

Transmission of COVID-19

The **transmission of COVID-19** is the passing of coronavirus disease 2019 from person to person. COVID-19 is mainly transmitted when people breathe in air contaminated by droplets and small airborne particles containing the virus. Infected people exhale those particles as they breathe, talk, cough, sneeze, or sing.^{[1][2][3][4]} Transmission is more likely when people are physically close. However, infection can occur over longer distances, particularly indoors.^{[1][5]}

Infectivity can occur 1–3 days before the onset of symptoms.^[6] Infected persons can spread the disease even if they are pre-symptomatic or asymptomatic.^[6] Most commonly, the peak viral load in upper respiratory tract samples occurs close to the time of symptom onset and declines after the first week after symptoms begin.^[6] Current evidence suggests a duration of viral shedding and the period of infectiousness of up to 10 days following symptom onset for persons with mild to moderate COVID-19, and a up to 20 days for persons with severe COVID-19, including immunocompromised persons.^{[7][6]}

Infectious particles range in size from aerosols that remain suspended in the air for long periods of time to larger droplets that remain airborne or fall to the ground.^{[8][9][10][11]} Additionally, COVID-19 research has redefined the traditional understanding of how respiratory viruses are transmitted.^{[11][12]} The largest droplets of respiratory fluid do not travel far, and can be inhaled or land on mucous membranes on the eyes, nose, or mouth to infect.^[10] Aerosols are highest in concentration when people are in close proximity, which leads to easier viral transmission when people are physically close,^{[10][11][12]} but airborne transmission can occur at longer distances, mainly in locations that are poorly ventilated;^[10] in those conditions small particles can remain suspended in the air for minutes to hours.^[10]

The number of people generally infected by one infected person varies,^[13] as only 10 to 20% of people are responsible for the disease's spread.^[14] It often spreads in clusters, where infections can be traced back to an index case or geographical location.^[15] Often in these instances, superspreading events occur, where many people are infected by one person.^[13]

A person can get COVID-19 indirectly by touching a contaminated surface or object before touching their own mouth, nose, or eyes,^{[6][16]} though strong evidence suggests this does not contribute substantially to new infections.^[10] Although it is considered possible, there is no direct evidence of the virus being transmitted by skin to skin contact.^[13] The virus is not known to spread through feces, urine, breast milk, food, wastewater, drinking water, or animal disease vectors (though some animals can contract the virus from humans).^{[16][17]} It very rarely transmits from mother to baby during pregnancy.^[13]

Transmission of COVID-19	
Other names	Mode of spread of COVID-19
The respiratory route of spread of COVID-19, encompassing larger droplets and aerosols.	
Specialty	Infection prevention and control
Types	Respiratory droplet, airborne transmission, fomites
Prevention	Face coverings, quarantine, physical/social distancing, ventilation, hand washing, vaccination

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Infectious period

After people are infected with COVID-19, they are able to transmit the disease to other people from one to three days before developing symptoms, known as presymptomatic transmission.^[6] Contact tracing is used to find and contact people whom have been in contact with an infected individual in the 48 to 72 hours before they develop symptoms, or before their test date if asymptomatic.^[6]

People are most infectious when they show symptoms—even if mild or non-specific—as the viral load is highest at this time.^{[6][16]}

Based on current evidence, adults with mild to moderate COVID-19 remain infectious (i.e., shed replication-competent SARS-CoV-2) for up to 10 days after symptoms begin. Adults with severe to critical COVID-19, or severe immune suppression (immunocompromised persons), may remain infectious (i.e., shed replication-competent SARS-CoV-2) for up to 20 days after symptoms begin.^{[18][7]}

Asymptomatic transmission

People who are asymptomatic are able to transmit the virus.^[10] A December 2020 systematic review estimated that about 17% of COVID-19 infections were asymptomatic (95% confidence interval of 14% to 20%; the review found that "the transmission risk from asymptomatic cases appeared to be lower than that of symptomatic cases, but there was considerable uncertainty in the extent of this."^[19] Persons with asymptomatic COVID-19 infection can have the same viral load as symptomatic and presymptomatic cases, and are able to transmit the virus.^[6] However, the infectious period of asymptomatic cases has been observed to be shorter with faster viral clearance.^[6]

Dominant mode of transmission: airborne/aerosol

The dominant mode of transmission of the COVID-19 virus is exposure to respiratory droplets (small liquid particles) carrying infectious virus (i.e., airborne or aerosol transmission).^{[8][21][22][23][24][25][9][26]} Spread occurs when the particles are emitted from the mouth or nose of an infected person when they breathe, cough, sneeze, talk, or sing.^{[9][27][28]} Human breath forms a roughly cone-shaped plume of air; in an infected person, the breath carries out the virus-containing droplets.^{[28][20]} So we expect the highest concentration of virus-containing droplets to be directly in front of an infected person, which suggests that the risk of transmission is greatest within three to six feet of the source of the infection.^{[8][3]} But breath contains many droplets that smaller than 100 micrometres in size, and these can stay suspended in the air for at least minutes and move across a room.^{[29][30][28][31][32]} There is evidence that infectious SARS-CoV-2 survives in aerosols for a few hours.^[33] There is substantial evidence for transmission events across a room (i.e., over distances larger than a metre or two) that is associated with being indoors, particularly in poorly ventilated spaces, although even indoor air drafts driven by air conditioning systems may contribute to the spread of respiratory sections.^{[5][34][35]} This has led to statements that transmission occurs most easily in the "three C's": crowded places, close contact settings, and confined and enclosed spaces.^[9]

This mode of transmission occurs via an infected person breathing out the virus, which is then carried by the air to a person nearby, or to someone across a room, who then breathes the virus in. Attempts to reduce airborne transmission act on one or more of these steps in transmission.^[36] Masks or face coverings are worn to reduce the virus breathed out by an infected person (who may not know they are infected), as well as the virus breathed in by a susceptible person. Social distancing keeps people apart. To prevent virus building up in the air of a room occupied by one or more infected people,^[36] ventilation is used to vent virus-laden air to the outside (where it will be diluted in the atmosphere) and replace it with virus-free air from the outside. Alternatively, the air may passed through filters to remove the virus-containing particles. A combination of shielding (protection from large droplet ejection) and air filtering, eliminating aerosols, ("Shield and sink" strategy) is particularly effective in reducing transfer of respiratory materials in indoor settings.^[37]

Because physical intimacy and sex involve close contact, public health authorities have discouraged unvaccinated persons and persons with COVID-19 from engaging in kissing, casual sex, or other activities.^[38]

The risk of transmission from all size droplets and aerosols is lower in indoor spaces with good ventilation.^[39] The risk of outdoor transmission is low.^{[40][41]}

Transmission events occur in workplaces, schools, conferences, sporting venues, dormitories, prisons, shopping facilities, and ships,^[42] as well as restaurants,^[35] passenger vehicles,^[43] religious buildings and choir practices,^[44] and hospitals and other healthcare settings.^[45] A superspreading event in a Skagit County, Washington, choral practice resulted in 32 to 52 of the 61 attendees infected.^{[46][5]}



Our breath, shown here when speaking, forms a roughly cone-shaped plume of warm humid air, that breaks up into rolls.^[20] The virus-containing droplets in the breath of an infected person, are carried out into the surroundings, by this plume (person speaking on right hand side of screen).



Video explainer on reducing airborne transmission of COVID-19 indoors

An existing model of airborne transmission (the Wells-Riley model) was adapted to help understand why crowded and poorly ventilated spaces promote transmission,^[5] with findings supported by aerodynamic analysis of droplet transfer in air-conditioned hospital rooms.^[34] Airborne transmission also occurs in healthcare settings; long distance dispersal of virus particles has been detected in ventilation systems of a hospital.^[45]

Some scientists criticized public health authorities in 2020 for being too slow to recognize airborne (aerosol) transmission of COVID-19, and to update their public health guidance accordingly.^{[47][48][49]} By mid-2020, some public health authorities had updated their guidance to reflect the importance of airborne transmission.^{[8][50][9]}

Medical procedures designated as aerosol-generating procedures

There is concern that some medical procedures that affect the mouth and lungs can also generate aerosols, and that this may increase the infection risk. Some medical procedures have been designated as aerosol-generating procedures (AGPs),^{[9][51]} but this been done without measuring the aerosols these procedures produce.^[52] The aerosols generated by some AGPs have been measured and found to be less than the aerosols produced by breathing.^[53] Less virus (strictly viral RNA) has been found in the air near intensive care unit (ICUs) with COVID-19 patients than near rooms with COVID-19 patients that are not ICUs.^[54] Patients in ICUs are more likely to be subject to mechanically ventilation, an AGP. This suggests that in hospitals, areas near ICUs may actually pose less risk of infection via aerosols. This has led to calls to reconsider AGPs.^[52] The WHO recommends the use of filtering facepiece respirators such as N95 or FFP2 masks in settings where aerosol-generating procedures are performed,^[16] while the U.S. CDC and the European Centre for Disease Prevention and Control recommend these controls in all situations related to COVID-19 patient treatment (other than during crisis shortages).^{[55][56][57]}

Rarer modes of transmission

Surface (fomite) transmission

A person can get COVID-19 by touching a surface or object that has the virus on it (called a fomite), and then touching their own mouth, nose, or eyes, but it is not the main mode of transmission, and the risk of surface transmission is low.^{[23][9][13][16][18][21]} As of July 2020, "no specific reports which have directly demonstrated fomite transmission" although "People who come into contact with potentially infectious surfaces often also have close contact with the infectious person, making the distinction between respiratory droplet and fomite transmission difficult to discern."^[16]

Each contact with a surface contaminated with SARS-CoV-2 has less than a 1 in 10,000 chance of causing an infection.^[23] Various surface survival studies have found no detectable viable virus on porous surfaces within minutes to hours, but have found viable virus persisting on non-porous surfaces for days to weeks.^{[23][16]} However, surface-survival studies do not reflect real-world conditions, which are less favorable to the virus.^[23] Ventilation and changes in environmental conditions can kill or degrade the virus.^{[16][23]} For example, temperature, humidity, and ultraviolet radiation (sunlight) all influence reductions in viral



Surfaces that are often touched such as door handles may transmit COVID-19, although is not thought to be the main way the virus spreads.

viability and infectiousness on surfaces.^[8] Fomite transmission risk is also reduced because the virus does not transfer efficiently from the surface to the hands, and then from the hands to the mucous membranes (mouth, nose, and eye).^[23]

The initial amount of virus on the surface (i.e., the viral load in respiratory droplets) also affects fomite transmission risk.^[23] Hand washing and periodic surface cleaning impede indirect contact transmission through fomites.^{[9][21][23]} Fomite transmission can be easily prevented with use of regular household cleaners or disinfection.^{[23][9][58]} When surface survival data and factors affecting real-world transmission are considered, "the risk of fomite transmission after a person with COVID-19 has been in an indoor space is minor after 3 days (72 hours), regardless of when it was last cleaned."^[23]

Animal vectors

Although the COVID-19 virus likely originated in bats, the pandemic is sustained through human-to-human spread, and the risk of animal-to-human spread of COVID-19 is low.^{[59][60]} COVID-19 infections in non-human animals have included companion animals (e.g., domestic cats, dogs, and ferrets), zoo and animal sanctuary residents (e.g., big cats, otters, and non-human primates); mink in mink farms in multiple countries; and wild white-tailed deer in numerous U.S. states.^[59] Most animal infections came after the animals were in close contact with a human with COVID-19, such as an owners or caretaker.^[59] Experimental research in laboratory settings also shows that other types of mammals (e.g., voles, rabbits, hamsters, pigs, macaques, baboons) can become infected.^[59] By contrast, chickens and ducks do not seem to become infected with, or spread, the virus.^[59] There is no evidence that the COVID-19 virus can spread to humans from the skin, fur, or hair of pets.^[60] The U.S. CDC recommended that pet owners limit their pet's interactions with unvaccinated people outside their household; advises pet owners not to put face coverings on pets, as it could harm them; and states that pets should not be disinfected with cleaning products not approved for animal use.^[60] If a pet becomes sick with COVID-19, the CDC recommends that owners "follow similar recommended precautions as for people caring for an infected person at home."^[60]

People sick with COVID-19 should avoid contact with pets and other animals, in the same manner that people sick with COVID-19 should avoid contact with people.^[60]

Vectors for which there is no evidence of COVID-19 transmission

Mother to child

There is no evidence for intrauterine transmission of COVID-19 from pregnant women to their fetuses.^[16] Studies have not found any viable virus in breast milk.^[16] Breast milk is unlikely to spread the COVID-19 virus to babies.^{[61][62]} Noting the benefits of breastfeeding, the WHO recommends that mothers with suspected or confirmed COVID-19 should be encouraged to initiate or continue to breastfeed, while taking proper infection prevention and control measures.^{[62][16]}

Food and water

No evidence suggests that handling food or consuming food is associated with transmission of COVID-19.^{[63][64]} The COVID-19 virus had poor survivability on surfaces;^[63] less than 1 in 10,000 contacts with contaminated surfaces, including non-food-related surfaces, lead to infection.^[23] As

a result, the risk of spread from food products or packaging is very low.^[64] Public health authorities recommend that people follow practice good hygiene by washing hands with soap and water before preparing and consuming food.^{[63][64]}

The COVID-19 virus has not been detected in drinking water.^[65] Conventional water treatment (filtration and disinfection) inactivates or removes the virus.^[65] COVID-19 virus RNA is found in untreated wastewater,^{[65][17][66]} but there is no evidence of COVID-19 transmission through exposure to untreated wastewater or sewerage systems.^[65] There is also no evidence that COVID-19 transmission to humans occurs through water in swimming pools, hot tubs, or spas.^[65]

Other

While SARS-CoV-2 RNA has been detected in the urine and feces of some persons infected with COVID-19, there is no evidence of COVID-19 transmission through feces or urine.^{[16][65]} COVID-19 is not an insect-borne disease; there is also no evidence that mosquito are a vector for COVID-19.^[67] COVID-19 is not a sexually transmitted infection; while the virus has been found in the semen of people who have COVID-19, there is no evidence that the virus spreads through semen or vaginal fluid.^[38]

Clusters and other patterns

Many people do not transmit the virus, but some transmit to many people, and the virus is considered to be "overdispersed" - the transmission rate has high heterogeneity.^{[13][68]} "Super-spreading events" occur from this minority of infected people, usually in high risk venues including restaurants, nightclubs, places of worship, and they generally occur indoors.^[13] It often spreads in these clusters, where infections can be traced back to an index case or geographical location.^[15] These generally occur usually indoors, where groups of people remain in poor ventilation for longer periods.^[13] It transmits via aerosols particularly in these crowded and confined indoor spaces, which are particularly effective for transmitting the virus,^[9] such as restaurants, nightclubs or choirs.^[69] Another important site for transmission is between members of the same household.^[13]

COVID-19 is more infectious than influenza, but less so than measles.^[21] Estimates of the number of people infected by one person with COVID-19—the basic reproduction number (R_0)—have varied. In November 2020, a systematic review estimated R_0 of the original Wuhan strain to be approximately 2.87 (95% CI, 2.39–3.44).^[70] The R_0 of the Delta variant, which became the dominant variant of COVID-19 in 2021, is substantially higher. Among five studies catalogued in October 2021, Delta's mean estimate R_0 was 5.08.^[71]

Effect of vaccination

The Pfizer-BioNTech, Moderna, and Janssen COVID-19 vaccines provide effective protection against COVID-19, including against severe disease, hospitalization, and death, and "a growing body of evidence suggests that COVID-19 vaccines also reduce asymptomatic infection and transmission" as chains of transmission are interrupted by vaccines.^[72] While fully vaccinated people can still become infected and potentially transmit the virus to others (particularly in areas of widespread community transmission), they do so at a much lower rate than unvaccinated people.^[72] The primary cause of continued spread of COVID-19 is transmission between unvaccinated people.^[72]

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External links

- [A room, a bar and a classroom \(https://english.elpais.com/society/2020-10-28/a-room-a-bar-and-a-class-how-the-coronavirus-is-spread-through-the-air.html\)](https://english.elpais.com/society/2020-10-28/a-room-a-bar-and-a-class-how-the-coronavirus-is-spread-through-the-air.html) (visualization of how COVID-19 does and does not spread)
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