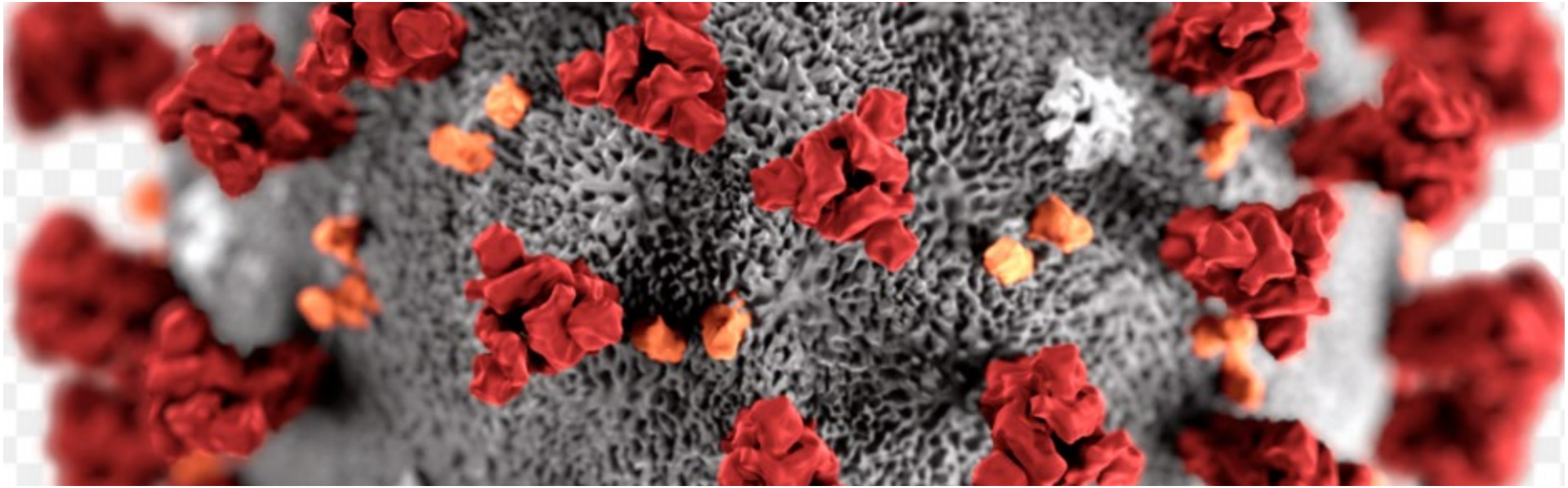
SOME BASIC BIOLOGY TO HELP US UNDERSTAND THE COVID-19 PANDEMIC

AND HELP YOU ANSWER MOST OF YOUR OWN QUESTIONS



DICTIONARY

Disease

Virus

Bacteria

Pathogen

Pathogen host

Infection

Immune system

Inflammation

Antibody

Protein

Cell

Reproduce

DNA

RNA

Cell membrane

Population

Species

Contamination

Public health

Infectious disease

Epidemiology

LET'S WARM UP

Please think for a minute: What questions do you have about COVID-19?

Please write your questions down. You will look at them again at the end of the lecture.

MAJOR QUESTIONS

- How was this coronavirus "born"? Where did it come from?
- Why people have different response to it? Why some get very sick and others - don't? Is it REALLY that serious?
- Why the coronavirus changes over time? Is that normal?
- Why we don't have a cure for coronavirus, a pill or sort?
- When can we finally travel again? Didn't we have enough restrictions already?

What is a virus? What is bacteria?

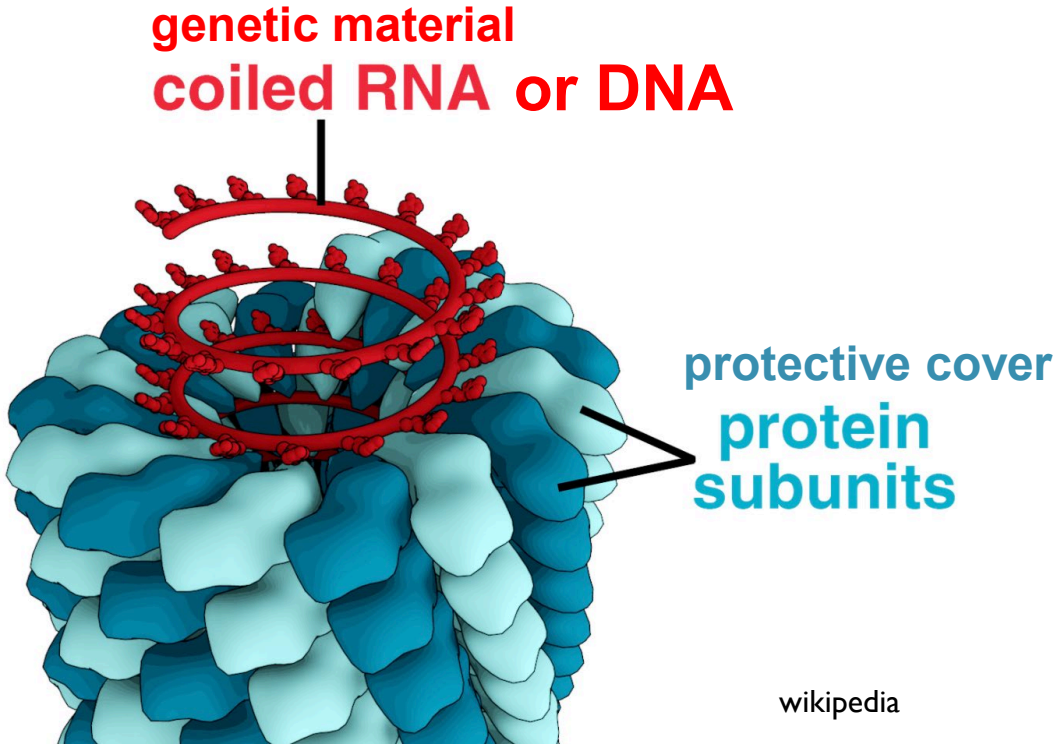
Are all viruses/bacteria causing disease?

How do viruses/bacteria cause disease? Why do they cause disease?

LET'S START FROM THE BEGINNIG

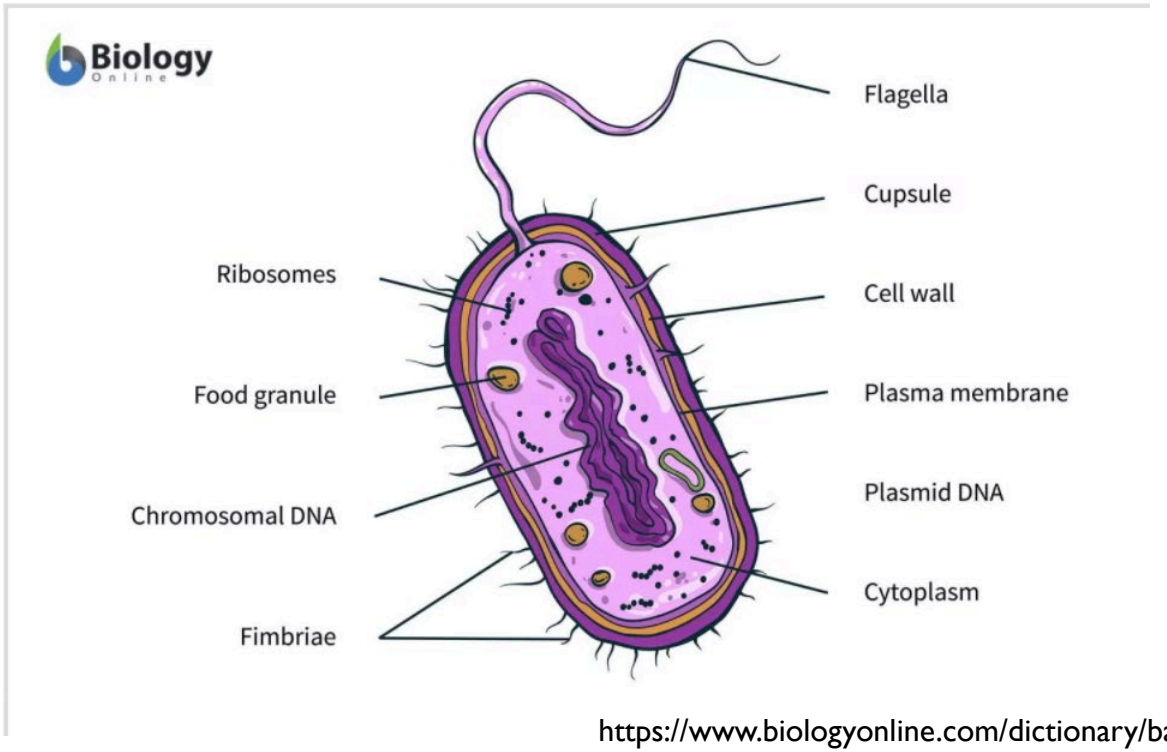
PATHOGENS

Virus: needs a host to reproduce



wikipedia

Bacterium: can reproduce by itself

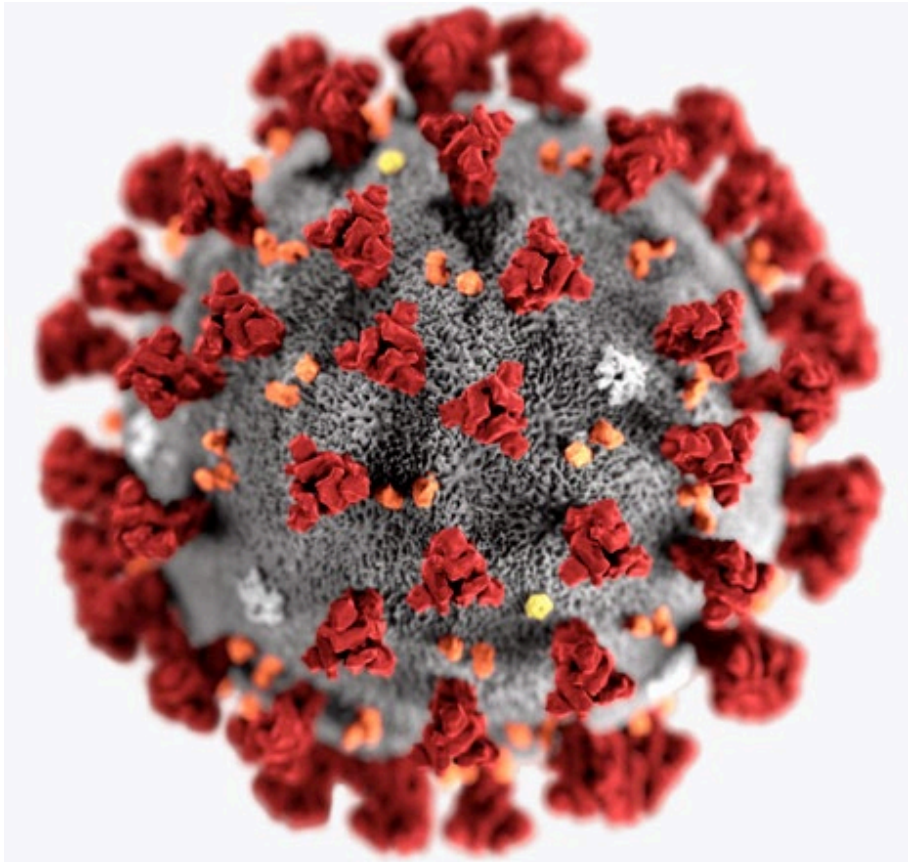


https://www.biologyonline.com/dictionary/bacteria

PATHOGENS

COVID-19 disease is caused by virus from the Coronavirus family with "formal name" SARS-CoV-2

Coronavirus family has many other members,
many of them cause only light infections



SARS-CoV-2, a member of the subfamily *Coronavirinae*

Wikipedia

PCR test

- Looks directly for viral genetic material in the sample
- If there is virus – there is viral genetic material
- Shows that the virus is CURRENTLY present

DISEASE

When body functions are disrupted – we feel sick

- To cause a disease pathogens have to:
  - Enter the body / enter individual cells
  - Kill cells
  - Disrupt body functions

Why viruses/bacteria want to invade animals (or plants)?
They want resources from us – food, shelter…

Sometimes getting what they want causes destruction (not very gentle invaders…)

Entering the host body is enough for most bacteria
BUT not for viruses – they need to get into cells!

Not all viruses or bacteria are pathogens – many do not cause disease at all, OR not in humans

HOW DO VIRUSES ENTER HOST?

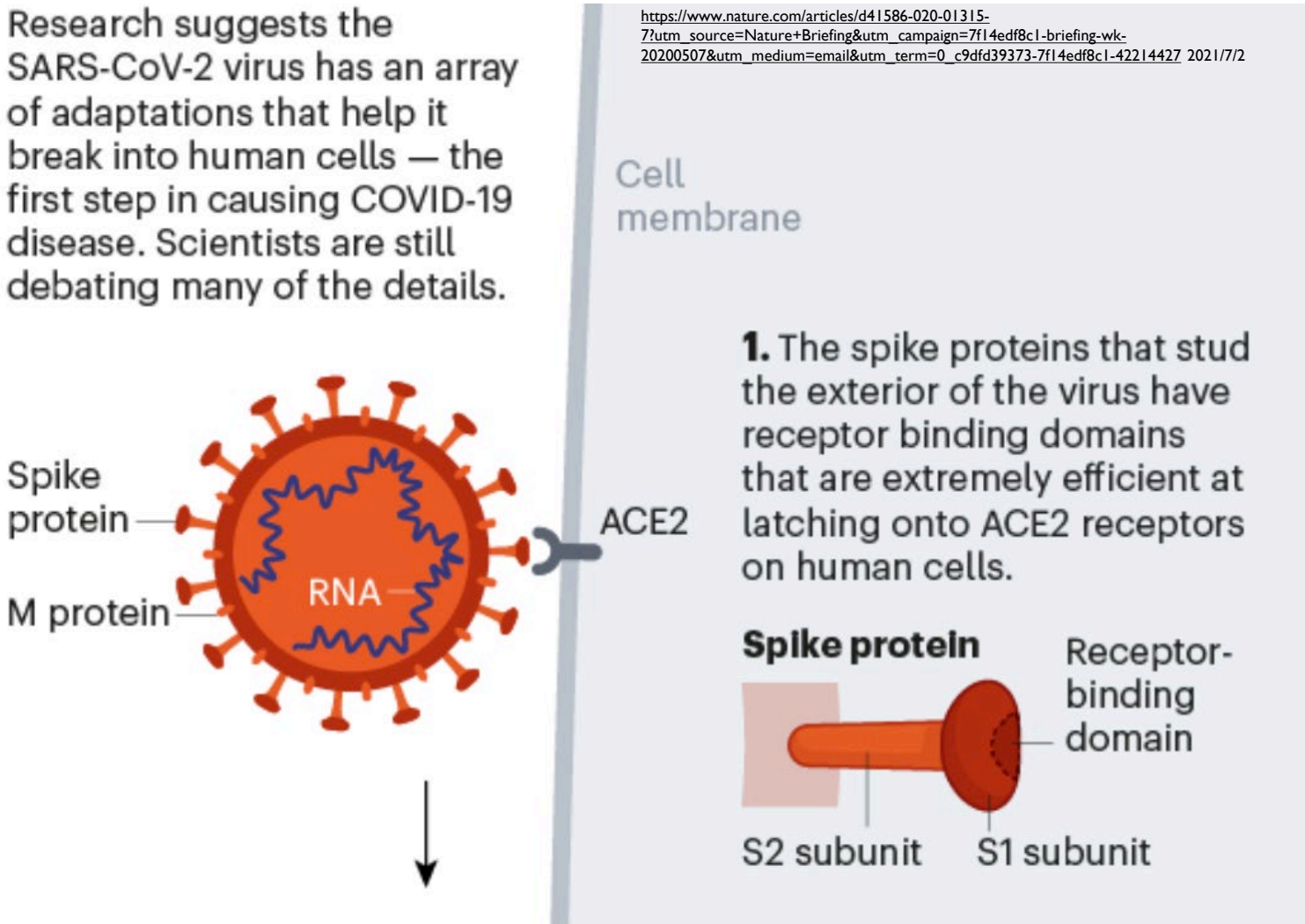
VIRUSES NEED A CELL to reproduce

So they need to enter a cell…

How do viruses enter into cells?
By attaching to cell membrane structures!

Why do these
cell membrane structures exist…?
The cell needs them for its own functions!

https://www.nature.com/articles/d41586-020-01315-7?utm_source=Nature+Briefing&utm_campaign=7f14edf8c1-briefing-wk-20200507&utm_medium=email&utm_term=0_c9dfd39373-7f14edf8c1-42214427 2021/7/2



WHAT HAPPENS AFTER VIRUSES ENTER HOST?

Viruses enter a cell,
use cell's internal structures to reproduce

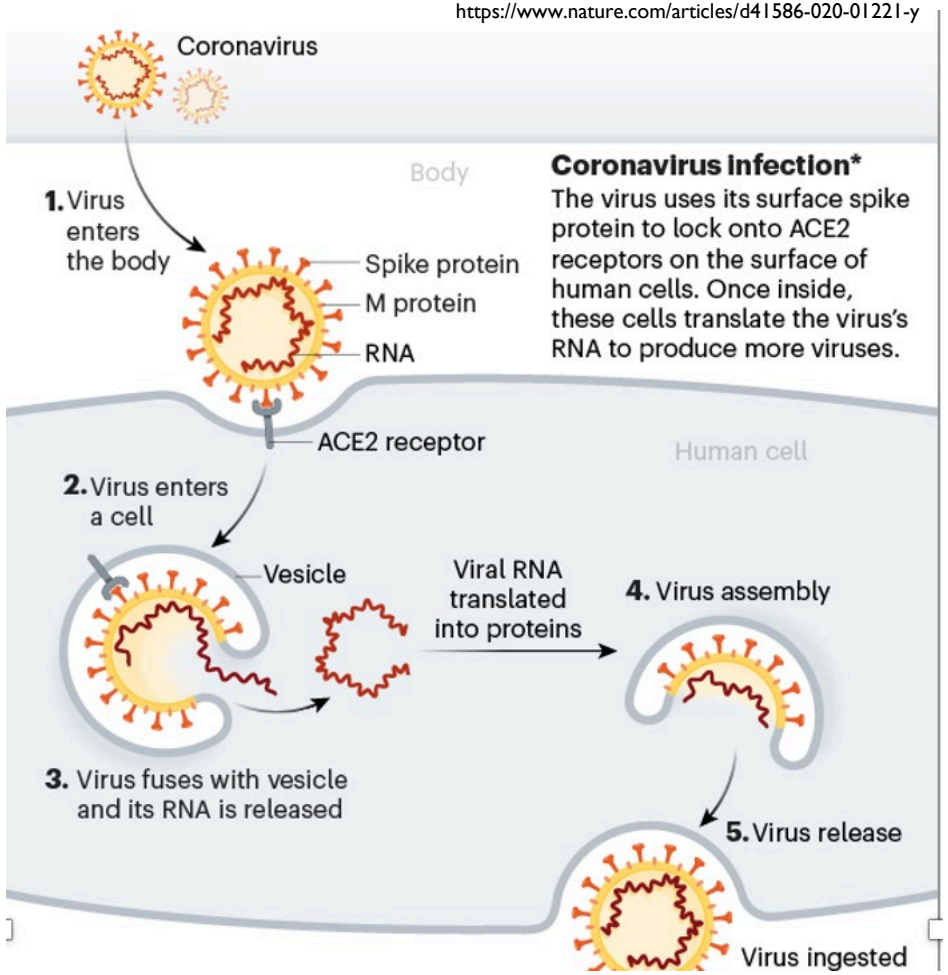
and when they leave, they often destroy the cell…

It takes time to invade a cell, reproduce, invade other cells, reproduce…cause enough damage to be noticeable…

This time is called INCUBATION PERIOD

In COVID-19 this is about 2 weeks

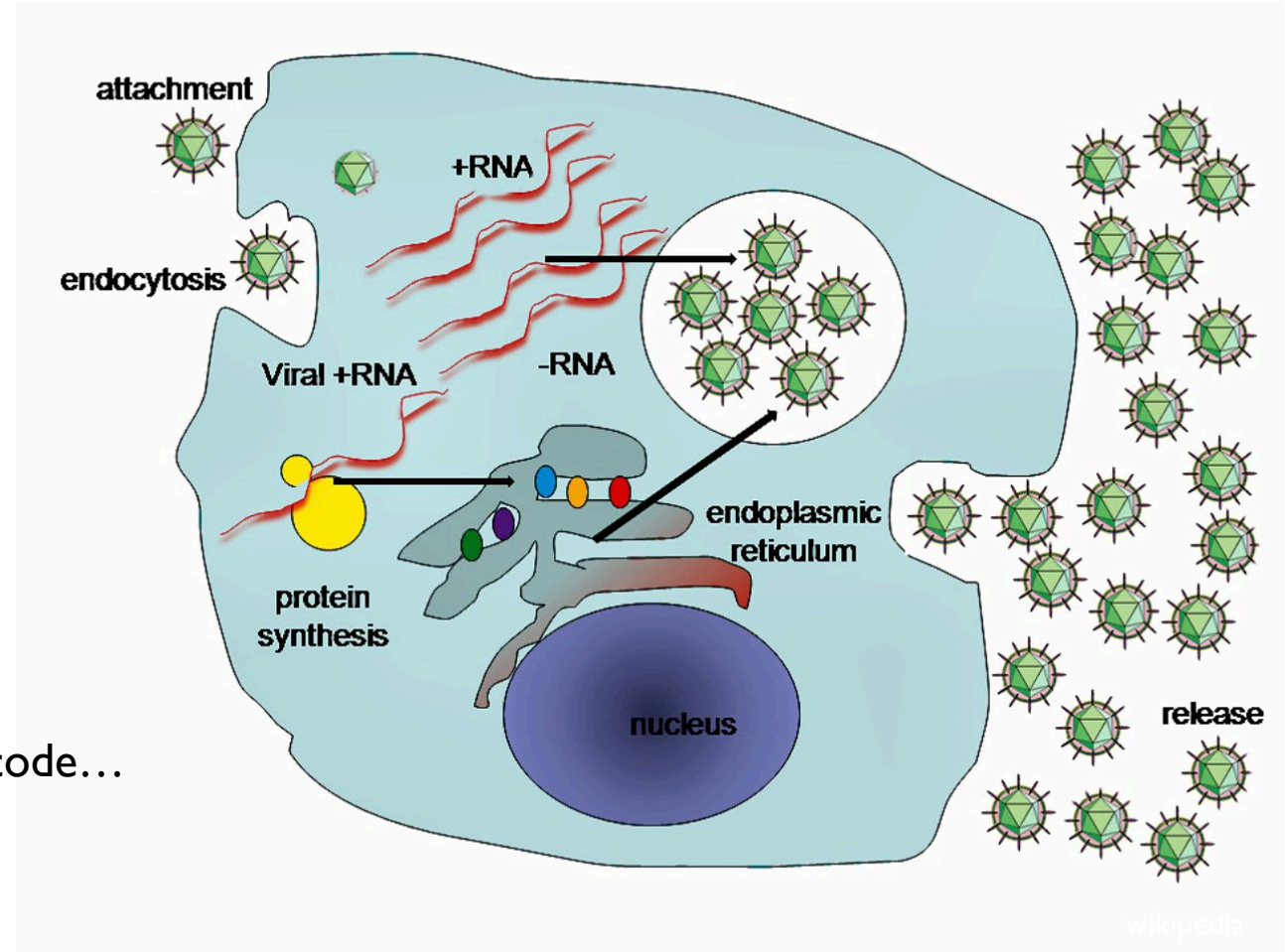
https://www.nature.com/articles/d41586-020-01221-y



WHAT HAPPENS AFTER VIRUSES ENTER HOST?

Wikipedia

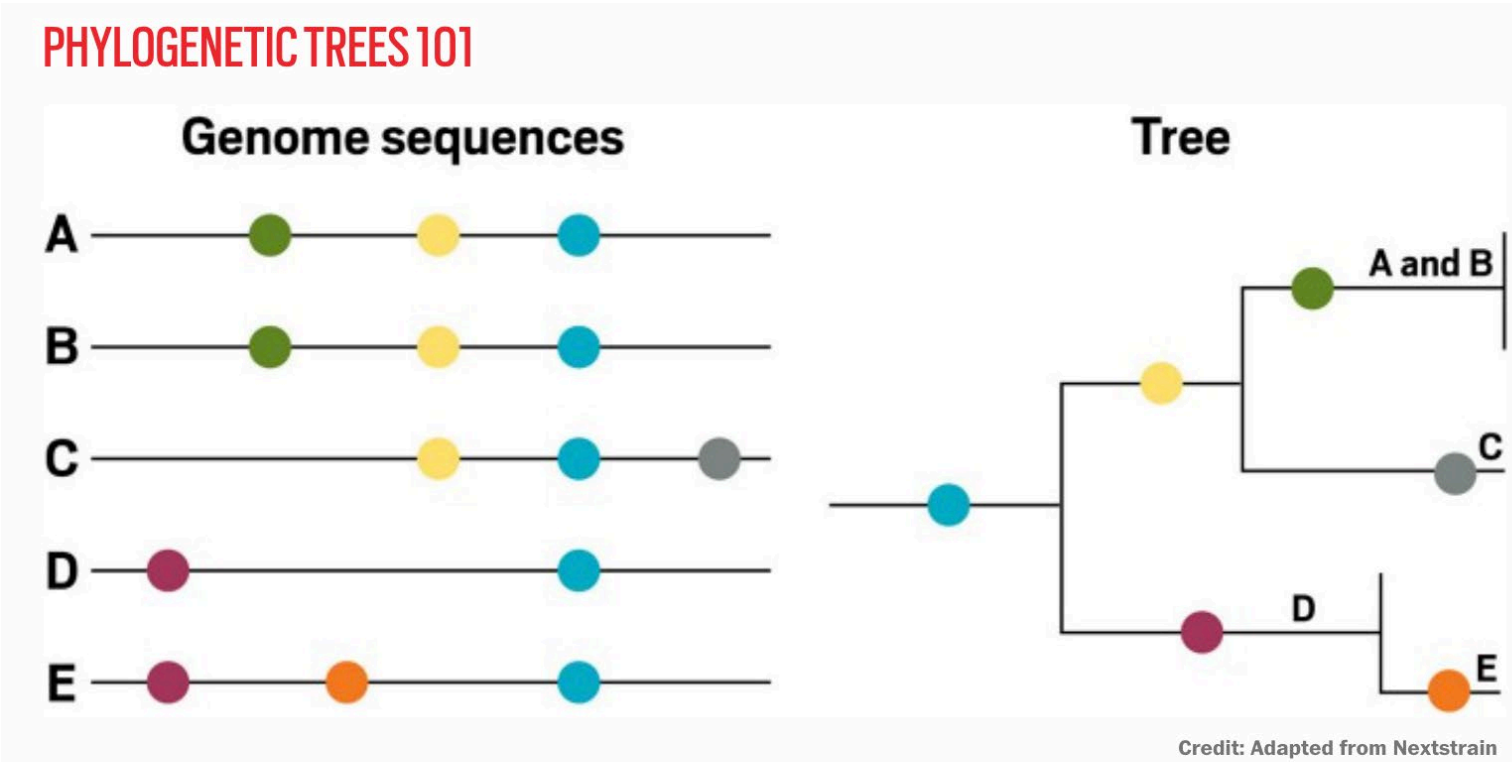
For a virus SPEED IS EVERYTHING:
making as many copies of itself as quickly as possible
before the immune system fights back!



PRECISION IS LESS IMPORTANT
Some virus copies might have small changes in the genetic code…

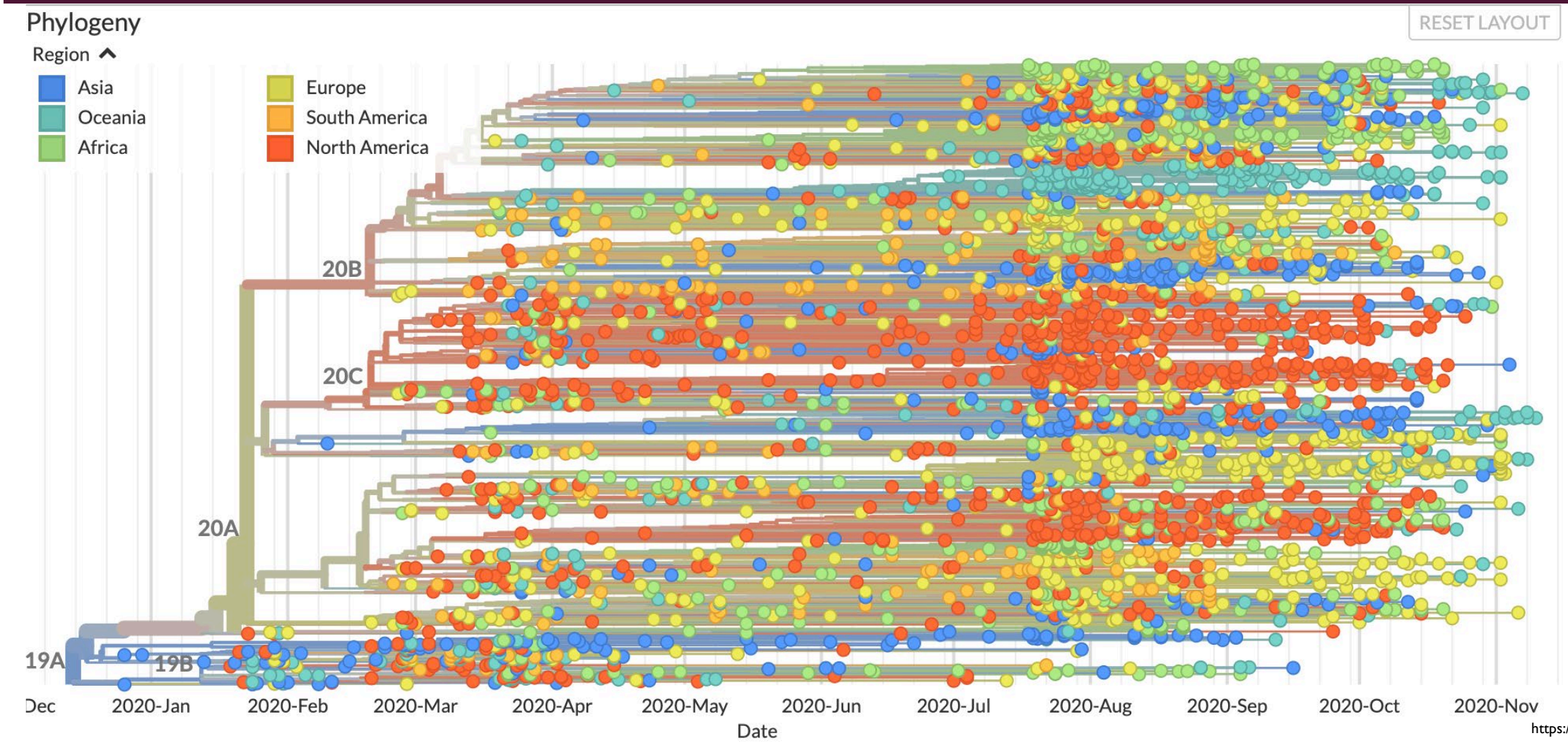
EPIDEMIOLOGY

We can look for these genetic changes!
And create a map of relationships



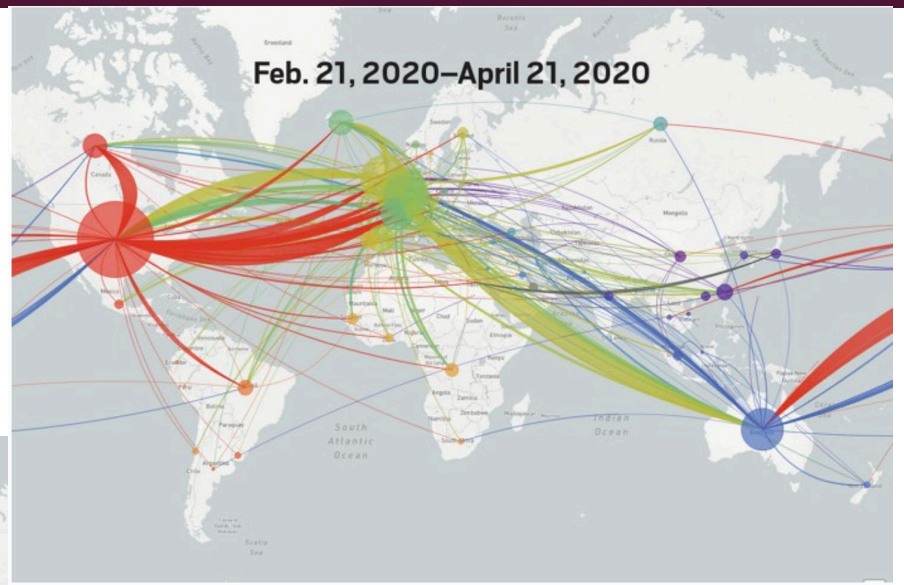
https://cen.acs.org/biological-chemistry/genomics/genomic-epidemiology-tracking-spread-COVID/98/i17

EPIDEMIOLOGY



https://nextstrain.org/ncov/global

EPIDEMIOLOGY



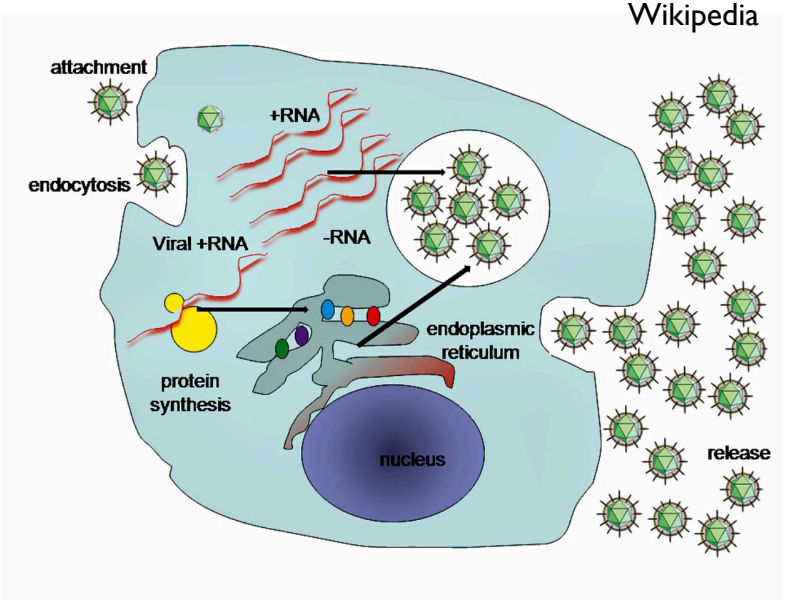
Credit: Nextstrain, with rendering in Leaflet, Mapbox, OpenStreetMap

https://nextstrain.org/ncov/global

https://cen.acs.org/biological-chemistry/genomics/genomic-epidemiology-tracking-spread-COVID/98/i17

Some virus copies might have small changes in the genetic code…
some copies might have BIG changes…

Wikipedia



WHAT HAPPENS AFTER VIRUSES ENTER HOST?

JUMPING SPECIES

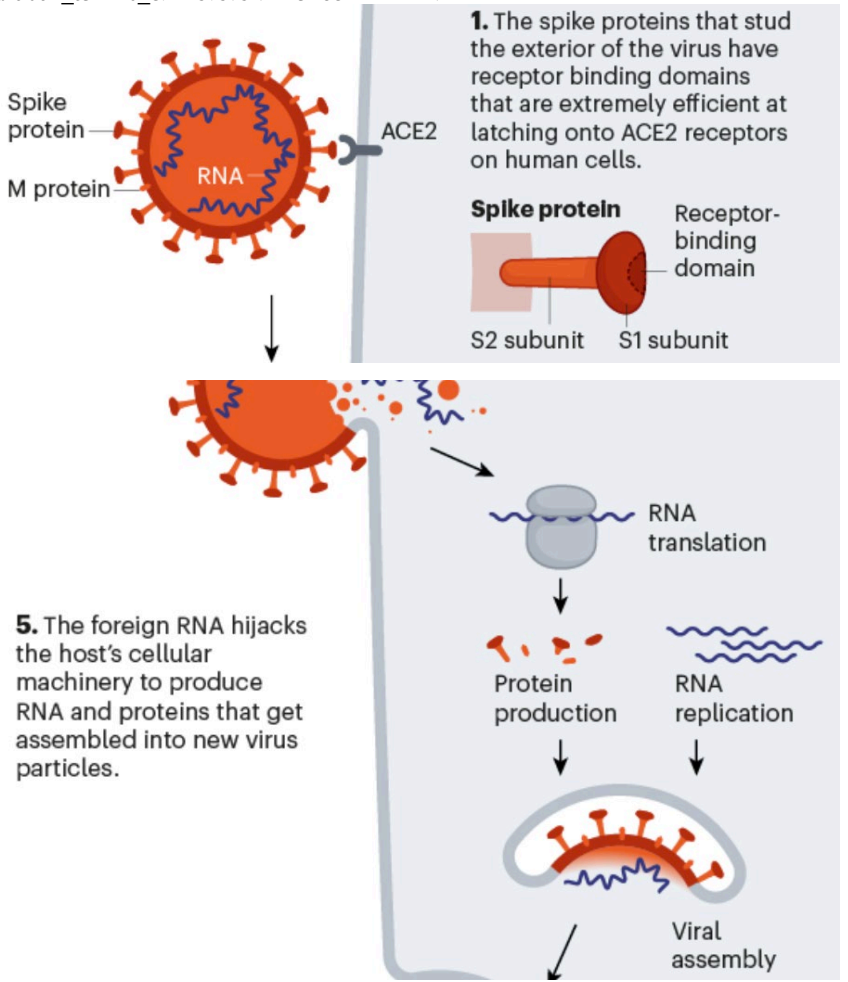
https://www.nature.com/articles/d41586-020-01315-7?utm_source=Nature+Briefing&utm_campaign=7f14edf8c1-briefing-wk-20200507&utm_medium=email&utm_term=0_c9dfd39373-7f14edf8c1-42214427

Viral ATTACHMENT structures are made based on genetic instructions!

As the virus replicates very fast
- small – or big - changes in the genes happen (mutations)
- small – or big - changes in the attachement structures may result!

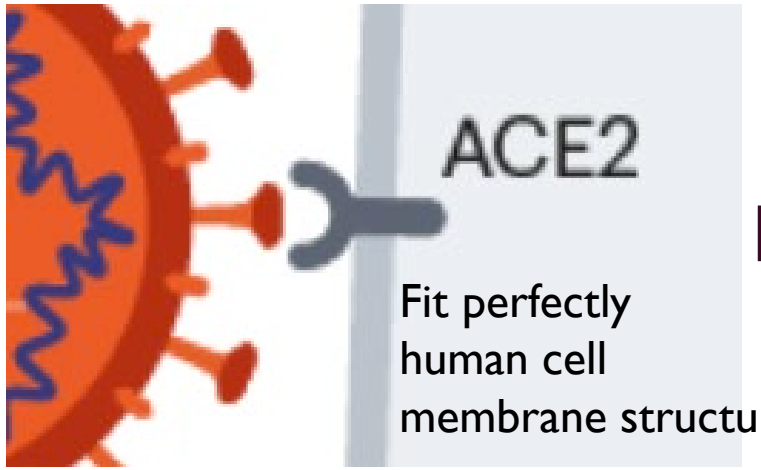
These new MUTATIONS in the ATTACHEMENTS may lead to:
- EASIER attachment – easier to enter host cells
- more DIFFICULT attachment – more difficult to enter host cells
- IMPOSSIBLE attachement – no longer can enter host cells

BUT ALSO may lead to new ability to attach to ANOTHER SPECIES!



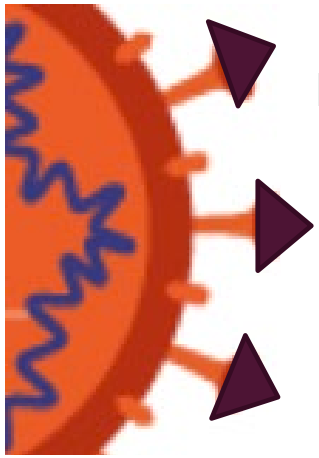
JUMPING SPECIES

Normal viral attachments



Fit perfectly
human cell
membrane structure

Invasion of human cells
Infection in humans



Mutated viral attachments

Don't fit anymore
human cell
membrane structures

Fit perfectly another species's cell
membrane strcutures

Invasion of another
animal cells
Infection in NEW SPECIES

JUMPING SPECIES

This is how viruses JUMP on to NEW SPECIES.

HOWEVER the virus with mutated attachements HAS to MEET its NEW HOST.

IF they NEVER MEET – there will NEVER be an infection in a new host.

The new coronavirus spreads rapidly among mink. Credit: Ole Jensen/Getty

nature

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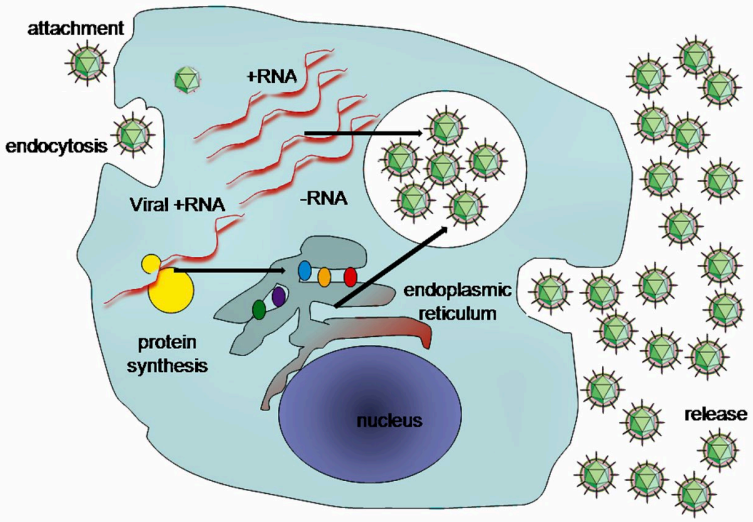
NEWS · 13 NOVEMBER 2020 · CORRECTION 16 NOVEMBER 2020

Health officials in Denmark have released genetic and experimental data on a cluster of SARS-CoV-2 mutations circulating in farmed mink and people, days after they announced the mutations could jeopardize the effectiveness of potential COVID-19 vaccines.

https://www.nature.com/articles/d41586-020-03218-z?WT.ec_id=NATURE-20201119&utm_source=nature_etoc&utm_medium=email&utm_campaign=20201119&sap-outbound-id=FBA69AF14A8C2C4CD2B401B7452050B6ED15EF61

The new baby viruses are ready to look out for new host cells!

Wikipedia



WHAT HAPPENS AFTER VIRUSES ENTER HOST?

HOW DO PATHOGENS SPREAD BETWEEN INDIVIDUALS?

Major routes of infection transmission:

- Fecal-oral route
  - contaminated hands – to mouth
  - contaminated food
- Airborne route
  - droplets from cough of one - into nose of another
  - contaminated dust
- Direct contact route
  - sex
  - vector-borne: bite

Respiratory droplets are released through talking, coughing, or sneezing.[13]

Wikipedia

HOW DO PATHOGENS SPREAD BETWEEN INDIVIDUALS?

Let's see the world from a pathogen's point of view

- A few hosts living close by:
  - A few chances to infect – a few chances to reproduce
  - Faster all hosts will become immune (or die) – SMALL DISTRIBUTION = SMALL RESULTS
- Many hosts living close by:
  - Many chances to infect – many chances to reproduce
  - Longer there will be new hosts to infect – BIG DISTRIBUTION = GREAT SUCCESS
- Many hosts traveling frequently and going to new places with many new hosts
  - Many new groups with new hosts to infect – even BIGGER DISTRIBUTION – GREATER SUCCESS

EXAMPLE: THE "SPANISH" FLU

1919 Tokyo, Japan

Wikipedia

Spanish flu

From Wikipedia, the free encyclopedia

(Redirected from 1918 flu pandemic)

The **Spanish flu**, also known as the **1918 flu pandemic**, was an unusually deadly influenza pandemic caused by the H1N1 influenza A virus. Lasting from February 1918 to April 1920, it infected 500 million people – about a third of the world's population at the time – in four successive waves. The death toll is typically estimated to have been somewhere between 17 million and 50 million, and possibly as high as 100 million, making it one of the deadliest pandemics in human history.[4][5]

The first observations of illness and mortality were documented in the United States (in Kansas and New York City), France, Germany, and the United Kingdom. To maintain morale, World War I censors minimized these early reports. Newspapers were free to report the epidemic's effects in neutral Spain, such as the grave illness of King Alfonso XIII, and these stories created a false impression of Spain as especially hard hit. This gave rise to the name "Spanish" flu. Historical and epidemiological data are inadequate to identify with certainty the pandemic's geographic origin, with varying views as to its location.

Most influenza outbreaks disproportionately kill the very young and the very old, with a higher survival rate for those in between, but the Spanish flu pandemic resulted in a higher-than-expected mortality rate for young adults.[6] Scientists offer

Spanish flu

Soldiers from Fort Riley, Kansas, ill with Spanish flu at a hospital ward at Camp Funston

Disease	Influenza

Wikipedia

EPIDEMICS AND PUBLIC HEALTH

WHY we call some diseases epidemic - and some – we don't care?

- Everyone has *E.coli* in their intestines – but this is not a pandemic?
- Imagine EBOLA was discovered in Nagoya – say, 10 cases…
  we would probably be in lock down on the spot!

Pathogens differ in TWO main characteristsics:

- How FAST they are – how fast they can be passed from one individual to another
- How SERIOUS they are – how many infected hosts get severe disease – or die

If a virus is VERY SERIOUS, even if not very fast – many people will get very sick

If a virus causes severe infection/ kills a small number of hosts, but is VERY FAST – many people will get very sick

EPIDEMICS AND ECONOMICS

- Each city has X number of hospitals
- Each hospital has X number of beds for seriously ill patients
- These numbers are based on some general expectations:
  - how many people will PROBABLY get sick every day/every month

IF all of a sudden A LOT of people get seriously ill – there won't be enough hospital beds, equipment and medical personel to treat them

Simple economics

EPIDEMICS AND GAMES

Plague Inc.'s new 'The Cure' mode is free until the coronavirus pandemic ends

Direct the world's pandemic response from your phone.

Announced back in March, *Plague Inc.'s* The Cure update is now available on iOS and Android. The new mode reverses the title's usual gameplay loop in which you design a virus to wipe out the human race. Instead, you'll need to implement measures such as contract tracing while teams of scientists work on a vaccine. Developer Ndemic Creations worked with experts from organizations like the World Health Organization and the Global Outbreak Alert and Response Network to make the mode a realistic reflection of the work that goes into stopping a global pandemic – though the studio is quick to note *Plague Inc.* is "not a scientific simulation."

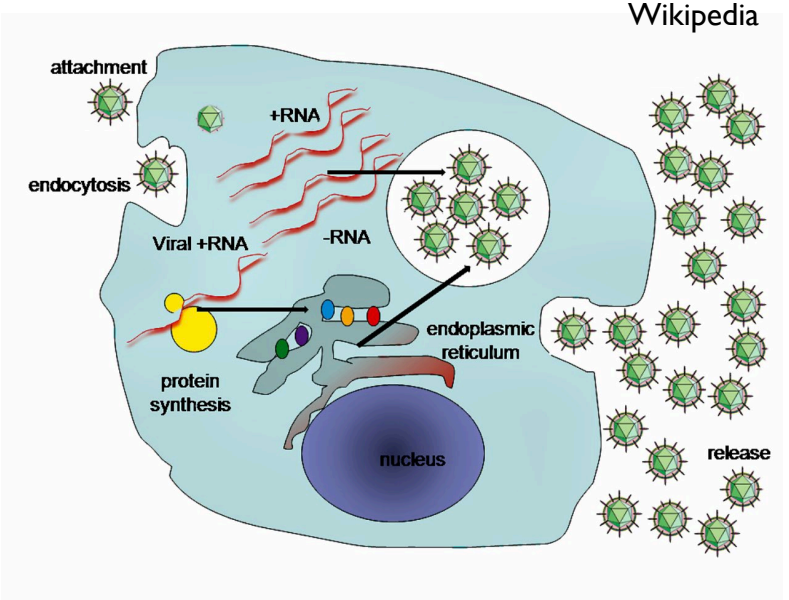
Still, scientists believe The Cure will be a helpful learning tool. "Games like *Plague Inc: The Cure* represent an incredibly important medium for education and public awareness that can be used to show the world the steps needed to address similar global health threats and their associated complexities," said Richard Hatchett, the CEO of the Coalition for Epidemic Preparedness Innovations (CEPI).

https://www.engadget.com/plague-inc-the-cure-mode-now-available-233222554.html

For a virus SPEED IS EVERYTHING:
making as many copies of itself as quickly as possible

BEFORE THE IMMUNE SYSTEM FIGHTS BACK!

Wikipedia



WHAT HAPPENS AFTER VIRUSES ENTER HOST?

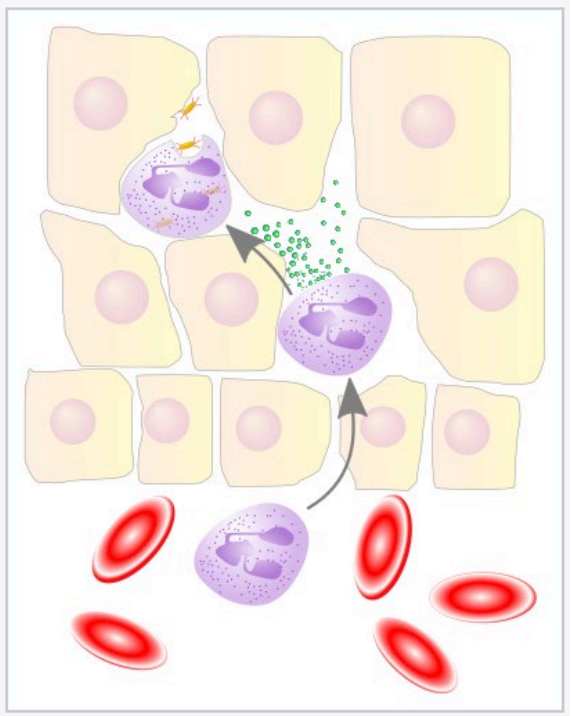
WHAT IS OUR BODY DOING ABOUT THIS?

STEP 1: INFLAMMATION:

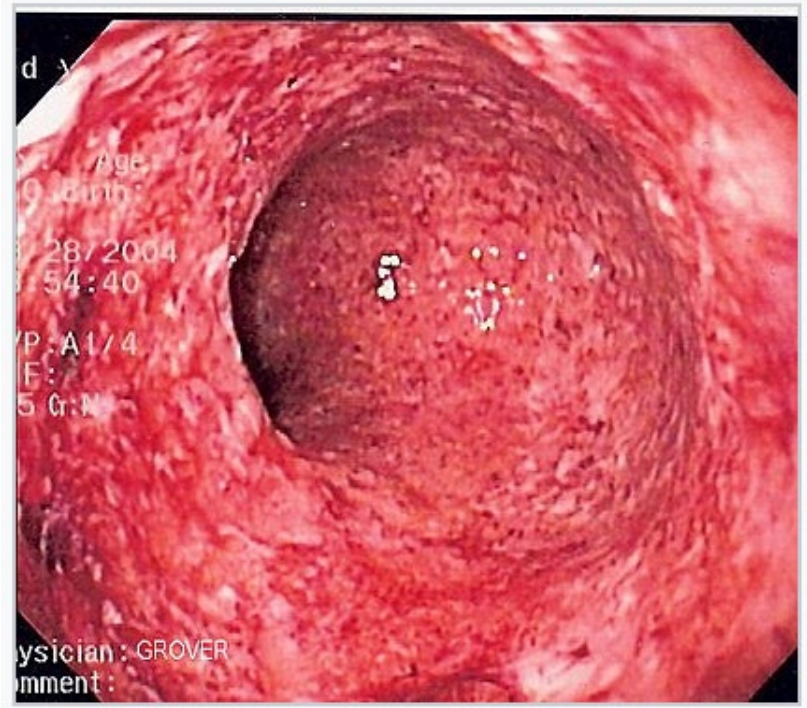
"INVADERS!" alarm
Always the same reaction to all pathogens

High temperature
Blood vessels enlarge: swelling, redness
Immune cells move into tissues from blood

Sometimes the ALARM ITSELF
is too long and too strong
can cause damage to body cells
and worsen the disease
THIS happens in worst COVID-19 cases



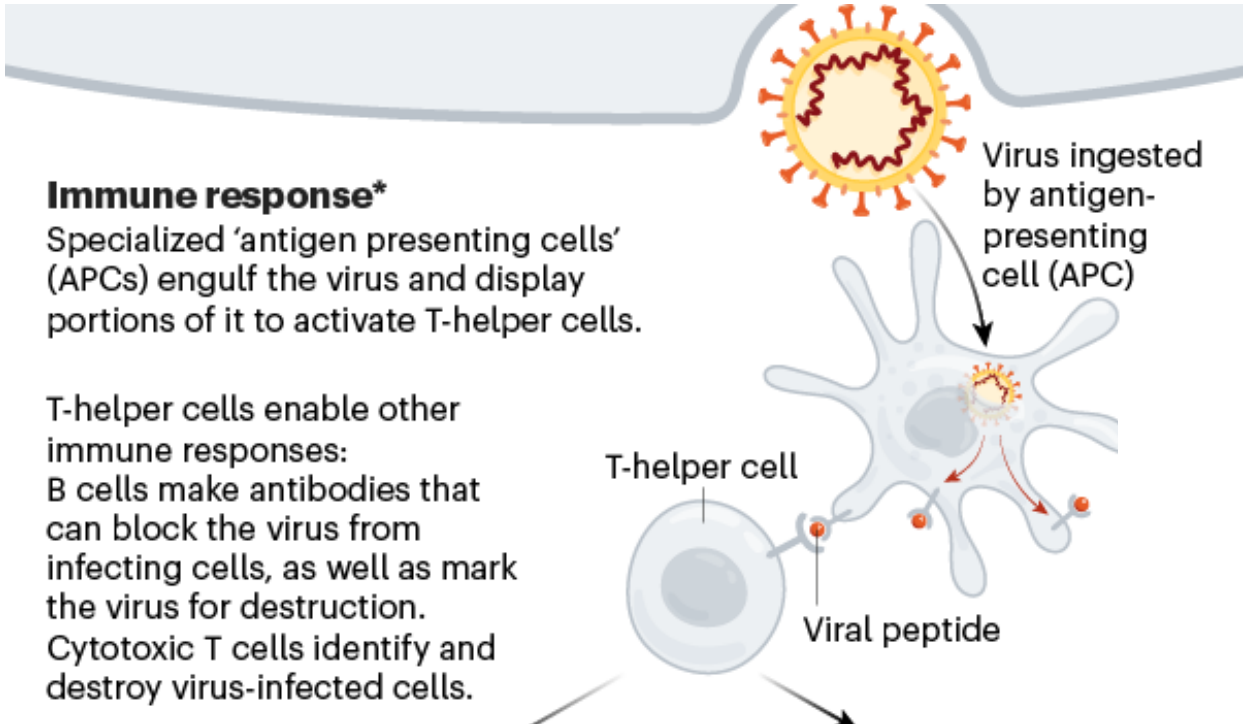
Neutrophils migrate from blood vessels to the infected tissue via chemotaxis, where they remove pathogens through phagocytosis and degranulation Wikipedia

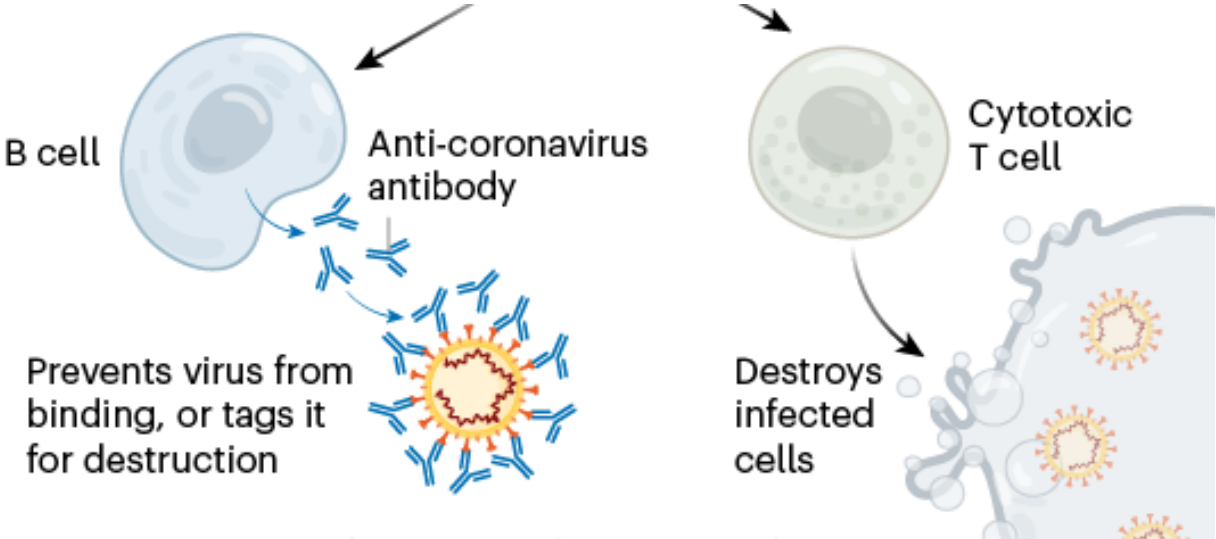


Colitis (inflammation of the colon) caused by Crohn's Disease. Wikipedia

WHAT IS OUR BODY DOING ABOUT THIS?

STEP 2: The ADAPTIVE IMMUNE SYSTEM gets activated





https://www.nature.com/articles/d41586-020-01221-y

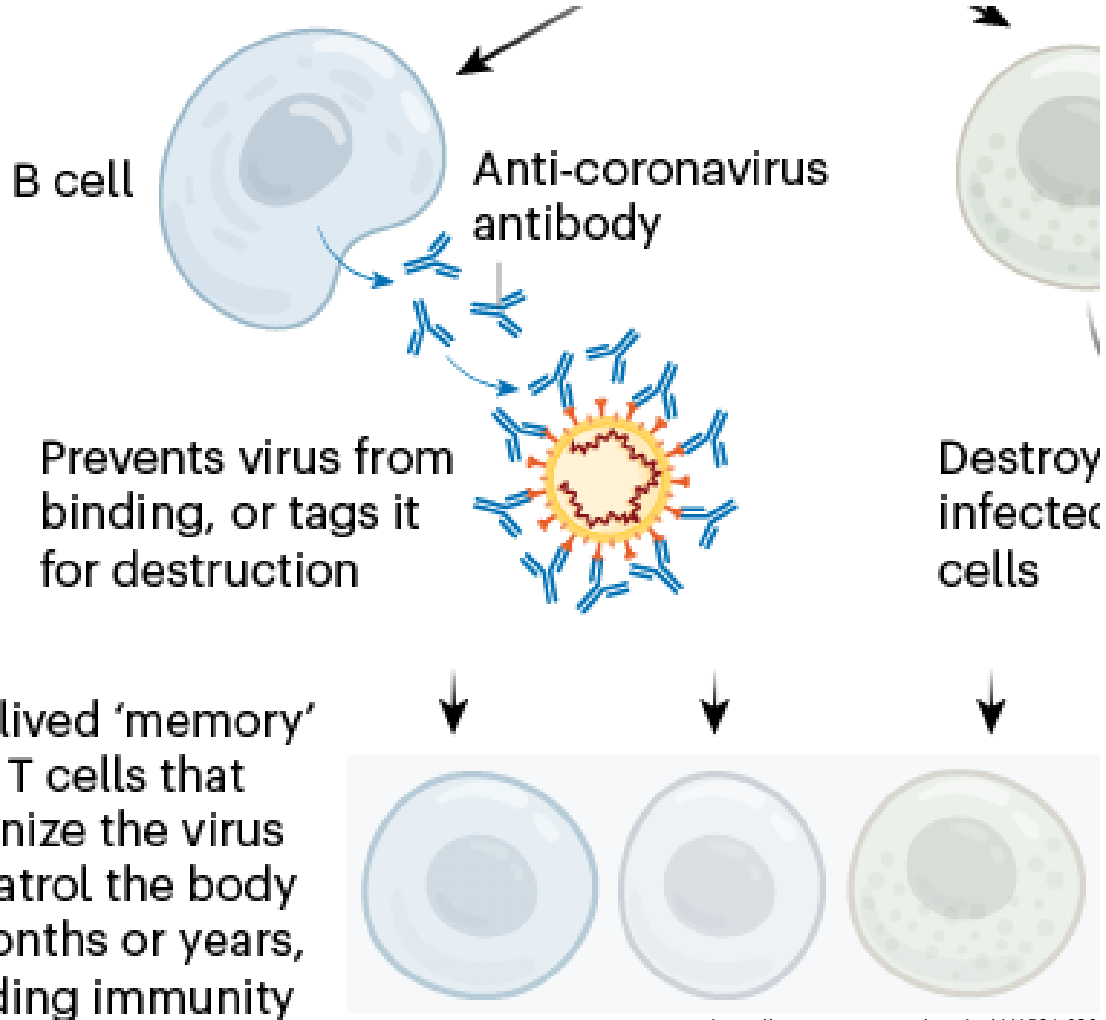
WHAT IS OUR BODY DOING ABOUT THIS?

ANTIBODIES:

Large proteins
that can bind SPECIFICALLY
to surface structures on a pathogen

Produced by immune cells
AFTER EXPOSURE to a pathogen
which TAKES TIME

Producing cells increse in numbers:
SPECIFIC "MEMORY"
for fighting future infections by the same pathogen



https://www.nature.com/articles/d41586-020-01221-y

IMMUNITY

Some individuals get very sick – some a little - some not at all!

WHY?

- We are slightly GENETICALLY different
  We are slightly different in HEALTH
  We are slightly different in AGE
- We get exposed to different AMOUNT of the virus
  The viruses land on different PLACES in our body

ALL of us, after recovering from infection, keep an IMMUNE MEMORY of it and are FAST TO FIGHT it the second time!

HERD IMMUNITY

Once majority of individuals in a population are immune against a pathogen – it has very little chance to invade

- "MAJORITY" – around 70% - is considered enough to protect the rest

- Japan is endemic to Japanese encephalitis
  I'm not immune to it. But I am not worried.
  WHY? Most Japanese nationals are VACCINATED against it.
- RABIES is an extremely deadly disease. We are not immune. But we are not worried.
  WHY? Because all cats and dogs around us are VACCINATED multiple times (every year).

For all our scientific and medical advances why don't we have a PILL or sort by now?

HOW CAN WE HELP?

HOW CAN WE HELP?

MEDICINES: pills and other fancy stuff

We have great arsenal against BACTERIA

ANTIBIOTICS
target bacteria's reproduction machinery
which is slightly different from ours

We have very little against VIRUSES!

WHY?
Viruses use OUR reproduction machinery

Targeting them means targeting our own cells…

HOW CAN WE HELP?

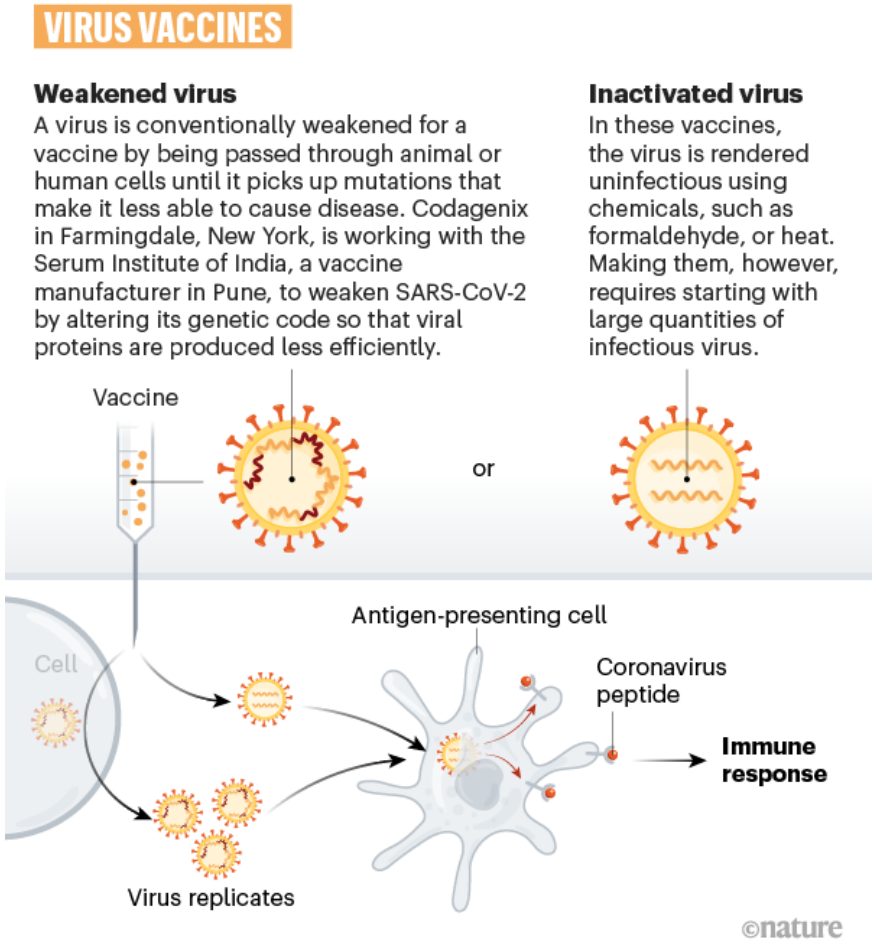
VACCINES!

Teach the body immune system to recognize a pathogen BEFORE it meets it
Be ready and attack it FAST before it causes any damage.

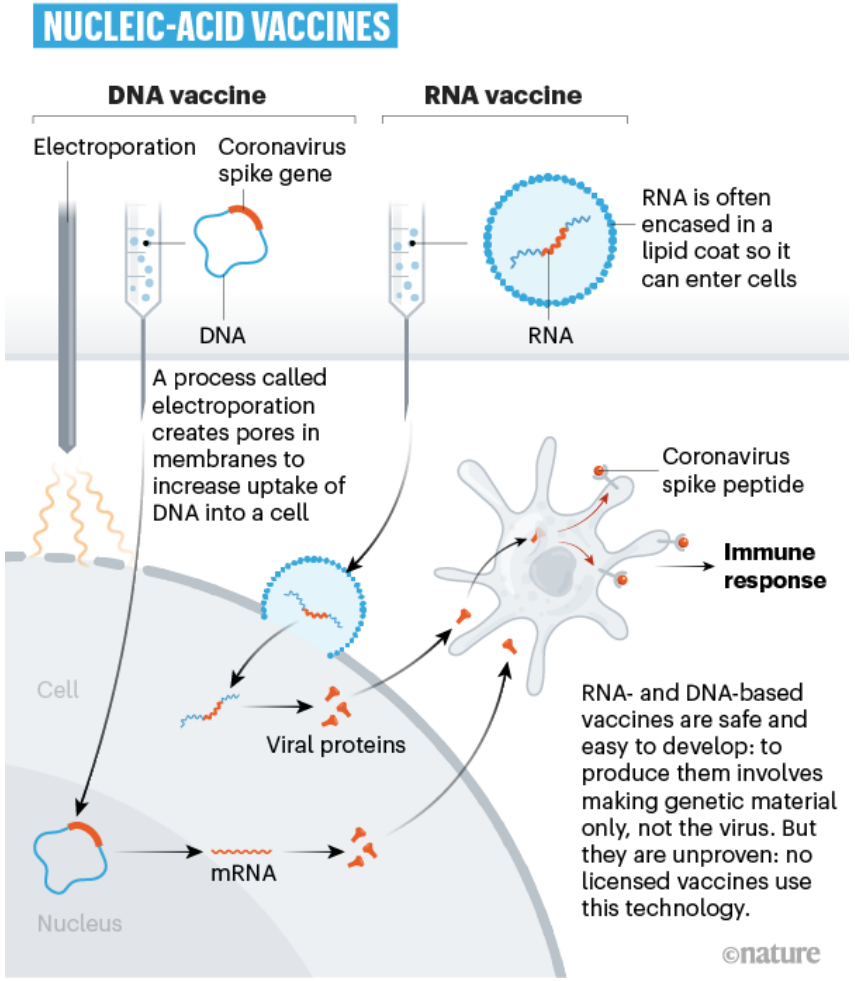
For viruses, this is the only real strategy we have…

VACCINES

Classics:



New gen:



https://www.nature.com/articles/d41586-020-01221-y 2021/7/2

VACCINES

What it takes to develop a vaccine?

A lot!

- You have to know WHAT you are fighting against
- You have to decide HOW to expose the immune system – trials in cells and labs
- You have to check whether your mixture is NOT HARMFUL – safety trials on animals
- You have to check whether your vaccine is actually EFFECTVE – efficacy trials – on animals and then on humans

- This usually takes decades!
- EBOLA vaccine took 5 years to first efficacy results! A record
- COVID-19 vaccine took less than an year to first efficacy results! This is a new record!

The discovery of the HIV virus won a Nobel Price not that long ago!

LET’S SUM UP

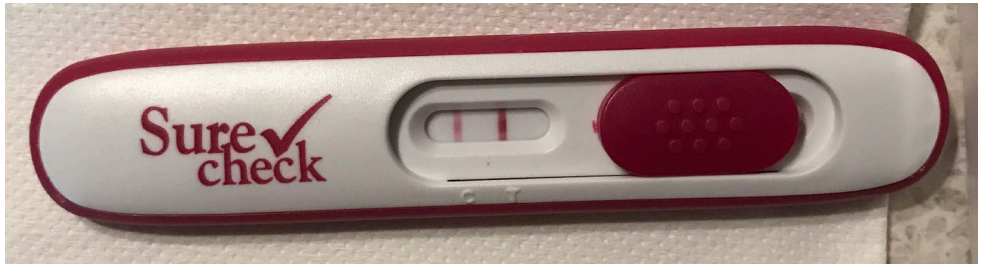
HOW DOES SCIENCE WORK?

Scientific research is a detective allowed to ask only YES/NO questions

Public question: What causes a disease?

- Science questions to answer the public questions:
  - Is it a toxin? Yes/No
  - Is it a bacteria? Yes/No
  - Is it a virus? Yes/No
    - Is it virus X?
    - Is it virus Y?
    - Is it virus Z?
    - ……

Pregnancy test



Answers exactly ONE question
YES or NO

PUBLIC HEALTH

Not all pathogens are serious enough to cause public health concerns. But some ARE serious enough.

First COVID-19 cases were identified in WINTER, amidst high influenza infections – which rarely cause pneumonia!

Prevention has TWO arms:

- Remove chances of exposure
- Prepare the immune system

These principles are NOT ONLY for COVID-19!

There are many other diseases – including the common flu – that can be reduced by following public health practices.

We live in a world relatively free of serious infectious diseases because of PREVENTION – not because of treatments!

MAJOR QUESTIONS - REVISITED

Hopefully now you have the answers of the questions we asked in the beginning:

- How was this coronavirus "born"? Where did it come from?
- Why people have different response to it? Why some get very sick and others - don't? Is it REALLY that serious?
- Why the coronavirus changes over time? Is that normal?
- Why we don't have a cure for coronavirus, a pill or sort?
- When can we finally travel again? Didn't we have enough restrictions already?

Take a minute to reflect on what you learned and answer these questions, and any other you might have noted down.

THANK YOU!