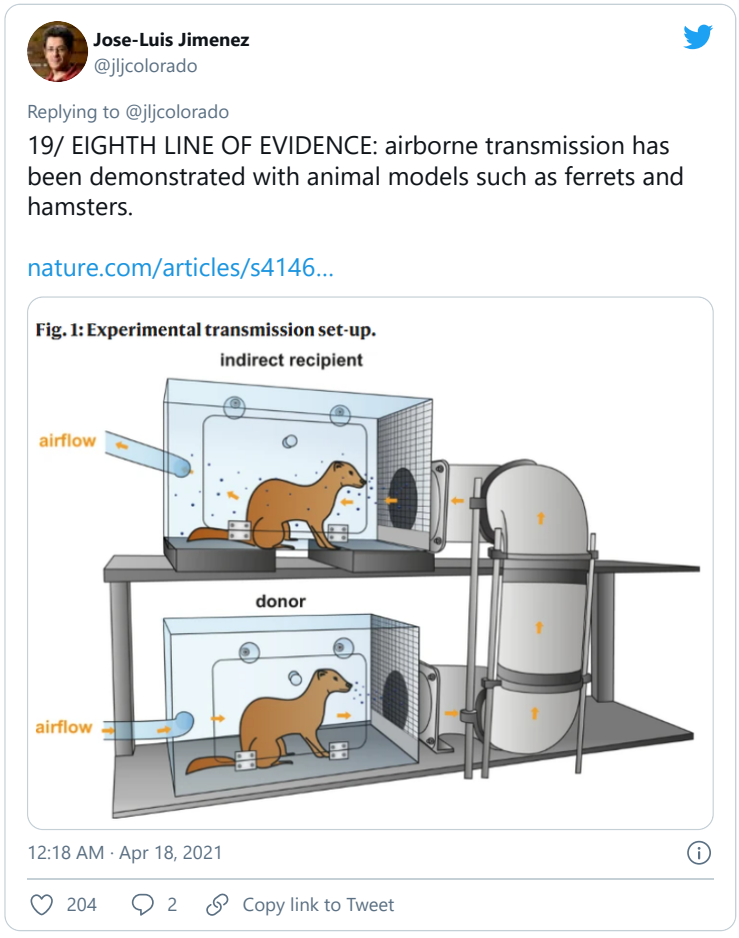
64/ Despite all the resistance, the Wellses, Robert Riley, and Cretyl Mills succeed in demonstrating aiborne transmission of tuberculosis in 1962, from people to guinea pigs.

65/ They have 150 guinea pigs in cages, and the air from a ward with TB patients is

channeled to them. 3 GP per month get infected. None get infected in a control group where the only difference is the air is UV irradiated, killing the TB bacterium.

66/ That's what it took to accept TB was airborne.

Notable that there are similar experiments for COVID-19 with ferrets and hamsters, but they are routinely dismissed as irrelevant by the dropletologists.



67/ Airborne transmission of smallpox is accepted in 1971. There is an obvious case of

long-distance transmission in a hospital in Germany.

68/ The article on the German smallpox outbreak notes the ongoing thinking: "The only remaining route of transmission considered reasonable was airborne spread of a virus-containing aerosol, ***a possibility against which all of the investigators were initially prejudiced***."

> The only remaining route of transmission considered reasonable was airborne spread of a virus-containing aerosole, a possibility against which all of the investigators were initially prejudiced. A smoke device was released in B.K.'s room on April 10, when weather conditions were similar to those of January, and the clear and distinctive patterns of air currents outside and within the building are shown in figure 2. The route followed by the smoke fits very well with the distribution of secondary cases.

69/ Smallpox airborne transmission accepted bc so obvious, even those prejudiced against it can't deny it!

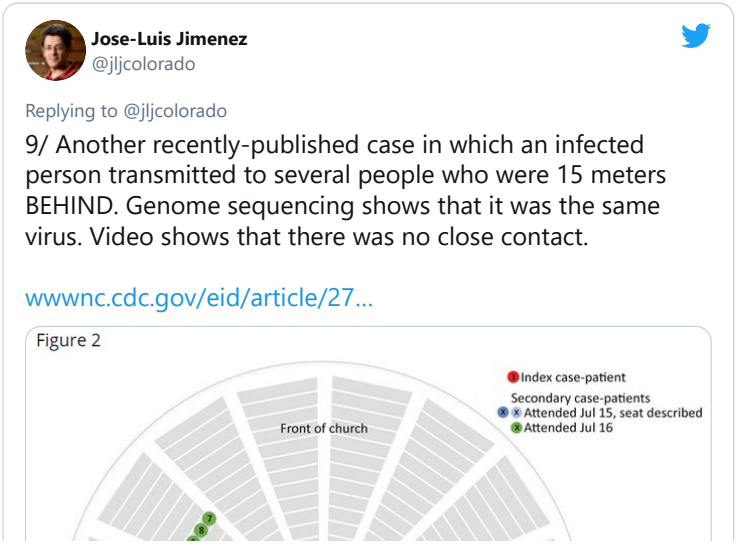
But it is still described as an unusual event, ¨a unique exception¨

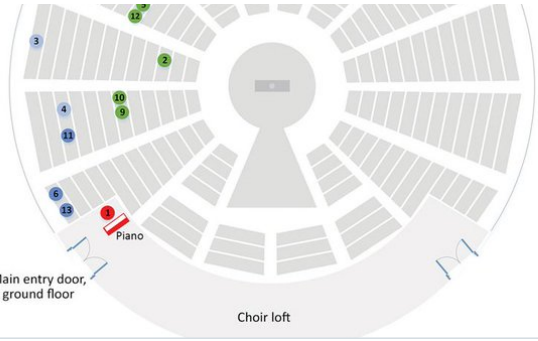
Smallpox still thought droplet-fomite, accepting as little airb. as possible

https://academic.oup.com/aje/article/144/Supplement_8/S39/110304

> This event cast some doubt on the theoretical basis for the entire smallpox eradication program, but the program leadership was convinced of its earlier success and that the outbreak in Meschede would prove to be a unique exception to the rule. History has shown that they were quite correct.

70/ The same is done today by droplet-proponents, when discussing obvious cases of long-distance COVID-19 transmission (e.g 15 m behind someone in a church, with video showing no contact and genomic match). "That's unusual, but COVID is droplet otherwise"





11:59 PM · Apr 17, 2021

299 4 Copy link to Tweet

71/ Eventually measles is also accepted as airborne after about 75 YEARS of calling it droplet / fomite. Bc of undeniable superspreading events

Makes me chuckle when droplet proponents suggest it'd be obvious COVID was airborne if it was like measles. It was quick last time...

72/ This is one of the articles on measles superspreading:

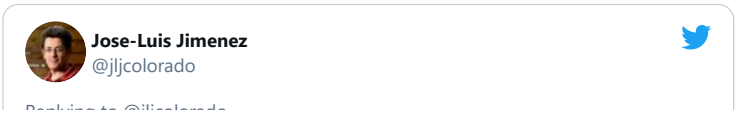
https://pediatrics.aappublications.org/content/75/4/676.long

73/ Eventually chickenpox is also accepted as airborne, also based on superspreading (

)

Both measles and chickenpox are much more contagious than COVID on average. (Although COVID superspreading is not that far from measles)

74/ Interestingly, despite all the resistance to accept TB, measles, and chickenpox as airborne for decades and decades, they were accepted with much less evidence than we have today for COVID-19 being airborne.



Replying to @jjjcolorado

37/ Incidentally, measles and chickenpox were accepted as airborne with A LOT less evidence than we have now for COVID-19.

(From: twitter.com/JenniferKShea/...)

EVIDENCE SUPPORTING AIRBORNE TRANSMISSION	MEASLES	COVID-19
In lab setting, aerosolized virus is still viable (infectious) in the air after significant time has passed	**De Jong 1964** *Viable virus at 2 hours (less decay at low RH versus high RH)*	**van Doremalen 2020** *Viable virus at 3 hours without rapid decay despite high RH*
Viral RNA detected in aerosol samples and on low-/no- touch surfaces in absence of "AGMPs"	**Bischoff 2015**	**Chia 2020** **Lednicky 2020** **Santarpia 2020** *Highest surface contamination on floor and air exhaust grates*
Viable (infectious) virus cultured from aerosol samples		**Lednicky 2020** *Other pre-print studies pending peer-review*
Animal model showing viral transmission through the air	*Humans are only natural host*	**Richard 2020** **Kutter 2021** *Ferret model – including transmission > 1m and against gravity*
Outbreak investigations showing high likelihood of transmission over "long distances" (ie > 2m)	**Bloch 1985** – *Dr. office outbreak* **Remington 1985** – *Dr. office outbreak* **Riley 1978** – *School outbreak*	**Azimi 2021** – *Cruise outbreak model* **Eichler 2021** – *NZ quarantine hotel outbreak* **Günther 2020** – Meat processing outbreak **Miller 2020** – *Skagit choir outbreak*
Studies showing virus **within** HVAC vents/ducts	***Riley 1978** often quoted in literature as showing spread via HVAC, but several weaknesses and does NOT prove this**	**Nissen 2020** *+ RNA in HEPA filters, 5-7 floors above COVID+ patient areas, connected via ducts*
Nosocomial infections despite droplet and contact precautions used by HCWs		**Klompas 2021** **Klompas 2021** **Goldberg 2021**

Jennifer K McDonald @JenniferKShea

It's widely accepted that #MeaslesIsAirborne

I summarized the evidence for airborne spread of Measles vs. COVID-19 in a table

The results were quite shocking to me ...

How is it that we are still discussing whether or not #COVIDisAirborne??

1/

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Nosocomial infections despite droplet and contact precautions used by HCWs		**Klompas 2021** **Klompas 2021** **Goldberg 2021**

1:03 AM · Apr 18, 2021

149 See the latest COVID-19 information on Twitter

75/ OK, have to take another break for dinner. Phew, this is the longest thread I have written. But I think it is worth putting the effort into it, because I am convinced history set us up for the huge error of denying that COVID-19 is an airborne disease. Will finish in few hrs

76/ So before COVID-19, TB (less contagious but undeniable) and measles / chickenpox (very highly contagious, obvious superspreading) were widely accepted as

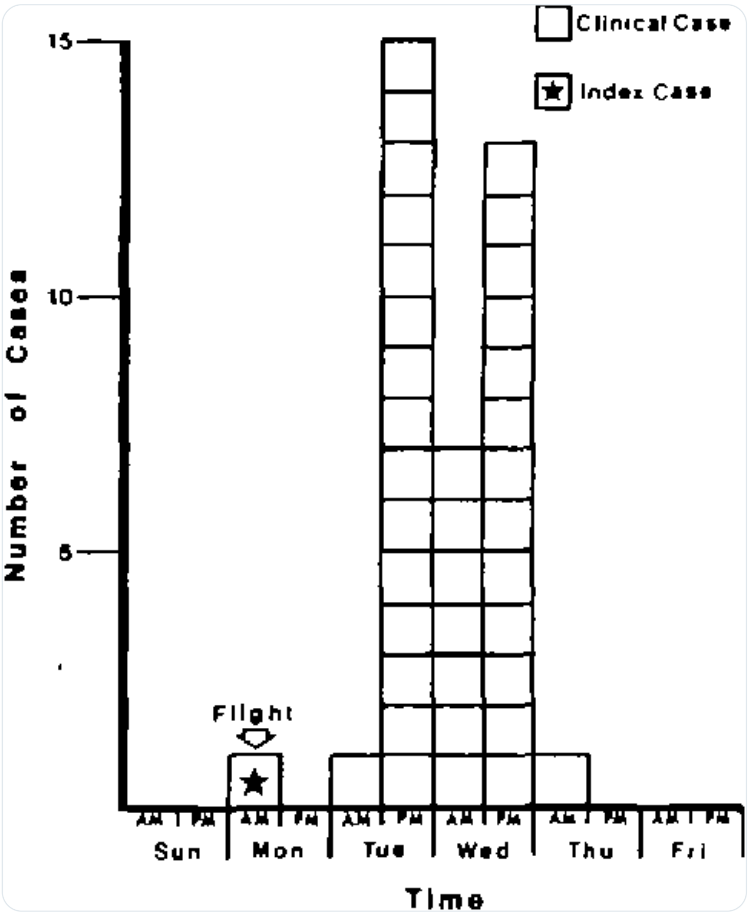
airborne

Turns out there is evidence for airborne transmission for a lot of respiratory diseases, but not widely accepted

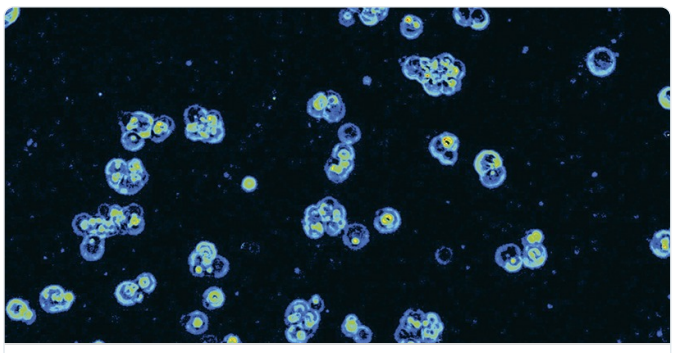
77/ E.g. the flu, very important for its pandemic potential. Superspreading in plane:

"A plane w/ 54 persons aboard was delayed on the ground for 3 hours without ventilation. Within 72 hours, 72% of passengers got the flu."

https://academic.oup.com/aje/article-abstract/110/1/1/62223?redirectedFrom=fulltext



78/ Infective flu virus has been captured from exhaled breath:



Infectious virus in exhaled breath of symptomatic seasonal influenza c...

Lack of human data on influenza virus aerosol shedding fuels debate over the importance of airborne transmission. We provide overwhelming evidence that humans generate infectious aerosols and quantit…

https://www.pnas.org/content/115/5/1081

Yet the flu is solidly considered a droplet / fomite disease.

79/ could go on & on. I recommend following @jmcrookston and reading his older threads for a look at the historical literature for many diseases.

It seems that airborne was pretty obvious all along for many diseases, but was rejected "as much as possible" (as smallpox Tw 68-69)

80/ Within this wider dominance of the droplet / fomite theory, an error slips in at some point.

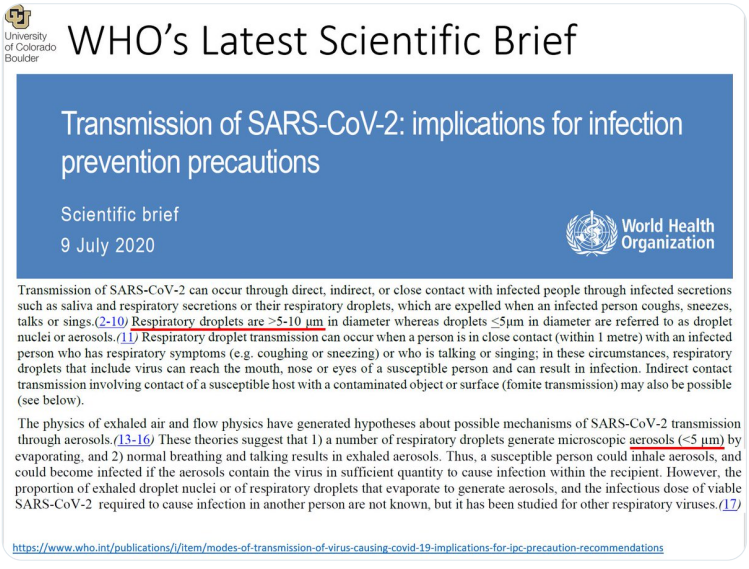
- Wells showed that aerosols are < 100 microns, to fall to the ground near person (tweet #51)

- Langmuir knew that to get deep into lung, need very small aerosols < 5 um (tweet 59)

81/ But somehow an error is introduced confusing the 2: @WHO and @CDCgov guidelines start saying that particles smaller than 5 microns fall to the ground.

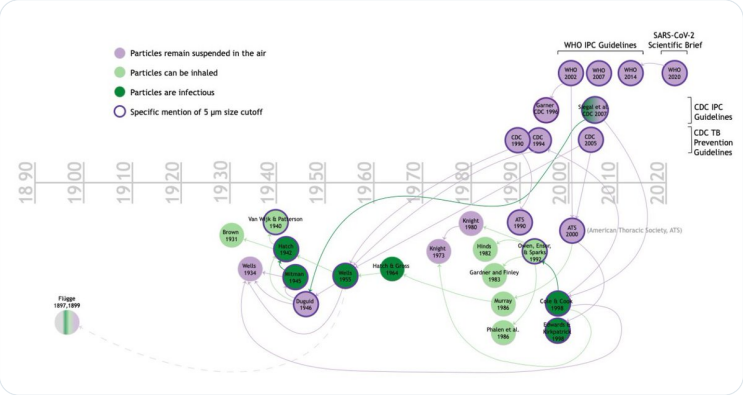
Do this for decades, e.g. the LATEST @WHO Scientific Brief on COVID-19 transmission! (no reference)

https://www.who.int/publications/i/item/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations



82/ We followed the references, and they lead nowhere. No primary study ever stated that particles smaller than 5 microns fall to the ground within 1-2 m of a person.

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3829873



83/ What seems to have happened:

- Tuberculosis was the main airborne infection of concern
- TB can ONLY infect if aerosols reach alveoli (< 5 microns)
- Someone confused reaching the deep lung (< 5 microns) w/ falling to the ground within 1-2 m (>100 microns)

84/ @CDCgov seems to have realized this error in their 2007 Infection Control Guidelines

Yet this never became common knowledge (e.g. not to the world-renowned @WHO experts that wrote its COVID-19 transmission scientific briefing)

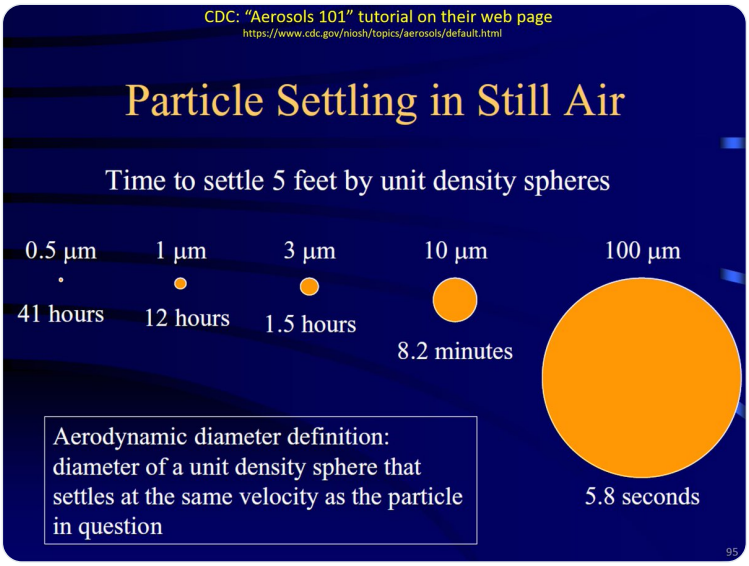
https://www.cdc.gov/infectioncontrol/guidelines/isolation/scientific-review.html

> Droplet size is another variable under discussion. Droplets traditionally have been defined as being >5 µm in size. Droplet nuclei, particles arising from desiccation of suspended droplets, have been associated with airborne transmission and defined as ≤5 µm in size,[105] a reflection of the pathogenesis of pulmonary tuberculosis which is not generalizeable to other organisms. Observations of particle dynamics have demonstrated that a range of droplet sizes, including those with diameters of 30µm or greater, can remain suspended in the air [109]. The behavior of droplets and droplet nuclei affect

85/ Many people say they don't care about microns.

But the key is the disregard of aerosol science that this reveals: for DECADES, an error was repeated over and over, despite the right answer being on the @CDCgov web page (occ. med. branch):

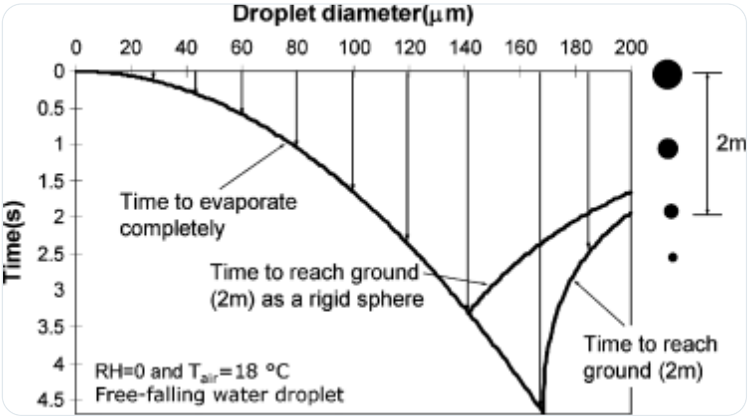
https://www.cdc.gov/niosh/topics/aerosols/default.html



86/ And the physics of the ~100 micron aerosol / droplet was re-examined and published again, e.g. by Prof. Yuguo Li, prominent expert in this field:

He is in @WHO committees, but droplet experts didn't listen.

https://onlinelibrary.wiley.com/doi/10.1111/j.1600-0668.2007.00469.x

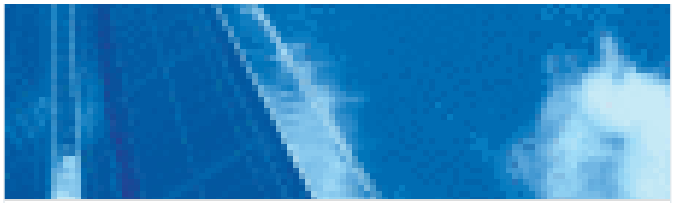


87/ So what the 5 micron error really reveals is a key sociological aspect. Despite droplet infection being a hypothesis without much evidence, it was SO dominant that the experts didn't even bother with the details, and ignored aerosol experts and their work.

88/ In reality, droplet infection is a house of cards.

From Y. Li's review of the scientific literature: It has NEVER been demonstrated directly for ANY disease in the history of medicine!

[If you have a paper that proves otherwise, pls send it to me]

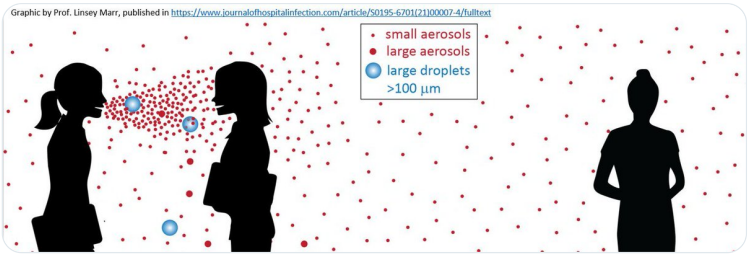


Short-range airborne route dominates exposure of respiratory infectio…
A susceptible person experiences the highest exposure risk of respiratory infection when he or she is in close proximity with an infected person. The …
https://www.sciencedirect.com/science/article/pii/S0360132320302183

> Reviewing the literature on large droplet transmission, one can find no direct evidence for large droplets as the route of transmission of any disease.

89/ Ease of infection in close proximity could be explained by droplets, but can also be explained by aerosols.

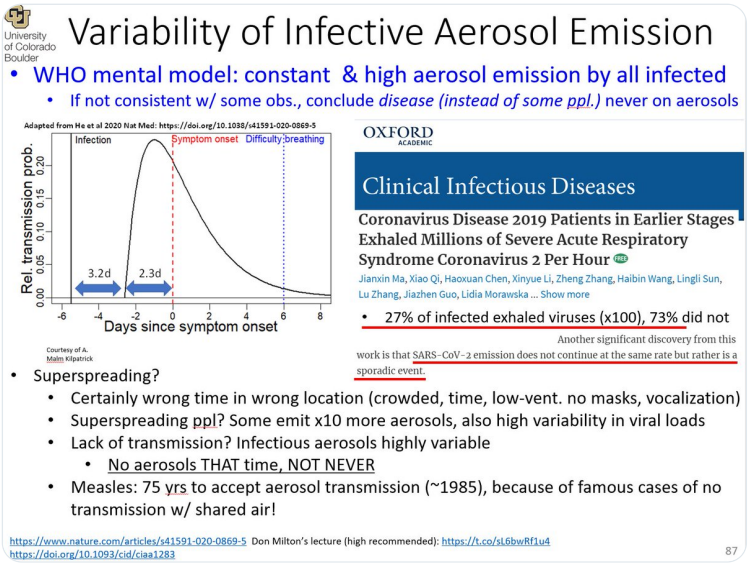
https://doi.org/10.1016/j.jhin.2020.12.022



90/ Lack of infection w/ shared air can be explained by some people not exhaling infective virus. Shown for SARS-CoV-2 (slide,)

As for measles for 7 decades, droplet proponents have a HIDDEN assumption: everyone infected sheds lots of infective virus

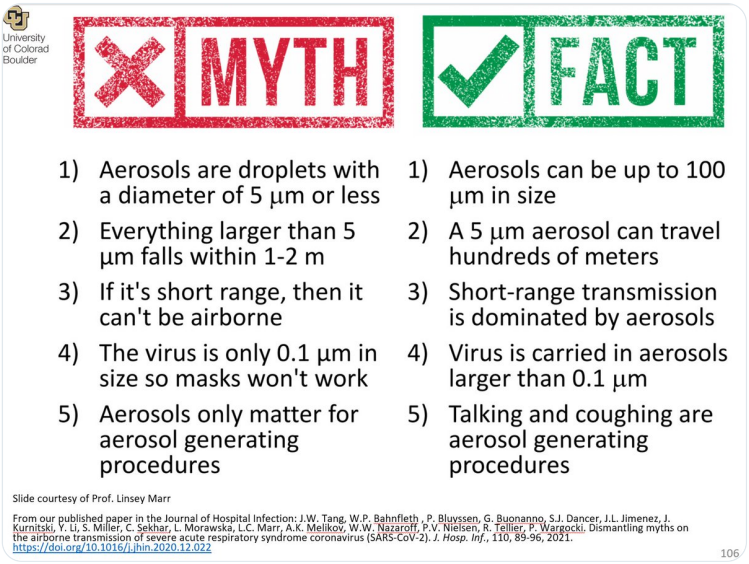
https://doi.org/10.1093/cid/ciaa1283



91/ We explain other myths about airborne transmission that have no basis, yet they

are constantly repeated by e.g. major @WHO advisors and Public Health authorities around the world to justify droplet transmission of COVID and deny airborne transmission.

https://doi.org/10.1016/j.jhin.2020.12.022



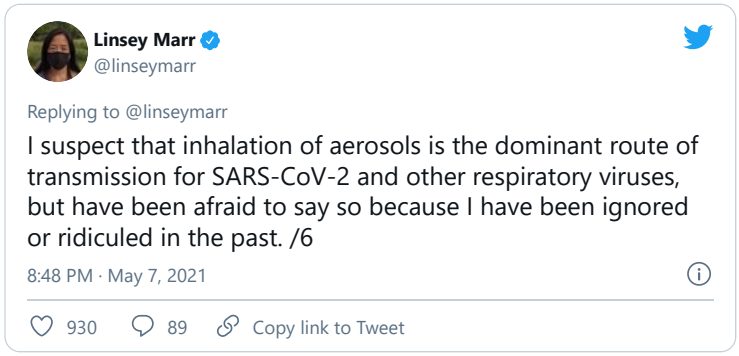
92/ During the last many decades, with antibiotics, vaccines, and no huge pandemics, these details of transmission had not been a priority. Droplet experts were in control of all key institutions, could ignore few airborne proponents.

93/ E.g. colleagues mention that often they would write a research proposal to fund a study of airborne transmission.

And the anonymous peer-reviews would come back saying "airborne transmission is not important, therefore we shouldn't waste funding on this."

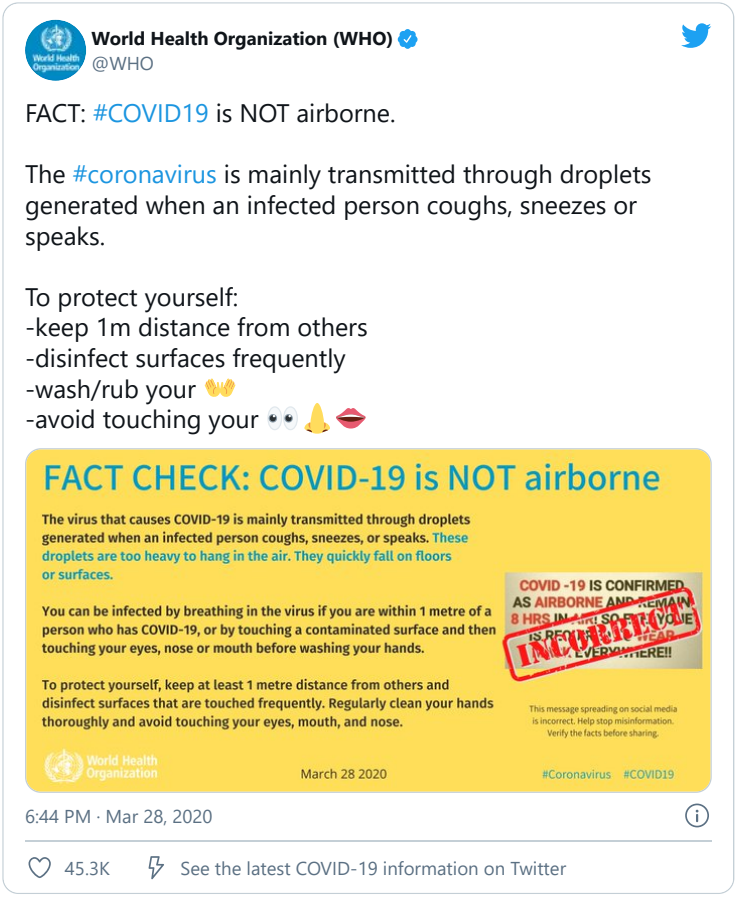
94/ When I started working on this in Feb. 2020, it seemed that the airborne transmission experts were VERY shy, compared to the significant evidence in favor of airborne.

With time I realized they had PTSD from being ignored and ridiculed over decades!



95/ So it is with this background that @WHO confidently declared on 28-March-2020 that "FACT: COVID is NOT AIRBORNE".

And that saying it was airborne was MISINFORMATION, that we need to help @WHO fight!



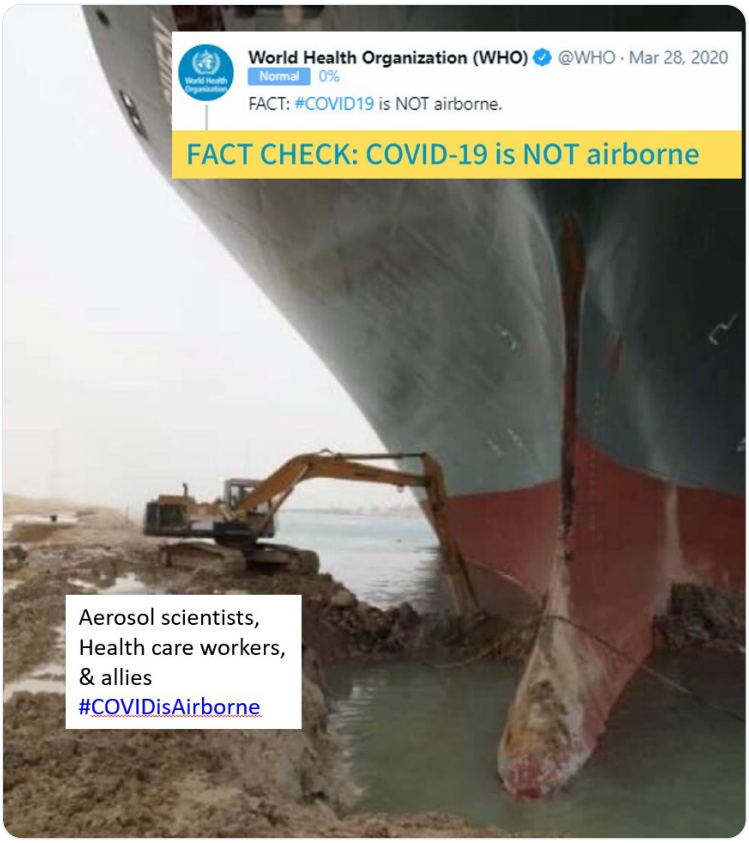
96/ Lidia Morawska organized an international group of scientists to talk to @WHO, which we did on 3-Apr-2020.

I found that meeting shocking, couldn't get my head around why the @WHO experts were SOOOO dismissive of airborne.

97/ @Don_Milton said the super-strong anti-airborne prejudice was due to history and this Chapin fellow.

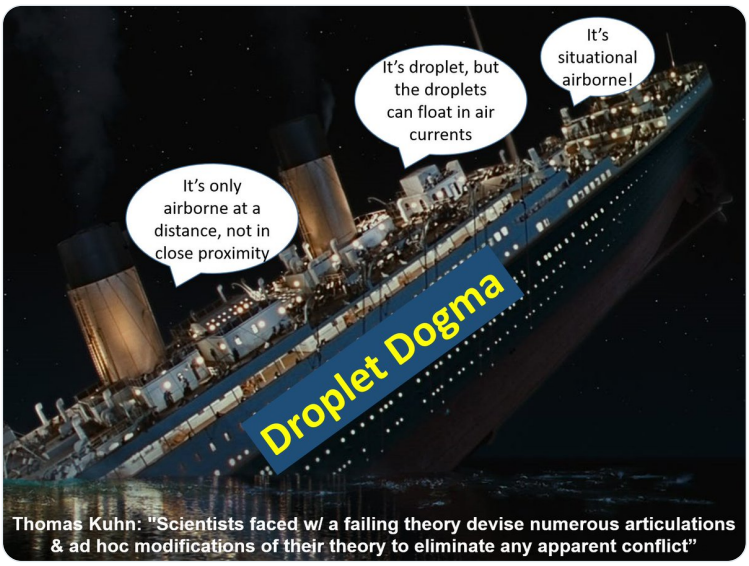
I was very perplexed. But I started reading on the history and talking to people. And I learned in the last year what I have told you today.

98/ So yours truly and 100s of scientists have spent the last year working on this, as exemplified by this depiction:



99/ Cleary droplet theory is sinking, unable to explain the observations. Still its proponents are resorting to the equivalent of epicycles, trying to save a failing theory by adding patches like "situational airborne"

But Thomas Kuhn is coming for them w/ a paradigm shift...



100/ Our work is not done. It is critical to tell the world loud and clear that this virus is airborne, 1-on-1 in close proximity and 1-to-several in shared room air.

The message, and the changes in mitigations, have not arrived to many countries, or not clearly.

101/ OK, I'll leave it there for today. But if you made it to here, please answer this question. Should I do something with this thread?

102/ For an automatic translation, see this link (change "Spanish" at the top of the page for the language of interest to you:

HT @DrZoeHyde

• • •