

WHITE PAPER

# COVID-19 & testing a basic primer

June 2020





## Introduction

This document is designed to give basic background information and may not be relied on as either medical or legal advice. Always consult a medical practitioner or the WHO for more detailed information.

## Doing things differently

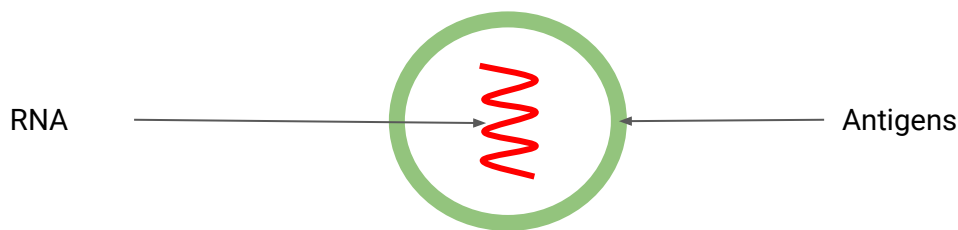
Given the work Yoti is doing to enable health testing organisations to offer digital credential management of test results, we are being asked many questions by businesses and journalists, so we are sharing our internal basic primer. We hope you find this helpful.

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## What is COVID-19?

**SARS-CoV-2** is the name of this new virus, which causes the disease **COVID-19**. This virus contains genetic material (single stranded RNA, which is similar to double-stranded DNA that humans have). This is surrounded by a coat of proteins, called antigens. This virus belongs to a family of viruses called the **coronaviruses**.



**Viruses** are smaller than bacteria. Unlike bacteria, which can also cause disease but can reproduce on their own, viruses require host cells in order to reproduce.

A **vaccine** works by training the body's immune system to recognise and attack a virus when it encounters it.

There is currently no vaccine for COVID-19, although more than a hundred projects around the world are now looking for a vaccine.

<https://www.healthline.com/health-news/heres-exactly-where-were-at-with-vaccines-and-treatments-for-covid-19#Vaccines>

Vaccines normally take years or even decades to develop and successfully test for safety and efficacy. Even with the global effort to find a vaccine for COVID-19, the best estimates suggest it will take at least 6-18 months before one can be found, if one can indeed be found - this is by no means guaranteed.

## Typical Infection Cycle

Animals (probably **bats**) are believed to be the original source of the virus. However, the virus is now **spreading from person to person** (i.e. human-to-human transmission).

It is estimated that, on average, **one COVID-19 infected person will infect between 2 and 3 other people** i.e. the **R0 ("R nought")** factor is between 2 and 3; for comparison, the R0 of the seasonal flu virus is 1.3, and the R0 of the measles virus is between 12 and 18.

The virus seems to be **transmitted mainly via small respiratory droplets** through sneezing, coughing, or even breathing out or talking when people interact with each other.

These droplets can then be inhaled, or they can land on surfaces that others may come into contact with, who can then get infected when they touch their nose, mouth or eyes.

The **incubation period for COVID-19** (i.e. the time between exposure to the virus and onset of symptoms) is estimated to be **between 1 and 14 days**. The average incubation period between getting the virus and getting ill seems to be 4-5 days.

The **infectious period** most likely begins **1 to 2 days *before* symptoms appear** (if indeed they do have symptoms: 20-80% of people may be infected without symptoms - also known as **asymptomatic**). This is likely to **limit the effectiveness of screening people for symptoms such as fever, or temperature screens with temperature guns**.

The **infectious period is estimated to last for 7-12 days** in moderate cases and up to two weeks on average in severe cases.

**Risk factors for severe infection** include: being above 70 years of age; male gender; underlying health conditions (e.g. hypertension, obesity, diabetes, cardiovascular disease, chronic respiratory or kidney disease and cancer).

<https://www.ecdc.europa.eu/en/covid-19/questions-answers>

## Symptoms of COVID-19

COVID-19 symptoms may include the following: (However, many infected people may not develop any symptoms - see more on this later)

- **Fever** - the most common symptom BUT fever is not universal when patients first present with symptoms - see more on this later

- **Fatigue**

- **Dry cough**

- **Loss of appetite**

- **Myalgia** (muscle aches)

- **Difficulty breathing**

- **Sputum production**

- Abnormality of the sense of **smell** (anosmia) or **taste** (dysgeusia)

- **Nausea and diarrhoea**

## Infection and transmission of COVID-19 without symptoms

"Asymptomatic infections have been well documented" in COVID-19;

<https://www.uptodate.com/contents/coronavirus-disease-2019-covid-19-epidemiology-virology-clinical-features-diagnosis-and-prevention>

Between 20-80% of COVID-19 cases are thought to be asymptomatic;

<https://www.uptodate.com/contents/coronavirus-disease-2019-covid-19-epidemiology-virology-clinical-features-diagnosis-and-prevention>

**Presymptomatic or asymptomatic people who will not have symptoms such a fever will still be able to transmit infection.** It is not yet known to what extent these types of infected people will transmit infection.

"It appears that SARS-CoV-2 can be transmitted prior to the development of symptoms and throughout the course of illness"- **people may indeed be most infectious just BEFORE they develop symptoms like fever** - a Chinese study "suggested infectiousness started 2.3 days prior to symptom onset, peaked 0.7 days before symptom onset" - **i.e. a person may actually be most infectious just before they have symptoms** such as a fever - this limits the effectiveness of using temperature guns to screen for people with a temperature, or by using self-reported symptom questionnaires.

<https://www.ncbi.nlm.nih.gov/pubmed?term=32296168>

# Measures that can help prevent the spread of COVID-19

## Hygiene measures

A study has shown that hand washing ten times a day cuts the spread of SARS coronavirus by more than 50% <https://www.bmj.com/content/336/7635/77>. It is also important to clean and disinfect frequently touched objects and surfaces.

## Physical distancing (e.g. >2 meters)

This reduces transmission of the virus between people in droplets as we speak, sneeze, cough or even breathe out. Common guidance suggests it is advisable to reduce exposure time with (potentially infected) people (<15 mins).

Although **lockdown measures** are effective in slowing transmission of the virus, they have **severe associated social, health and economic harms - there is an ongoing debate about the balance of the benefits of lockdown versus its harms both in the short and longer term.**

## Regular screening

This may be with self-reported symptom questionnaires, temperature screening or, in the best case, testing for COVID-19 itself - **weekly screening of healthcare workers and other at-risk groups using PCR** (a type of virus test - see later for more details) or point-of-care tests for infection irrespective of symptoms is estimated to **reduce their contribution to transmission by 25-33%**, on top of reductions achieved by self-isolation following symptoms.

<https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-16-testing/>

## Contact tracing

This enables the interruption of further onward transmission. Contact tracing has been a key part of the response in several Asian countries that have successfully reduced case numbers. However, contract tracing alone will still rely on contacts self-isolating, which may prove unreliable. **Manual contact tracing is labour-intensive, and technologically automated contact tracing (e.g. using mobile phone apps) has significant technical limitations, and deep social risks**, such as transparency, accountability, proportionality, civil liberties, data sovereignty.

<https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-Contract-tracing-scale-up.pdf>

<https://www.mobihealthnews.com/news/experts-warn-technical-limitations-contact-tracing-coronavirus>

<https://www.adalovelaceinstitute.org/our-work/covid-19/provisos-for-a-contact-tracing-app-4-may-2020/>

## Masks

These help with 'source control' i.e. preventing potentially infected people from spreading their infection to others - well-fitted surgical face-masks can help to significantly reduce the spread of infected droplets that people expel.

<https://www.nature.com/articles/s41591-020-0843-2>

Well-fitted N95 masks will also offer some protection to the wearer, but those with valves may allow potentially infected air to escape from the wearer to infect others.



## Temperature checks as a sole means of screening for infection

Temperature checks (e.g. by using temperature guns to screen people) as the sole means of controlling spread are unlikely to work.

There are various reasons for this:

- **Presymptomatic or asymptomatic people who may not have a temperature will still be able to transmit infection.**
- **Asymptomatic infections have been well documented** and between **20-80%** of COVID-19 cases are asymptomatic.  
<https://www.uptodate.com/contents/coronavirus-disease-2019-covid-19-epidemiology-virology-clinical-features-diagnosis-and-prevention>
- **Patients may indeed be most infectious just BEFORE they develop symptoms such as a fever.**
- **"Fever is not a universal finding on presentation."** - different studies suggest different numbers of SYMPTOMATIC people may lack the symptom of fever - **it is likely that most may have a fever at SOME POINT (but not necessarily at the beginning ) of their illness.** A study in New York (<https://www.ncbi.nlm.nih.gov/pubmed?term=32320003>) showed that of hospitalised patients, **only 31% had a temperature >38°C at presentation** (i.e. when they first appeared to health care setting). Another study from Wuhan itself (<https://www.ncbi.nlm.nih.gov/pubmed?term=32109013>) showed that **only 44% of patients had a temperature >37.5°C on admission to hospital.**
- **This article also says temperature checks alone will not work, for similar reasons:**  
<https://www.businessinsider.com/temperature-checks-flawed-coronavirus-cases-asymptomatic-no-fever-2020-5?r=US&IR=T>
- All of the asymptomatic infected patients (20-80% of infection cases) by definition won't have any fever (i.e. the symptom of a raised temperature).
- There are many other **NON-COVID causes**, both pathological (e.g. bacterial and other viral infections such as the flu) and physiological (e.g. recent exercise), **that can raise the body's temperature.** A temperature screen will not be able to distinguish these from a raised temperature due to COVID-19.
- **Temperature measurement devices can vary significantly in their reliability.**
- **Infected people can take temperature-lowering medication (e.g. paracetamol/acetaminophen),** which may make a temperature normal, and thus falsely reassure authorities using temperature screening alone that they are not infected when they are.
- **"Taken on its own, experts say absence of fever isn't a reliable screening tool for COVID-19";**  
<https://www.healthline.com/health-news/temperature-checks-not-effective-preventive-measure-against-covid-19#Does-it-help-stop-spread-of-COVID-19> (this article quotes an expert saying that 37.8°C is generally used as the cutoff for a true fever with regard to COVID-19 screening)

## Immunology - a very brief guide

When a person is infected with a virus, their body mounts an immune response, and produces particles called **antibodies** (also called “Ig” – pronounced “eye-gee”), which circulate in the blood and recognize a specific virus by the antigen on the virus coat, and then kill it.

The body takes some time to mount this immune response and produce various types of slightly different antibodies to a new virus that it has not seen before.

The first antibody that is produced by the body is called **IgM** – It is thought that this is produced in coronavirus infection after about 5-10 days from the start of symptoms. It is not yet known how long IgM lasts in the body/blood, but it usually declines once the next antibody (IgG) starts to be produced. IgM may slowly decline in the blood for several days, weeks or months – nobody yet knows.

The next antibody to be produced is called **IgG**. It is thought that IgG is produced in coronavirus infection after about 10-14 days from the start of symptoms. IgG should then remain circulating in your blood (hopefully for many years) so that if the virus tries to re-infect you again in the future, the circulating IgG can immediately kill it (i.e. you are immune).

A way to remember this is: when you are told something you have to remember, you say “Mmm...Got it, Good!” – so initially you produce IgM, and then you produce IgG, which hangs around in your blood for good/long-term (it is hoped! - it must be stressed that nobody yet knows how long IgG may remain in your body in COVID-19 to fight off future infections).

These tests that look for antibodies are also called **serological tests**, because they look for antibodies in blood samples, and blood is also called ‘serum’, hence ‘serological’.

## How to test for infection by the virus (present infection or past infection)

There are two types of tests that can each look for current virus itself in a person (e.g. from a throat swab):

- **ANTIGEN test**: this looks for the viral coat. These are often quick to do, but may require a special analyzer to do (e.g. at a hospital).
- **RT-PCR test (also called molecular tests)**: This looks for the viral genetic material called RNA. This requires a special machine to process (often in a laboratory) and may take longer to do - more on this later.

There is a third type of test which looks for **ANTIBODIES** that the body produces in response to a virus, rather than looking for the virus itself. These tests may indicate very recent or more remote previous infection.

## Does having IgG circulating in your blood mean you are immune to future re-infection from SARS-CoV-2?

Nobody knows this for sure – only time will tell. It is possible that being infected does not offer any lasting immunity from re-infection.

However, there are some reasonably good indicators that having developed IgG antibodies, you will be immune for some period of time (at least for some months /possibly years).

These include:

- Low rates of re-infection in corona cases.
- How immunity to other coronaviruses behaves – including the similar virus SARS-CoV (which was responsible for the SARS pandemic in 2003).
- Animal studies.
- Some doubt cast on some of the studies that have shown rapid re-infection.

The World Health Organization (WHO) has stated that:

"We expect that most people who are infected with #COVID19 will develop an antibody response that will provide some level of protection."

If having antibodies does not mean that you will have any immunity from future infection, then vaccines may also not work.

It is not yet known if getting very sick from COVID-19 means you will make more antibodies than someone who is only mildly affected by the illness or has the virus without any symptoms.

Also, it is not yet known if having a high level of antibodies in the blood (called the antibody titer) will offer you more immunity than if you have a low level of antibodies in the blood.

## Testing

### RT-PCR tests - how they work

**Reverse Transcriptase Polymerase Chain Reaction (RT-PCR)** is a technique for detecting genetic material (in this case, the genetic material of the SARS-CoV-2 virus, which causes the disease COVID-19).

The technique uses reverse transcription (RT) to convert the single-stranded viral RNA into double-stranded DNA, through the use of enzymes, so it can be amplified.

This 'transcribed' viral DNA is then amplified hundreds of thousands of times in order to help make it detectable.

- Short fragments of DNA specific to the target sections of the viral DNA are added, along with fluorescent markers for those fragments, and the Polymerase Chain Reaction (PCR) cycles through hot and cool temperatures which induce chemical reactions that copy the viral DNA with every temperature cycle.
- Each cycle doubles the previous amount of viral DNA. So after about 35 cycles, a single strand of viral DNA may produce around 35 billion new copies.
- If the virus (DNA) is present, once it is amplified sufficiently, the fluorescent markers are then detected by the machine.

## Isothermal amplification tests (e.g. the FRANKD test) - how they work

Whereas RT-PCR tests use heating/cooling cycles to help amplify the amount of genetic material present in a sample, more modern **Isothermal amplification tests** work in a very similar way, but **use special enzymes** to allow DNA amplification without requiring these time-consuming heating/cooling cycles (or the particular equipment to produce those heating/cooling cycles).

This makes Isothermal amplification tests **quicker and easier to do**, and furthermore they do not rely on the same reagents that classical PCR tests require, and which may be in short supply during this global pandemic.

The **FRANKD test is one such Isothermal test**, and can be carried out on a portable analyser that can be located at any site that requires testing at point-of-care.

Optigene is another such isothermal test that has in the process of being approved for use in the UK/NHS. It is currently being trialed in a hospital, care home and health clinic.

## RT-PCR tests - reliability

RT-PCR is a type of test called a Molecular test. Molecular tests can be very sensitive, as tiny amounts of viral genetic material can be amplified and detected. **RT-PCR tests tend to have higher Sensitivity and Specificity measures than Antigen or Antibody tests** (see more on these test reliability measures and Antibody tests later).

Another way of detecting the virus is an **Antigen test**. Antigen tests detect the presence of protein structures that are unique to the virus (e.g. spike proteins).

Antigen tests are in general relatively less expensive and quicker to do, but are not as sensitive as molecular tests, especially during the early stages of infection.

Both **RT-PCR and antigen testing will only test for the current presence of virus in a person's sample** (e.g. from a throat swab). They will not tell you if a person has previously been infected with the virus which they have now cleared.

If a **poor sample is taken**, or is taken from a site in a person's body where there is currently no virus (even though there may be virus elsewhere in the body) then the test will come back as a false negative. This may also happen if the sample is taken too early or too late in an infection of COVID-19. **The UK government has been advised that these factors of poor sampling may contribute to a false negative error rate of between 2% and 20%**, irrespective of the technology of the particular test or analyser equipment used. <https://www.bbc.co.uk/news/health-52906909>

One way to reduce this sampling error is likely to be through **more frequent testing**, which will be easier to facilitate with Isothermal amplification on-site testing.

Some tests (e.g. FRANKD) can also **work with a less invasive saliva sample** (rather than a swab of the back of the throat or deep in to the nasal passage i.e. a nasopharyngeal swab sample). This sampling mode is likely to make frequent testing **easier to do and more acceptable to patients**, and thus **improve the overall testing accuracy**. It may also pose a **reduced risk of infection to healthcare workers compared to nasopharyngeal swab sampling**.

**Saliva samples have recently been shown to be a reliable tool for detecting COVID-19** (paper in press; this study even found some patients whose salivary samples proved positive while their respiratory swabs showed negative results on the same days).

<https://reader.elsevier.com/reader/sd/pii/S0163445320302139?token=F06DA41011BA53E8D04C6A33B3CAD1A568B5BA0FBB20BF74D1D66BD98E8236DC334E0F88537197E7EBC754DA979B204F>

The reliability of the RT-PCR test can be measured in several ways:

- How **specific** the added DNA fragments are for enabling only the amplification of the viral genetic material you are interested in (in this case, that of SARS-CoV-2 virus).
- Analytical sensitivity: **Limit of Detection (LOD)** - the minimum concentration of DNA which consistently gives a positive PCR result using a particular method.
  - Other measures exist such as Limit of Quantification (LOQ), which is the minimum concentration of DNA that can be measured and quantified with defined precision and accuracy.

## FRANKD SARS-CoV-2 Isothermal amplification test - initial results

**Sensitivity - Limit of Detection (LOD):**  $1 \times 10^{-6}$  ng RNA virus, which corresponds to about **10 copies of the virus** (after 30 mins analysis).

- Detection of about 1000 PFU after 18 minutes

**Specificity: 100% specificity** - tested against high levels of four other non-COVID-19 viruses from the coronavirus family (i.e. this test did not result in any false positives result when these other non-COVID-19 coronaviruses were tested).

**Clinical validation:** An independent clinical trial (by DiMedical Diagnostic Laboratory) compared the gold-standard reference RT-PCR test (as per World Health Organisation (WHO) guidelines) to the FRANKD Isothermal Amplification test (using nasopharyngeal swab samples in both groups) in 120 clinical samples (60 positive for COVID-19, and 60 negative, as per RT-PCR) and found:

- **Sensitivity of 97%**
- **The FRANKD isothermal reaction method required less time to analyse than the RT-PCR method recommended by WHO**
- A further independent clinical study starting in June will be carried out with a higher volume of sample data, comparing the RT-PCR reference test (using a nasopharyngeal sample) to the **FRANKD test (using a less invasive mouth saliva sample)** to verify this reliability

## Reliability of antibody tests

As mentioned, all medical tests have some inherent inaccuracy. In the case of antibody tests, scientists try to measure the reliability of any new test using two main measures:

- **Sensitivity** – this represents the probability of the test identifying patients who do in reality have the antibody ('reality' being defined by the established reference test for antibodies). In other words, the true positive rate.
- **Specificity** – this represents the probability of the test diagnosing the presence of the COVID-19 antibody specifically, without giving a false-positive result in a patient who in reality has, say, antibodies to a *different* virus. In other words, the true negative rate.

In order to know if a person really has the antibody, one needs to use an established reference test to compare a new antibody test, such as a 'fingerprick' antibody test. A reference antibody test might be an ELISA laboratory antibody test. ELISA stands for Enzyme-Linked Immunosorbent Assay. ELISA tests are a subset of a group of tests called EIA tests (Enzyme ImmunoAssay).

Another way to compare the reliability of a new antibody test is to compare it to patients who have tested positive for the viral RNA particles themselves (as tested for by the RT-PCR test).

Sensitivity and Specificity are very useful measurements of how reliable a new test is compared to the established reference test.

All of these measures of test reliability are calculated in formulas using measured values for a new test of True positives, False Positives, True Negatives and False Negatives.

There are other measures of the reliability of a test, such as Positive Percent Agreement, Negative Percent Agreement and Accuracy:

- **Positive and Negative Percent Agreement:** these measures are used when comparing agreement of a new test to a non-reference test for that measurement (e.g. comparing an antibody test to a test for viral RNA particles such as the RT-PCR test).
- **Accuracy:** In addition to sensitivity and specificity, the accuracy is also determined by how common the condition is in the selected population. A diagnosis for rare conditions in the population of interest may result in high sensitivity and specificity, but low accuracy. Accuracy needs to be interpreted cautiously.

## Setting in which the test is carried out

No antibody, antigen, or molecular (RT-PCR) tests have so far been approved (either FDA EUA or CE mark) for home sample collection combined with home result processing.

Samples collected and processed at home may be less reliably collected and processed than those carried out by trained personnel.

There is also debate about whether serological (antibody) tests that use fingerprick (capillary) blood samples are as reliable as those that use blood taken from a vein (venous blood samples). All of the regulatory approvals for serological (antibody) tests to date have required that the blood sample be taken from a vein (via a needle) rather than be from a fingerprick blood sample.

## Mortality rate from COVID-19 infection

**Mortality rate** - The percentage of people who die after being infected **is still not known**, because it is not yet known how many people have been infected with the virus in total (given that a proportion of infected people will only have mild symptoms or no symptoms at all, and so would not have been tested/diagnosed with COVID-19).

There is a **wide range** of estimates of the **risk of dying** from COVID-19 infection, which range from **1 in 1000 to as high as 1 in 30**.

<https://www.newscientist.com/article/2239497-why-we-still-dont-know-what-the-death-rate-is-for-covid-19/>

**Risk factors** (e.g. age, existing medical problems, obesity, male gender, etc.) will increase an individual's risk of dying from COVID-19.

A study from the United Kingdom (not yet peer-reviewed) has found that **one third of of COVID-19 patients admitted to hospital died, and over half of COVID-19 patients put on a mechanical ventilator died**.

<https://www.medrxiv.org/content/10.1101/2020.04.23.20076042v1>

## Longer term health effects for people infected with COVID-19

Although most people recover from the acute COVID-19 infection within a few weeks, there are growing concerns amongst doctors about the **longer-term health effects of having been infected with COVID-19**. These include:

- Longer-term **lung damage** and shortness of breath
- **Kidney damage**
- Problems with the heart and **heart failure**
- Longer term **neurological symptoms** such as loss of taste or tingling sensations
- **Cognitive problems**
- **Chronic fatigue**
- **Psychological effects**

<https://www.thetimes.co.uk/article/coronavirus-is-our-generations-polio-says-doctor-who-saved-boris-johnson-w2tk8pth0>  
<https://www.bbc.co.uk/news/uk-scotland-52506669>  
<https://www.dailymail.co.uk/health/article-8303305/Will-Covid-19-survivors-face-lifetime-illness-like-battled-polio.html>





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