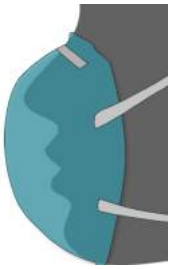
HIGH-PERFORMANCE COVID-19 MASKS



As concern grows about more contagious, deadly, vaccine-resistant virus variants,[1] experts recommend upgrading to high-performance masks —highly breathable masks that approach the performance of an N95 respirator.[2] Below, **N95DECON** *scientists explain what high-performance masks are, when they are needed, how to avoid fakes, how they can be worn effectively, and why no cloth masks qualify. Several that are easily available in the United States are highlighted.*

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[1] For example see Marr's comments here (**link**), Grint (**link**), Davies et al (**link**), Challen et al (**link**), Baker (**link**), and a case of possible very rapid airborne transmission (**link**).
[2] For examples of recent expert recommendations regarding better masks, see, e.g., Karan et al. (**link**) and a recent interview with Michael Osterholm (**link**).

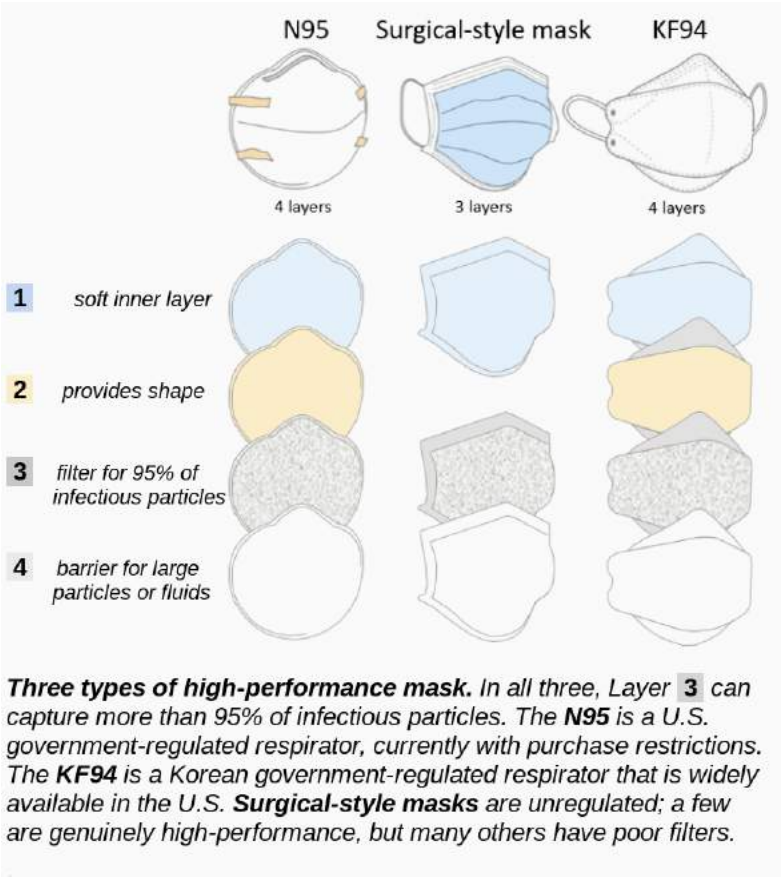
FOUR PILLARS OF HIGH PERFORMANCE

A *high-performance mask* is one that approaches the total protection of an N95 respirator. To accomplish this requires exceptional **filtration, fit, breathability,** and **quality assurance:**

➢ **Filtration:** High-performance masks use the same kind of high-tech filter[3] used by an N95 to capture nearly all microscopic particles. (See 'Layer 3' in the illustration to the right.) Cloth masks can't match this filtration.

➢ **Fit:** Like N95s, high-performance masks have edge-sealing features that limit the leakage of microscopic particles under the mask's edges.[4]

➢ **Breathability:** Air flows easily through the filters of high-performance masks. Studies show that when a mask is easier to breathe through, people wear it more consistently, which protects them better. More breathable masks also tend to leak less around their edges. Some high-performance masks are more breathable than others; this guide points out some especially breathable ones.



Three types of high-performance mask. *In all three, Layer* **3** *can capture more than 95% of infectious particles. The* ***N95*** *is a U.S. government-regulated respirator, currently with purchase restrictions. The* ***KF94*** *is a Korean government-regulated respirator that is widely available in the U.S.* ***Surgical-style masks*** *are unregulated; a few are genuinely high-performance, but many others have poor filters.*

➢ **Quality Assurance:** Each high-performance mask should protect as well as any other mask from the same assembly line. Many high-performance masks come close to this ideal, but some models and types offer much better quality assurance than others. This guide explores those differences.[5]

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[3] Usually an electrically charged *meltblown polypropylene*, but occasionally *electrospun nanofiber*. Different grades of materials are used in different high-performance masks, but they use the same principles. To understand how they work, see the video, "The Astounding Physics of N95 Masks" (**link**). Image adapted from an image by S. Paseman.
[4] Each of the mask types that we consider is more likely to function as high-performance with added fit-enhancements, such as an around-the-head earloop connector or a mask-fitter. Which kind of enhancement is most useful depends on the type of mask.
[5] Our focus is currently on the U.S. market for masks, so many models mentioned may be available only in the U.S. We hope to eventually produce an international edition. Illustration adapted from an earlier work by S. Paseman.

WHY ARE HIGH-PERFORMANCE MASKS NEEDED?

Because a cloud of exhaled virus can fill an entire room's air—

To understand this risk, think about how a cloud of cigarette smoke builds up:

Like smoke: One minute of one person's breath can fill a room's air with millions of microscopic floating particles. Just like exhaled smoke, those exhaled particles will float into every corner of the room. If the room isn't ventilated well, the particles will begin to build up into a dense cloud.[6] Just like a cloud of smoke, the "breath cloud" can then linger in the room for hours. Ask yourself where smoke would build up in your indoor space if everybody were chain-smoking. The answer may help to predict where exhaled *breath* is also likely to build up.

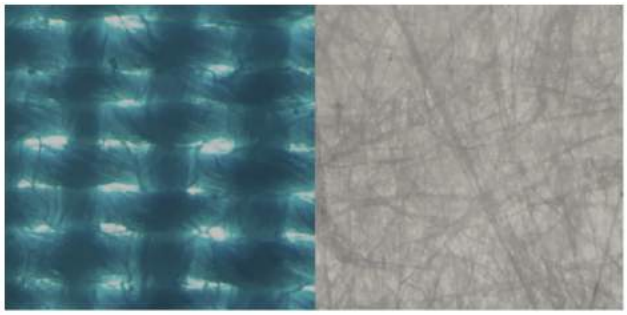
***Unlike* smoke:** Exhaled breath is invisible and odorless. This means you can't know for sure when you are inhaling it. That's important to keep in mind, because during the pandemic, an exhaled cloud of breath can carry a payload of viruses[7] that may cause infections after just a few minutes of exposure.[8]

***Above**: A spotlight reveals a cloud of cigarette smoke in indoor air. **Breath particles** build up the same way in indoor air—but those breath particles can't be made visible.*

Because cloth filters are outmatched by those microscopic particles—

A good cloth mask can filter larger incoming droplets really well, and prevent your own from spraying out very far onto other people.[9] That's really important. But if you need protection from invisible clouds of infectious particles, switch to a high-performance mask.

To understand why, first consider the nearby illustration of a woven cloth filter versus a high-performance filter: **The cloth has holes called *pores* that are many times larger than most infectious particles.** Those pores can be tightened up to block more particles, but tightening them will make the mask less breathable. **As a result, the best-filtering cloth masks tend to have the poorest breathability**.



***Left**: The holes in this woven cloth mask are large enough to let many airborne infectious particles through. If the cloth were woven any tighter, breathability would suffer. **Right**: In this high-performance filter, fibers are criss-crossed randomly. Air flows through it easily, but particles can't find a path through.*

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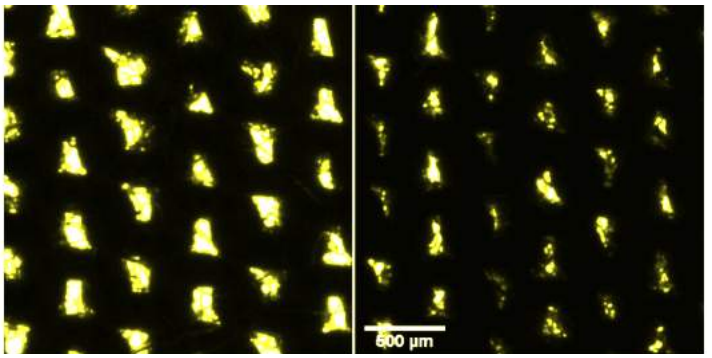
[6] This brief video clip illustrates what we mean by smoke-like: microscopic, exhaled droplets that accumulate like "clouds" indoors (**link**).
[7] See Edwards et al. (**link**) and discussion here (**link**).
[8] Many uncertainties persist about the infectious dose, or time required for infection, as new variants confound previous estimates. For example, this case study documents a case of possible airborne transmission in a poorly ventilated space in under one minute (**link**), but definitive studies are still lacking. Until we have a definitive account, caution is advised.
[9] See Pourdeyhimi et al. (**link**). Top photo credit: istockphoto//ilbusca. Bottom photos: R. Wilson

One problem with low breathability is that it causes leakage to increase around an unsealed mask's edges, which can defeat the purpose of improving the mask's filter, as shown by NIST scientist Matthew Staymates[10] and others.[11] People also find less breathable masks less comfortable, so they tend to wear them less consistently.[12] These tradeoffs are unnecessary: Many high-performance masks provide superior filtration *and* breathability.

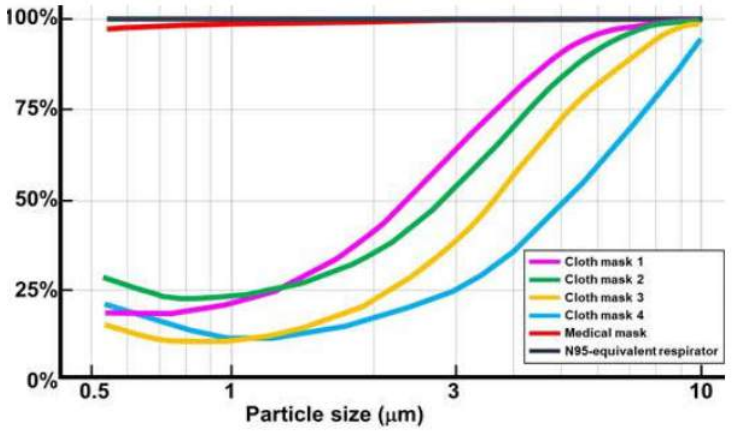
Cloth masks are less *reliable* filters than high-performance masks: Cloth masks may not filter similarly from one mask to the next, or over time. One of cloth's reliability problems is illustrated in the adjacent photo: Pulling many kinds of cloth masks tightly across the face, or laundering them, may cause their tiny pores to stretch— allowing more airborne virus through.[13] Even two batches of the same cloth may differ in average pore size.[14]



Above: A single-layer of cotton t-shirt material shown unstretched (right) and stretched as though worn tightly (left). Most of the cloth's pores are greatly enlarged. Many have expanded to over ten times the width of most infectious airborne viral particles.

Image courtesy of NYU-Langone Microscopy Core

With all of that in mind, consider this graph adapted from John Volckens' lab.[15] The curves show the percentages of particles that different mask materials were able to filter, across the full range of particle sizes of airborne infectious concern. The two nearly perfect lines near 100% are both high-performance masks (the **black** line is an N95-equivalent respirator; the **red** line is a premium surgical-style mask). The four bottom curves are cotton masks. The cloth masks are doing a poor job of filtering many sizes of small infectious particles. This same general pattern shows up in many studies of cloth masks.[16]



Above: Comparing the percent of airborne particles filtered by two high-performance masks (the highest lines, near 100%) versus four cloth masks (the lower curves). Tests were conducted at an air speed similar to an adult breathing during mild activity (10 liters/minute). See footnote.

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[10] Staymates notes, "[W]e found that fabrics with very tight and nonporous weaves actually increase air leaking out by the nose and chin. So, while these tight fabrics may filter droplets at a greater efficiency, they are not breathable and could possibly defeat the purpose of the face covering." He comments on this and other issues here: (**link**).

[11] For example, Smaldone and colleagues have shown that lowering a surgical mask's breathability causes edge leakage, resulting in more total exposure (**link**).

[12] Thicker cloth masks and certain industrial respirators tend to produce complaints in shift workers of excessive warmth and humidity, muffled speech, and difficult breathing. The masks that elicit the most such complaints may be two or more times as hard to breathe through and much thicker, compared to most of the models in this guide. This kind of discomfort can lead to less mask wearing, especially if a mask must be worn for long hours (see Radonovich et al., **link**). That is one reason we search for the most breathable and overall comfortable high-performance options. Gosch et al. (**link**) recommended a specific level of breathability to avoid respirator-tolerability problems during prolonged wear. Most of our recommended models appear to meet or exceed their guideline, and the few that do not nonetheless come extremely close to it.

[13] In one study, stretching some cloth masks by 20% allowed over 60% more virus-sized particles to penetrate (Kim, 2017; **link**). Similar findings reported by Neupane et al. (2019; **link**), and M. Cammer (2021, personal communication with A. Solomon). High-performance filters have not exhibited this tendency.

[14] See Neupane et al. (2019; **link).**

[15] Our graph is estimated from data presented in Leith et al. (**link**). See that article for the original figure (the top panel in Figure 1). Adapted by M. Cammer & L. Parameswaran.

[16] For another example, see this graph (**link**) from the Rogak Aerosol Lab. It shows three-layer cotton masks' filtration in comparison to an N95 respirator and premium surgical mask. For discussion of that graph and more, see this Rogak Lab link (**link**); scroll to the section "Three Layer Cloth Masks."

High-performance masks are *also* needed to protect *others* better—

A third reason to consider upgrading to a high-performance mask is that such masks don't just help protect you from *inhaling* clouds of infectious particles. They also help prevent you from *creating* those clouds.

That's because a high-performance mask controls your own breath's total *outward* leakage better than any other kind of mask. Controlling outward leakage protects people around you, which helps to prevent the spread of deadlier new variants.

These photos from engineer Scott Sanders' laboratory[17] show how a high-performance mask can help to protect other people: This surgical-style mask has poor fit when worn normally (left photo), so a lot of exhaled microscopic particles are escaping through unsealed gaps around its edges.

Worn normally, it is a low-performance mask. But with a simple modification called a *mask-fitter* (or *mask-brace;* right photo), the same mask's edges are sealed and the leakage has been controlled: It has become a high-performance system, able to block almost all particles from getting in *or* out.

Adding a mask-fitter to a breathable *cloth* mask does not have the same effect, because the cloth will still allow many more potentially infectious particles to pass through its fibers than a high-performance mask does. See "Mask-Fitters."

[17] Sanders and his colleagues' work on the effectiveness of mask-fitters is reported in a preprint (a non-peer-reviewed initial report) here (**link**).

How We Identify High-Performance Masks

Unscrupulous mask sellers have figured out how to falsify a mask's tests or credentials, repackage it in a high-performance model's wrapper, make counterfeits, and more.[18] As a result, many unsafe masks have been sold to the public as if they were high-performance models. Due to such problems, we consider only masks with these features:

1. **Well-established, conventional designs that have stood the test of time.**[19]
2. **Masks with credible test reports for filtration and breathability, available for our inspection.**
3. **Masks with a reputable, authorized U.S. distributor who ships directly to U.S. customers.**

Once a mask gets approved as a ***respirator*** by a highly trusted regulatory agency,[20] we may relax the first two requirements, because the trusted approval implies that the mask has already been expertly reviewed for safety and effectiveness.[21]

Respirator is an additional name awarded by government regulators to masks after they meet high performance and quality-assurance standards to protect people from dangerous airborne particles. Some countries regulate their respirators more strictly than others do. In the United States, the most-familiar disposable-respirator classes are **N95 (U.S.), KN95 (China), FFP2 (European),** and **KF94 (Korea).** We will sometimes use the term "mask" to refer to *all* disposable face coverings in this guide—even though some of these masks are officially called "respirators."

Our requirements steer us toward just a few well-studied mask categories:

- ✓ **Any Korean-made KF94 or higher-class respirator**
- ✓ **Any valveless NIOSH (U.S.) respirator**
- ✓ **Carefully evaluated KN95 and FFP2 or higher respirators**
- ✓ **Carefully evaluated surgical-style masks**

We then consider more detailed questions about particular types and models of masks, including breathability, availability, quality assurances, what fit enhancements will be necessary, and more. A list of some of those questions is in the footnotes.[22] After weighing the issues, we develop a list of some—not all—of the masks we consider "good bets." This kind of list can be useful, but it has limitations, such as:

- ❑ **Without an airtight seal, *no* mask is truly high-performance.** Each of these masks requires some fit enhancement, such as a mask-fitter or an earloop connector, in order to be considered high-performance. See "Fit and Leakage."
- ❑ **These are good bets, not *sure* bets:** Your purchase may perform differently.[23]
- ❑ **Many *other* good bets aren't on this list:** We had too little information about many. We omitted some types that were prioritized for frontline workers' needs. Some weren't as breathable.
- ❑ **We don't conduct a complete safety assessment**.[24]
- ❑ **Breathability values differ among labs and samples, so exact rankings aren't possible.** Most masks on this list show some evidence of what we consider good to excellent breathability.[25] If a result was only modestly less breathable than that, we may make a note that breathability so far seems "acceptable."

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[18] Here are examples of massive counterfeiting of N95s (**link**, **link**) and occasionally KF94s (**link**), deceptive distributors (**link, link**, **link**), and poor quality (**link**, **link**). Even experts get fooled by online sellers, including expert medical purchasing staff (**link**) and, yes, mask scientists.

[19] Some creative new mask designs perform really well. But before we can recommend them, they need to be expertly evaluated for safety flaws. Few have been.

[20] We especially trust approvals from the United States National Institute for Occupational Safety and Health (NIOSH), Korea's Ministry of Food and Drug Safety (MFDS), or Korea's Ministry of Employment and Labor (KMOEL). FDA clearance doesn't provide the same quality assurance, and FDA *registration* is no quality assurance.

[21] We also have more confidence overall in manufacturers that hold one or more of the stricter worldwide approvals. Our reasoning is similar to NIOSH's greater confidence in its own approval-holders, "because they have quality systems that are part of the manufacturing process" (**link**).

[22] Additional questions: *Have several mask samples all received high scores on important tests?(If so: Were tests conducted by a leading laboratory? Do reports seem unaltered? Were tests the > 85 LPM high-challenge kind?) Are there repeat reports? Are there reports using samples chosen by a third party? Have additional meaningful quality-related credentials been earned? Does the manufacturer provide necessary product data upon request? Is the mask nonmedical, so healthcare purchases won't be affected?* For respirators: *Is there a clear regulatory history, without recissions, recalls or safety warnings?* Some questions are more important for certain masks; no one answer is decisive.

[23] Examples include unannounced changes in manufacture quality; a manufacturer (or distributor) that sends unrealistically good samples to a lab for testing or that published only the most favorable report; honest production errors; rare defects that affect a small number of samples; and outright counterfeiting or other falsifications. Some masks may lose some filtering power in extended storage for a year or longer, but the possibility has not been fully studied yet. Filtration and resistance are merely considered estimates, due to limited sample size, instrumentation limits, and method variance.

[24] Seek information from the manufacturer about safety issues of importance to you. Review important safety warnings in our Cautions and Disclaimers (**link**).

[25] The standard we rely on for good breathability is *less than 10 mm H2O at 85 LPM*. An expert working group (See Gosch et al., **link**) reviewed what level of breathability workers are likely to experience as fully tolerable for long shifts. They recommended *less than 10 mm H2O at 85 LPM*. We are influenced by that specification, although sensitive individuals may wish to seek masks with even lower resistance.

➤ Certified KF94 Respirators

These very lightweight, breathable masks combine the comfort of a surgical-style mask with much better fit and quality assurances.

Overview

The typical KF94 respirator is a simple foldable earloop mask with three panels (see photo above). These masks are slender, breathable, and comfortable to wear, and if used with care, they may provide fit and filtration similar to an N95 respirator.[26]

This respirator class is strictly supervised by Korea's regulatory authorities and has exhibited consistently excellent performance. For example, a recent peer-reviewed report tested ten KF94 models and found filtration above 98% for all brands[27] with all 30 samples exceeding the studied regulatory requirements. The many laboratory tests we have reviewed have been exemplary, later screening tests of production samples have been excellent, and quality has seemed consistently excellent.

KF94 respirators are often made in several sizes, including a size for children. Trying several sizes and types will help you find your best fit, which research suggests is a key step toward minimizing exposure to contaminated air. A small around-the-head connector is sometimes included and may greatly improve fit (see "Fit and Leakage"). The included kind seems especially likely to get used because it stays conveniently on the mask between uses. Adjustable earloops are another common feature in this class, but a connector's fit advantage is better studied.

Only certified KF94 respirators may print "KF94" on their labels, and all models we know of do so.[28] KF94s are almost always sealed inside sturdy, colorful plastic envelopes, with a silver-foil lining. Other packaging is likely to be counterfeit, but it could be a rare legitimate exception.[29] The deluxe wrappers protect the masks from puncture, tampering, or contamination, and can provide many clues to authenticity. We recommend comparing the materials, design and text[30] of the packaging you receive to images from a trusted site.

We highlight a few models with impressive scores below, but any genuine KF94 might be expected to have very good to excellent performance.

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[26] See a summary of some of the KF94 testing requirements **here**. The KF94 is used as an N95 equivalent in healthcare settings in Korea, but not in the U.S. Because of that, and because the Korean government carefully regulates the rate of KF94 exports, purchases by U.S. consumers are unlikely to compete with either country's healthcare needs.
[27] The study is here (**link**).
[28] It can be difficult to find the word on their cluttered labels. Sometimes it is featured in oversized print on the front; sometimes it is merely stated in fine print on the back
[29] Of the dozens we have examined, the only exceptions so far are the wrapper on GoodDay KF94's English-language export version and Aer's KF94s, but both have sturdy, semi-sheer, elaborate color packaging. Counterfeits have so far seemed to favor flimsy, clear, cellophane-like wrappers, which are very different from all known KF94s. Legitimate masks that merely emulate the KF94 style, like MaskLa''s KF Series, are unlikely to use foil-lined wrappers. If in doubt, seek advice from an expert..
[30] If you don't read Korean, we recommend choosing any of the many authentic KF94s sold in English-language wrappers, so that you can understand the claims made on the wrapper and can more easily compare the packaging details to a known authentic wrapper. Photos this page: A. Solomon

➢ KM's *Dr. Puri KF94* *sold directly*

In U.S. government testing,[31] all ten Dr. Puri samples showed > 99%[32, 33] filtration. A university laboratory screening of two later production samples yielded similar values.

➢ Tia's *BOTN KF94* *generously sized; collapse-resistant; **especially breathable**[34]*

Manufacturer-commissioned reports from an accredited Korean laboratory showed average filtration > 99% for 12 total samples; and from a leading U.S. laboratory found that 20 samples averaged > 99% filtration. There was little variability among all of the scores.

➢ Bluna's *Face Fit KF94* *generously sized; collapse-resistant in black*

A university-laboratory screening of two samples estimated average filtration > 99%.

➢ Dongwha Vitax's *La Hauteur KF94* *independent tests pending*

A manufacturer-commissioned report from a leading Korean lab showed filtration > 99% for all six samples.

➢ EverGreen's *CleanTop KF94* *independent tests pending*

A manufacturer-commissioned accredited report found > 99% filtration for all six samples. EverGreen is a NIOSH approval-holder. See footnotes.[35, 36]

Where to Buy KF94 Respirators

KM's *Dr. Puri KF94* can be purchased online directly from KM's U.S. subsidiary, KMACT; orders are shipped from Texas. For other Korean brands, we recommend finding a manufacturer-authorized reseller that has a credible website, a physical business location in the United States that preceded the pandemic, and a favorable reputation with its customers. Resellers BeHealthy, Kollecte, and Everyday Beauty Lab meet many of these standards. Some of these sellers offer affordable single-mask purchasing, which can help you to find your best fit by allowing you to try on many models and sizes.

Usage Notes for KF94 Respirators

- **Some KF94s collapse onto the mouth with hard breathing:** Allowing your mask to continually collapse onto the mouth is not recommended. See "The Problem With Facepiece Collapse." For many KF94 wearers, this issue never arises.

- **KF94s fit a lot better than unmodified surgical masks, but still need fit improvements:** KF94s typically provide much more protection than a surgical-style mask. But a lot of leakage sometimes occurs, so fit enhancements can be crucial for a close fit.

- **KF94 earloops need improvement:** Adjustable earloops are better than non-adjustable ones, but for a much better-tested fit, use a behind-the-head earloop connector.

- **Many KF94 nose strips need improvement:** Many aren't strong enough to maintain a shape around the nose. Excellent self-adhesive ones are available. See "Fit and Leakage."

- **Many KF94s' grip on the nose needs improvement:** On many faces, KF94s will slip down the nose. This can create catastrophic leaks, but solutions exist. See "Fit and Leakage."

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[31] U.S. National Personal Protective Technology Laboratory. NPTTL Report on Dr. Puri here (**link**).
[32] All filtration tests performed by Korean laboratories were conducted at 95 LPM; U.S. laboratories at 85 LPM; our screening tests are performed on smaller samples of the mask at an 85 LPM-equivalent face velocity. These are all tests that represent considerably higher challenges than AST"s PFE test for surgical masks.
[33] All samples in the NPTTL report were within rounding error of 99.9%, as were several other KF94 models in this list, but we reclassified them as >99% to reduce spurious precision.
[34] Models noted as "especially breathable" may not be more breathable than every other model. The notation indicates that findings across independent samples or measurement methods especially support an expectation of class-leading breathability. But conclusions about breathability are still tentative for almost all masks considered here, due to variability among samples and test methods.
[35] See **link**.
[36] See discussion of why this is relevant here (**link**).

➢ KF94-Style Masks

The KF94 design is now widely copied. Some of the KF94 lookalikes are impressive, but—unlike actual KF94s—quality will tend to vary widely for different brands or models.

Overview

Manufacturers in the United States and around the world have begun copying the popular Korean KF94 "boat" style of respirator. These lookalikes often have KF94-style fit or comfort features, but with much less consistent credentials. For example, the model listed below has secured the European Standard FFP2 respirator credential *and* ASTM Level 3 surgical-mask testing,[37] with excellent breathability, while other models considered for this category were not yet certified to any standard.

➢ MaskLab's *KF Series* (FFP2 & ASTM-3)

Sold directly; ***especially breathable***

This colorful KF94-like series (one design is illustrated above) is certified as a European FFP2 respirator, not as a KF94. This respirator is made in a Hong Kong ISO-certified facility of a multinational textile manufacturer. In testing by an accredited Hong Kong laboratory, nine samples all filtered > 98%. A university-laboratory screening of two samples yielded average filtration > 99%. All tests of this mask that we have reviewed so far have shown consistently excellent breathability. Filtration and safety testing reports, including a report on the safety of the color dyes, are provided on MaskLab's website.

Where to Buy KF94-Style Masks

MaskLab is a Hong Kong-based company with manufacturing and shipping facilities in the United States. Sales to U.S. customers through masklab.us ship from a U.S. point of origin. A plain white version is also sold which is much less expensive.

Usage Notes for KF94-Style Masks

See Usage Notes for KF94s.

[37] FFP2 is a European respirator standard that is considered substantially equivalent to the N95 standard and that provides some quality assurances

➤ Surgical-Style Masks *(if paired with a mask-fitter)*

Surgical-style masks with excellent filters and good breathability are plentiful now. Edge leakage is unacceptable if worn in the usual way, but with a mask-fitter, the best ones can protect very well.

Overview

High-performance surgical-style masks are more available now than ever before. In the United States some can even be purchased directly from their manufacturers, for the best assurance of authenticity.

The tricky part is knowing *which* surgical-style masks are high-performance: Many that look exactly like the best performers have turned out to be shockingly deficient. Others seemed perfect when judged only by ASTM's PFE test[38]—PFE scores as high as 99.5%—but when retested with a more challenging test, their performance was not ideal.[39] Surgical-style masks also require especially major modifications before they can fit securely enough to be considered high-performance.

Surgical-style masks are not made under the strict regulations required for U.S., Korean, and European respirators, although each of the manufacturers we feature below describes some important in-house quality-assurance measures.

➤ Lutema's *Regular 3-Ply Mask*

This is a U.S.-made surgical-style mask. A manufacturer-commissioned report from a preferred laboratory shows filtration > 97% for all five samples with high breathability.[40] Screening tests of two later production samples estimated an average of > 99% filtration with acceptable breathability.

➤ Armbrust American's *ASTM Level 3 Surgical-Style Mask*

Several samples of this U.S.-made surgical-style mask all showed estimated filtration > 96% in screening tests using different methods, with acceptable breathability.

➤ Hygenix's *3-Ply Disposable Face Mask No. 88368*

These are Chinese-manufactured masks sold in the United States by Aduro Technologies. Screening tests for two samples were estimated at > 95% filtration with high breathability. This mask is included provisionally, pending review of a full high-challenge accredited-laboratory report.

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[38] PFE test = Particle Filtration Efficiency test, which measures the filter's ability to capture 0.1 micron spherical latex particles at relatively low velocities (**link**).

[39] This has been a recurring pattern: Even a very high score on ASTM's PFE test has not necessarily predicted similar scores on a more challenging, higher-flow-rate type of filtration test similar to the ones used to evaluate respirators. It's possible that a very high score on the PFE test indicates superior filtration of airborne SARS-CoV-2 in most or all common real-life situations. But since it isn't known for sure, we have restricted our list to masks that did well on one of the more challenging tests at 85 LPM or 95 LPM. Still, knowing that a mask obtained a high score on the PFE test from an accredited laboratory is *far* better than not knowing *any* viral filtration-test result for a mask.

[40] The test report is archived **here**.

Photo credits this page: A. Solomon.

Where to Buy Surgical-Style Masks

All three manufacturers sell directly to consumers from their websites: Lutema.com, HygenixMasks.com, and ArmbrustUSA.com. Purchasing directly could help ensure authenticity and quality.

Usage Notes for Surgical-Style Masks

Some surgical-style models filter really well—but many filter really poorly.
Some surgical-style masks capture over 95% of the smaller infectious particles flowing through them, but many capture under 30%.[41] In each case, expert testing is necessary. This is a very different situation from shopping for a KF94, FFP2, or N95 respirator, where *any* genuine model is expected to contain a superior filter.

These masks leak too much along their edges to be high-performance—unless improved.
Even the best of this kind of mask is likely to leak a great deal around its edges. But they can become true high-performance masks with fit enhancements. The best-tested enhancement is a *mask-fitter (or brace)*. See "Fit and Leakage".

These masks tend to collapse onto the mouth with hard breathing.
When this happens, breathing becomes more difficult, and the mask can become inappropriately moist. For solutions see "The Problem With Facepiece Collapse".

Many of these masks are sold unsealed which can create hazards.
Unsealed packaging leaves some of these masks vulnerable to counterfeiting, contamination, and tampering.[42] Some of these problems may be solved by direct-from-manufacturer sales.

Scores on ASTM's BFE and PFE tests do not identify the best virus filters.
A high score on the **BFE** ('Bacterial Filtration Efficiency') test isn't relevant to filtering out smaller infectious particles. The **PFE** test is more relevant but still doesn't detect all of a virus filter's limitations.[43] We rely on more challenging tests similar to the ones used for respirators.[44]

FDA registration is not an indicator of mask quality.
Manufacturers sometimes emphasize that they are "FDA-registered," but registration is not an indication of the quality of the masks they make.

FDA clearance is not comparable to respirator approval.
A trusted respirator certification[45] provides much more satisfactory performance assurances than FDA clearance does. Some FDA-cleared masks lack highest-performance viral filters.

A claim of a "medical grade" product does not guarantee excellent virus filtering.
Some masks lack FDA-clearance as medical masks, yet claim to be "medical grade." It is unclear what is meant by "medical grade" in such cases. Other masks that make the 'medical grade' claim may indeed be FDA-cleared, yet nonetheless lack highest-performance filters.

Many of these masks have other quality problems.
Problems like poorly attached earloops, chemical odors, easily torn pleats, easily broken nose strips and more, are unfortunately common for surgical-style masks.

Only some high-filtering masks of this kind are also highly breathable.
Even the best-filtering surgical-style masks rarely match the breathability of leading KF94s.

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[41] One report found that filtration varied from ~10% to ~90% for masks used in healthcare (**link**). Top-performing masks perform better now, but the range is still that wide.
[42] See, e.g., **link**.
[43] See, e.g., **link**.
[44] We prefer any test that resembles the way NIOSH tests respirators—i.e., with a face velocity equivalent to 85 LPM (95 LPM is used in some international tests), charge-neutralized particles, and other, more challenging parameters. It's also easier to compare meaningfully between such tests. But if you must choose a mask without any other tests available, a score in the high-nineties on ASTM's PFE test is an indication that the mask will likely filter out *most* viral particles, especially at calm breathing rates.
[45] Specifically, we view Korean approval at the 94% class or higher, FFP2 or higher, or any U.S. respirator approval as a more important credential for a virus mask.

➤ KN95 Respirators

This respirator class promises N95-like performance, but has often fallen far short of expectations. Stick to the best-tested models.

Overview

The KN95 is a vertical flat-fold disposable respirator. On paper, the Chinese KN95 standard seems equivalent to the U.S. N95 standard, but KN95s sold in the United States have suffered from a range of small and large quality problems that are not characteristic of N95s or KF94s.

Examples of defects found in some masks sold as KN95s.

During the pandemic, many or even most masks labeled as KN95s have failed expectations in major re-testing projects.[46] N95DECON scientist Avilash Cramer studied respirators labeled as KN95s and concluded that some are "catastrophically bad."[47] NIOSH noted in its early re-testing program that most masks labeled as KN95s were measuring well below the advertised protection level,[48] a pattern confirmed by N95DECON scientist Lalitha Parameswaran, who has tested many dozens of presumptive KN95s at MIT Lincoln Laboratory. Some masks labeled as KN95s have emitted an unknown inhalable dust that concerned researchers.[49] Others have exhibited catastrophic integrity problems like leaking seams.[50] Many simply have low breathability. Counterfeiting and other kinds of falsification have been common.[51]

With these concerns in mind, we focus on models from reputable manufacturers with U.S.-based distribution, anti-counterfeiting measures, direct sales, and credible repeat-test results from different sources.

[46] See, e.g., "Most KN95 Masks Imported From China Fail to Meet US Standards,"(**link**). See coverage of NIOSH's findings regarding most KN95s here (**link**).
[47] A. Cramer, personal communication with A. Solomon, April 17, 2021. N95DECON members Cramer and Deb Plana's research is presented here (**link**).
[48] See the CDC's warnings about international respiratory PPE quality problems here (**link**).
[49] Described in Plana et al. (**link**).
[50] Some examples of physical defects are documented here (**link**).
[51] See exploration of this in Sickbert-Bennett et al. (**link**) and Plana et al.(**link**). Photos courtesy of SmartAir Filters (**link**).

➢ Powecom's *KN95*

Sized smaller; anti-counterfeiting

All 90 samples of this Chinese KN95 tested by a U.S. government laboratory[52] exceeded the filtration and breathability requirements for an N95 respirator. But breathability scores varied by about twofold among the samples, from high in some cases to lower than preferred in other cases. A university-laboratory screening test of two later production samples yielded a similar filtration result. Powecom's parent company holds several NIOSH respirator approvals, which is a meaningful credential.[53] This model is available with the very unusual option of dual around-the-head elastic bands, which provides a known fit advantage over earloops. It is authorized for U.S. healthcare emergency use,[54] but our best current information is that the manufacturer's production capacity means purchases do not compete with healthcare needs.

➢ 4CAir's[55] *Aire Trust Nano KN95*

Sized larger; sold directly; ***especially breathable***

4CAir's internal testing[56] of 47 samples of this nanofiber respirator yielded unusually high breathability, with little variability. The samples averaged > 99% filtration. In an independent scientific report, two 4CAir KN95 samples again achieved > 99% filtration and much higher breathability than the three certified KN95s to which it was compared.[57] Its inclusion is provisional pending review of a report by an accredited laboratory.

Aer Pro KA-100N

➢ KN95-Style Masks (Other "Vertical Flat-Folds")

Many masks are now copying the design of a KN95—most of them without any regulatory approvals.

Overview

Some masks in this category copy the KN95 respirator's design very closely but have not been certified by any regulatory authority. Some are certified as respirators under other respected standards. For ones that are *not* certified, testing is important to confirm performance claims. We focus on companies that sell directly or through a known reliable distributor, to minimize the risk of receiving falsified or substandard stock, and which describe relevant quality assurances, such as ISO-certification or ongoing testing.

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[52] Search the page at this **link** for the name "Powecom."
[53] For discussion of why being a manufacturer designated as a NIOSH approval-holder is a meaningful credential, see **link**.
[54] Powecom FDA EUA: **link**.
[55] 4CAir founder, Stanford University Professor Yi Cui, is an alumnus of the N95DECON consortium. He was not a member at the time this report was prepared.
[56] Collected by 4CAir using the state-of-the-art TSI 8130 particle counter.
[57] See Ardon-Dryer et al. (**link**). Due to limitations of the study, its comparative ratings of KN95 resistance are considered more valid than absolute values. Photo: A. Solomon.

➢ FLTR's FLTR95 Sealing Face Mask

This mask is made in China for FLTR, a new U.S. corporation, and sold reliably online. It is not a certified respirator but seems to conform closely to the KN95 style. An accredited international laboratory describes filtration for all 20 samples as > 99% and acceptable average breathability for three samples. Screening tests of two much-later production samples estimated an average > 95% filtration. The company describes an ongoing quality-assurance program.

➢ Aer's Aer Pro KA-100N Industrial Class 2 Respirator *Sized large; **especially breathable***

The Aer Pro KA-100N is a Korean Class 2 industrial respirator,[58] a class that has only an 80% submicron-filtration regulatory requirement but comes with extensive quality assurances; many such respirators in fact exceed 95% filtration.[59] This model resembles a KN95 with additional facial coverage (see photo of the black mask above). The included earloop connector provides an always-available fit advantage. A manufacturer-commissioned report by an accredited Korean laboratory describes all three samples' filtration as > 95% at 95 LPM[60] with unusually high breathability for this class. This model is included provisionally pending independent re-testing.

Where to Buy KN95 Respirators and Other Vertical Flat-Folds

The Powecom KN95 is available from its largest authorized U.S. distributor at BonaFideMasks.com. The AireTrust Nano KN95 is sold directly by the manufacturer via 4Cair.com. FLTR's products are available from Costco and Best Buy; FLTR95 is also available with rush delivery from BestBuy.com to most U.S. addresses. KollecteUSA is authorized to sell the Aer Pro KA-100N.

Usage Notes for KN95 Respirators and Other Vertical Flat-Folds

Fit issues: Most fit-related problems are similar to the KF94 class' problems; see the KF94 usage notes. Enhancements are almost always necessary. Many KN95 nose-strips must be completely straightened out before they can be reshaped to fit the top of your nose. (See "Fit and Leakage.") Many KN95s are too short for larger faces.

Warm exhaled air may linger: The cup style of some KN95s may permit warm, exhaled breath to linger inside the cup, which can be uncomfortable for sensitive persons.[61] If so, consider an unusually-breathable KN95 or one with an especially small cup, arrange for more-frequent fresh-air breaks with the mask off, or try an especially breathable KF94.

Breathability of certain models has varied widely: For some models, if you buy ten or twenty, it is possible that a meaningful difference in breathability will occur among those samples.

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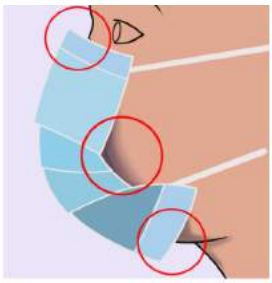
[58] This is a unique entry on this list because it is a Korean respirator that is intended for industrial use, regulated by KMOEL (roughly analogous to the U.S. NIOSH) rather than MFDS (roughly analogous to the U.S. FDA), and subjected to additional quality tests.
[59] See study (**link**).
[60] This is a more-challenging flowrate than is used in U.S. studies.The company has since advertised an even higher filtration-test result, but the report was not available. We plan to confirm the filter's performance and, in the meantime, recommend the respirator provisionally.
[61] See the CDC's advice regarding how to minimize discomfort in tightly worn respirators with limited breathability, especially during prolonged wearing (**link**). Similar concerns may arise during prolonged wearing of any tightly worn, thicker, resistant cloth mask. Comfort may be better in a mask or respirator with a somewhat smaller cup volume and higher breathability—which describes a number of the models featured in this guide. Comfort can also be improved by taking unmasked fresh-air breaks.

➤ Special Topic: *Fit and Leakage*



Edge leakage commonly happens around the nose, cheekbones, cheeks, and chin.

Overview

Most masks and respirators don't seal tightly enough around their edges to stop air from leaking. For example, premium surgical-style earloop masks commonly let in 50% or more[62] of all nearby airborne particles—and almost all of those particles get in via the mask's edges. Respirators leak a lot less on average, but even they leak a lot on *some* faces.

Masks may *seem* tightly sealed when their edges are leaking. Try this: With both hands, form a thin-edged oval with your forefingers and thumbs, and then fit it around your mask's edges. Make an airtight seal all around. Do you notice more warmth lingering inside the mask now that it's tightly sealed? That can be a sign that you've closed off some previous leakage.[63]

There are techniques that can solve this edge-leakage problem. It could be useful to learn about them, because **properly sealing a high-performance mask could make it far less likely that you ever inhale or exhale an infectious dose of virus.**

For a simple example of how much the quality of a mask could matter, imagine that we somehow knew that ten minutes sitting with others in a very small waiting room without good ventilation would be long enough to infect you *without* a mask on.

Of course, in the real world we *don't* know how long unmasked infection takes for any particular person, in any particular situation. (See the footnote[64] for more information about why your unmasked "time until infection" is just not knowable in advance.) But just imagining for the moment that we somehow *could* know that infection would occur for you in **ten minutes unmasked** in that very small room, then according to leading theory of how this airborne infection works:

- Wearing a **50%** edge-sealed mask,[65] you might be able to spend only **twenty minutes** in that same room without getting infected.
- Wearing a **90%** edge-sealed mask, you might be able to spend **well over an hour** in that room without getting infected.
- Wearing a **95%** edge-sealed mask, you might be able to spend over **three hours**.
- Wearing a **99%** edge-sealed mask, you might be able to spend over **sixteen hours**.[66]

Remember that this example began with a made-up "time until infection,", and then relied on mere educated guesses about how much a high-performance mask might be able to extend that time. So it doesn't predict actual infection time in any particular room for you. But the example helps to make it clear that a low-leakage, high-performance mask should provide the longest protection in high-risk air.

Scientists have been working to figure out mask modifications and behavior techniques that can control edge leakage. The best-studied of these is called a **mask fitter**[67] or **brace**.

We begin our review below with that kind of device.

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[62] This 50% estimate for a surgical-style mask assumes it is being worn with normal care, and that the filter itself is high-performance. If you wear your mask halfway down your nose, or extra loosely around the cheeks or chin, or if it's two sizes too large for you, or if the filter is poor, its protection may be far less than this. If it happens to fit you unusually well, it may protect better.

[63] Unfortunately, a "no" doesn't guarantee that it hasn't been leaking. Small-to-moderate leaks can be impossible to reliably detect with this kind of check.

[64] Scientists don't know exactly how long it takes for infection to happen in any particular room, at any particular concentration in the air. Many variables might affect the answer. Just for example, different virus variants may infect at different rates; some people get infected more easily than others; a few people with SARS-CoV-2 infection are unusually infectious; and a mask sometimes leaks a lot more than we think it does. These uncertainties underscore that mask performance should build in a margin of error. Many concepts pertaining to airborne infectious doses for the original SARS-CoV-2 variant are reviewed by Miller et al. (**link**) and in this article about computational modeling (**link**). For an example of possible rapid transmission despite wearing a "50%" edge-sealed (surgical-style) mask, see Goldberg et al (**link**). This time-to-infection risk calculator (**link**) provides one set of estimates of aerosol-transmission risk for the original variant of SARS-CoV-2. For example, in a 300 square foot room, with slow air circulation, no open windows, no masks, and 10 people talking normally while seated, assuming the original variant of the virus, then very significant risk of infection is predicted within 15 minutes. Of course, all such predictions can be wrong.

[65] The example assumes your mask has a high-performance filter, so particles almost all enter via its leaking edges and almost none through its filter.

[66] The best strategy is always to avoid inhaling highly contaminated air in the first place. For example, whenever possible, *don't* wait in a small, stuffy waiting room.

[67] Also called a *mask brace* or a *mask frame*. (A *mask bracket* is a different device, intended to solve *facepiece collapse*.) Illustration Rob Wilson.

Edge-Sealing Methods

1. Mask-Fitters (Also Called Mask Braces

Mask-fitters (also called **mask braces**) are frames or clamps that are strapped over a mask to seal down its loose edges. So far, the best-performing mask-fitters have all been at least partly made of very stretchy material. Stretchiness allows a fitter to move with your face while also keeping a firm grip on your mask.

In this photo mechanical engineer Sabrina Paseman is wearing one of her earliest mask-fitters, which was made out of just three rubber bands. The machine is comparing the number of particles outside of Paseman's mask (the blue tube), to the number of particles inside her mask (the clear tube).

The "fit score" on the machine's screen shows us that even this very simple mask-fitter was able to keep out over 99.5% of the particles that were trying to leak in under the mask's edge. That is really impressive edge-sealing for just three rubber bands—similar to the edge-sealing expected for N95 disposable respirators.[68]

In the year since Paseman's early pilot experiment, various other preliminary investigations have also found that **tightly worn, well-shaped fitters provide very large reductions in edge leakage when worn over a surgical-style mask or a KF94**. Some examples:[69]

- In **Runde et al.**,[70] eleven healthcare workers with very different faces were all able to achieve over 99% control of edge leakage by wearing the rubber-band mask-fitter over a surgical mask.
- **Fernandez**[71] found that two versions of the rubber-band fitter over a high-performance surgical mask kept out 91% and 96% of all microscopic particles while she sat still, versus 53% without the fitter.
- **Yan et al.'s**[72] fitter (for the mask's top-edge only) doubled a surgical-style mask's total control over microscopic particles (from about 42% to about 88%) and improved a poorly fitting N95 respirator's control from about 40% to about 97%, in a study that used a highly realistic manikin.
- In **Rothamer et al.'s** manikin study,[73] control over infectious-size airborne particles was under 25% for a four-layer cotton mask even with the best-fitting mask-fitter, but two high-performance surgical-style masks were each able to achieve over 90% control of microscopic particles with the authors' own Badger Seal mask-fitter and with the Essential Mask Brace. Supplementary analyses with the Badger Seal indicated a very good fit-testing score with a single human subject.
- In unpublished **pilot fit-testing by Paseman**, four people with diverse face shapes and sizes wearing the Essential Mask Brace (EMB) over a high-performance surgical-style mask achieved over 99% control of edge leakage on all subtest trials; similar results were obtained for the EMB on five extremely different manikin face shapes and sizes and for the EMB with the same number and range of subjects wearing the Dr. Puri KF94, an especially unstructured ("floppy") KF94.[74]
- WVU health scientist **Brandon Takacs** reported > 99% control of edge leakage for a single subject wearing a surgical-style mask with both a Paseman DIY prototype mask-fitter and with the EMB,[75] more than ten times and twenty times the control he achieved without the respective fitters.

Such studies have many limitations,[76] but so far they seem to support the view that especially careful users might be able to achieve 90% or greater control over edge leakage with just a high-performance surgical mask and a well-fitted mask-fitter.

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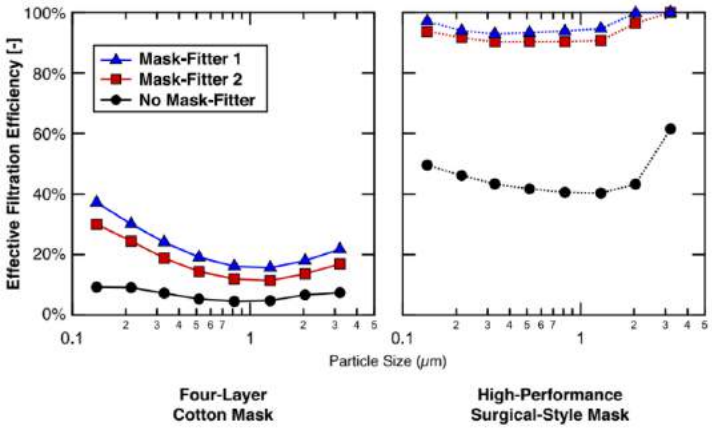
[68] Not every person''s results are this good, and we don't actually recommend using the rubber-band fitter Paseman was testing in this photo, because they're relatively uncomfortable and fragile. Mask-fitters have improved a lot in the year since this research was done. Still, the result gives a sense of what may be possible with due care.
[69] Not all research has yielded such an ideal result, so perhaps the best conclusion is simply that a carefully worn elastic mask-fitter will tend to provide *a great deal more* control over edge leakage than the same mask worn without one.
[70] A peer-reviewed study (**link**). This is the most rigorous peer-reviewed study of a mask-fitter to date, in that it involved subjects with a wide range of facial proportions who all completed a full, standardized N95 fit-testing protocol, a protocol that deliberately strains the mask's fit. See the introduction to "Fit and Leakage."
[71] The results mentioned above are presented in supplementary analyses to support her peer-reviewed report (**link**).
[72] Their peer-reviewed manikin study is at this **link**. Instructions to make the custom-shapeable mask brace are available in a YouTube video cited in the article.
[73] A manikin pre-print study by Rothamer et al. plus a single successful fit-test (reported in the supplement) can be found at this **link**.
[74] S. Paseman, personal communication with A. Solomon, April 23, 2020 and unpublished data.
[75] See non-peer-reviewed documentation of his test series **here**, and video demonstration **here**.
[76] All of the studies have used small samples, several did not complete a complete human fit-testing protocol, none of the studies necessarily bears on performance in more challenging real-life usage (example: slippage that may occur only during extended wear), and some have other method problems. Some of the studies are not peer-reviewed, two were conducted by a device's inventors, and in one case data are unpublished by the inventor. Still, the consistency of the pattern is encouraging. Photo courtesy S. Paseman.

Can mask-fitters turn *cloth* into a high-performance mask, too? Unfortunately, studies have found that even with a mask-fitter, cloth continues to leak too much directly through the fabric to count as high-performance.

For one example, the graphs nearby come from Scott Sanders' manikin research.[77] The **lowest curve on each of the two graphs** (in **black)**, shows the percentage of microscopic airborne particles that a cotton mask (left) and a high-performance mask (right) were able to keep out **without** a mask-fitter.



The **highest two curves on each graph** (in **red** and **blue**) show how those same two masks performed ***with*** **mask-fitters**: Even when helped by mask-fitters, the cotton mask could only keep out about 10%–20% of infectious particles in a particularly concerning size range.[78] But the same mask-fitters helped the surgical mask keep out over 90% of particles in that size range. Some types of cloth can perform somewhat better than this—but getting better filter performance from cloth can require reduced breathability.

It can be safer to stick to the best-studied devices when modifying a mask. Mask-fitters have so far mainly been tested with surgical-style masks, so we have more confidence in that combination. We also have more confidence in the two best-studied[79] mask-fitters. They are the **Essential Mask Brace**, or **EMB**, developed by engineer Sabrina Paseman and team, and the "**original version" Badger Seal**, without earloops, developed by engineer Scott Sanders and team. The EMB currently offers certain assurances because it has been evaluated on a more representative range of human and manikin faces, its quality is controlled by one manufacturer, and some of its design features may help to limit beginner errors. On the other hand, some people prefer the Badger Seal, and it is valuable to find a solution that you really use.

Above: A Badger Seal fitter over a Bluna Face-Fit KF94. It is increasingly popular to pair a fitter with a very breathable KF94, but not much is known about that combination's safety or effectiveness.

It takes time to get accustomed to a mask-fitter. If you aren't persuaded by yours after a long try, a different style may help. If a different style doesn't help, several ideas offered below in "Mask Fitter Solutions" may be of interest.

Where to Buy Mask-Fitters (Mask Braces)

Various independently-made versions of the Badger Seal are currently sold in online marketplaces. Some can deviate from the original invention in concerning ways. On the other hand, several samples of Tabsynth's version have all seemed to follow the original specifications. The EMB comes with important quality assurances if purchased directly from FixTheMask.com. Correct sizing matters for the EMB; a video provides guidance. Samples of EMB counterfeits sold widely on e-commerce sites have seemed unsuitable.

[77] Graph modified from Fig. 13 in this report (**link**). The data shown here are for control over inward leakage (protecting the wearer), but effects are similar for outward leakage.
[78] Particles of approximately 1–3 microns
[79] To be clear, no mask-fitter is yet *well* tested compared to any federally approved respirator. Research on mask-fitters is still preliminary, and most is not peer-reviewed. These devices are only better-tested than *other* fit-enhancement options. Photo this page A. Solomon

2. *Enhancements for Disposable Respirators (& Some Other Masks)*

Overview

Studies have shown that KF94s, KN95s, N95s and similar disposable respirators provide pretty good edge-seals, most of the time, for most people, when worn tightly around the head. **Studies have found that when chosen, adjusted, and sized appropriately, worn snugly around the head and used gently and carefully, such disposable respirators may commonly provide 90% edge-sealing**[80]— even without the large advantage of specialized testing that industrial workers receive, and without a mask-fitter.

On the other hand, those same studies reveal that *sometimes* such respirators don't fit well. The studies suggest that a *particular* respirator's fit on *you*, and how snugly you wear it, matter a great deal. So here's the puzzle: Without a specialized workplace fit-test, how can you be sure whether *your* respirator is one of the more-typical, "pretty good," respirator fits?

You can't be sure. But weighing all of the available research on disposable respirators, informal and systematic studies alike, **we expect that with careful attention to fitting techniques**[81] **and, especially, gentle use, people should usually be able to get 90% or better control over edge-leakage with such respirators.**[82]
No promises, but we think it's a realistic expectation for many.

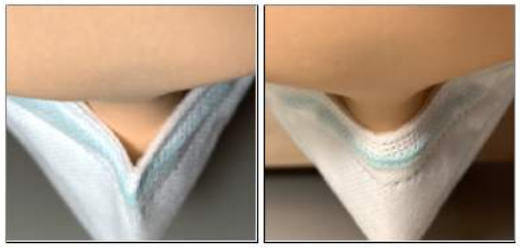
Below we introduce stepwise **fit-enhancement ideas that might improve the odds of getting to 90% edge-sealing or better with a disposable respirator.** We focus as much as possible on techniques derived from research and expert opinion on how to help masks fit well:[83]

1. Inspect your respirator.

Inspect for signs of crushing. Hold it up to a bright light and check for punctures or loose seams.[84] Check that the straps and nose-strip seem securely attached. Put it on, making sure the nose-strip is along the top edge. Does the respirator's cup (or flaps) easily span the distance from under your chin to your nose bridge? Is the mask wide enough so that when you smile, the "pockets" that form at the corners of your mouth aren't visible?

2. Reshape the metal nose-strip.

➤ *For vertical flat-fold respirators:* Many KN95s and other vertical flat-folds have a severe crimp in the metal nose-strip that prevents a good fit (see photo). Fixing this defect may



Above left and right: *A KN95 viewed from above the nose.* ***Left:*** *The nose-strip was shaped while on the face, as the manufacturer recommended. The fit is poor.* ***Right:*** *The same nose-strip after reshaping with the alternative method.*

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[80] See the section *Respirator Use By The General Public* in this CDC article (**link**). As the CDC scientists noted, a tight-fitting respirator has been found in some studies to provide much higher than 90% edge-leakage control for most people, even without fit-testing. But it's also clear from the same studies that the outcomes are highly dependent on the quality of the device"s face-seal, how well it fits a particular face"s size and shape, and how much care and knowledge the wearer is applying to the task of ensuring a good fit.
[81] What if you don't plan to study and apply fitting techniques for your respirator—does it make sense to wear one anyway? Your respirator is a much less confident solution when you don't learn how to use it well, but studies suggest it would still be better to upgrade to a snugly fitted high-performance model than not to upgrade.
[82] Our expectation for the fit of surgical masks after applying these techniques is not as optimistic, because even with enhancements, surgical-style masks have not yet accumulated enough evidence to suggest that they provide high-performance protection for most people, most of the time—except when worn with a well-studied mask-fitter. If it is necessary to rely on a surgical-style mask without a mask-fitter, then adapting the techniques in this section is likely to at least help more than not using any fit techniques. Also see "Knotting the Corners" further below, for another very important fitting technique for surgical-style masks.
[83] Based on pilot testing, expert experience, or manufacturer guidance.
[84] Note: It is normal for many of these respirators to have thin, transparent logos, writing, and "pinstriping." These are created by melting layers together and are not leakage points.

sometimes yield a large gain in leakage control. **With the mask off your face**: **1**. Slowly straighten out the nose-strip, smoothing out the bumpiness around the crimp. **2**. Reshape the strip around your finger until it matches the curve of your nose bridge. **3**. Put on the mask and check the fit around the nose. **4**. Remove the mask and continue reshaping and checking until the shape is a very close fit. **5**. Make a final adjustment to the strip so that it is a bit *narrower* than your nose, so that your nose can push back against it. ➤ *For other respirators*: Because they aren't crimped, skip the straightening step and begin with reshaping the nose-strip.

3. Check that the edge of your mask is in contact only with smooth skin.

For a close fit, nothing but bare skin should be under a mask's outermost edges. Even short stubble or a bit of stray hair can cause edge leakage; see footnote for research on this. If shaving isn't possible see "Solving the Problem of Beards."

4. Fasten the respirator around your entire head, not your ears.

Elastic headbands are better than earloops at preventing edge leakage,[85] but research suggests that connecting earloops together behind the head with an *earloop connector (*usually called an *ear saver)* provides some of the advantage of around-the-head headbands. One convenient style of connector that can remain attached even when the mask is not in use is shown in a nearby photo. The style shown can be purchased inexpensively on the internet. An earloop connector can also be improvised.[86] If an earloop connector pulls too hard on your earloops, adding a short loop of elastic or rubber band can allow more stretch. An end of the hook can be taped shut to prevent the hook from falling off.

5. Inspect the respirator's fit during speech and face and head movement.

You can watch for gaps along all of the mask's edges while smiling widely, counting, turning your head side-to-side and up-and-down, bending over, and simulating a yawn. The video camera in your phone may be easier to use than a mirror. Even a well-fitted mask may gap briefly or slightly during some of these exercises, but no gaps should persist after the exercise.

6. Breathe in-and-out quickly. (But this may only reveal the *largest* leaks.)

As you breathe in and out quickly several times, your respirator should puff out and pull inward visibly. When it doesn't, there is likely a large leak. Even if it does, there still may be a medium or smaller leak, so more checking could be useful.[87] Next, watch in a mirror as you blow out quickly: Is the mask blowing off your face a little bit along the cheeks? That may happen if a mask is too loose. Hold your fingertips very near the mask's edges and blow out: Do you feel air leaking anywhere?

7. Compare how the mask feels with and without an airtight clamp around it.

When a mask is well-sealed it feels somewhat more difficult to breathe through, and more warm breath lingers inside it than when it is poorly sealed. This provides a very approximate way to investigate leaks: Form an oval with your forefingers and thumbs, then fit that oval around the edge of your mask to create an airtight seal along the mask's edges. Breathe through your mouth, not your nose, with your mask clamped like that for two minutes. Then do the same without clamping the mask. Did you notice more warm air lingering inside the mask when clamped?

Now try to take a deep breath, from empty lungs to full, through your mouth, with and without the mask clamped: Does it feel harder to complete that breath with the mask clamped? Does it take

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[85] Some relevant expert opinion and findings found **here**, **here**, and on page 5 **here**.
[86] See video for a simple paper-clip earloop connector (**link**).
[87] It is a common assumption that a strong movement of the facepiece during this procedure demonstrates that an airtight seal has been achieved. It does not, especially not for the thinnest, more flexible, and lightweight facepieces featured on many of the respirators and masks discussed in this report. This checking procedure should be thought of more like blowing up a tire that might have a leak: If it fills with air, that tells you the *biggest* leaks can be ruled out. But medium-sized or small leaks might still exist—so the tire might be flat again in a half-hour. See, e.g., Frost & Mogridge in *Journal of the International Society for Respiratory Protection* (**link**). Photos this page: A. Solomon

longer to get all the way to the end of the breath? Does it feel like more work to finish it? Does the mask pull in more as you inhale with it clamped? (If so, how large is the difference?)

Such differences can be hints that your mask was leaking significantly before you clamped it and that it could benefit from better edge-sealing. But the procedure is not precise, and perceiving small differences is possible even after a good seal is achieved, since no *perfect* seals are expected.

8. **"Test drive" your mask safely for an hour of your typical daily activities.**

   "Test drive" your mask at home for an hour or longer while doing activities that resemble what you usually do around other people. Be sure to include a conversation in the activities. Your test drive is a chance to detect and solve slippage that could gradually worsen the mask's fit while you were wearing it out in the world: Does it slip or shift out of position? Also use the test drive to increase your awareness of how leaks feel in your particular mask, on your particular face (see "Behavior Techniques" below). From time to time during the hour, inspect the mask's fit with a phone camera, checking for any visible gaps that may have developed. Seek a solution for whichever type of leak it seems most prone to developing during use.

9. **If your mask still doesn't seem stable, consider** "Anti-Slippage Techniques."

10. **If anti-slippage techniques don't help, a different mask might be needed**.

3. Behavior Techniques

A high-performance mask is not "set-it-and-forget-it" protection. How one *behaves* while wearing it can affect how well it works. Here are several behavior techniques that have been suggested to possibly reduce a mask's leakage:

1. **Limiting the strain your movements cause along your mask's edges.**
   Masks (and mask-fitters) tend to leak the most when people *move* the most: During head motion, large facial expressions (especially wide smiling or grimacing), bending, talking, or vigorous breathing or walking/running/jumping. The lowest leakage happens when people stay still in their masks, without talking. So it has been suggested that if you cannot get out of an indoor situation where you suspect highly contaminated air,[88] it could be helpful to **minimize vigorous activity, especially facial movement.** This may include avoiding hard breathing, laughing, shouting, bending, twisting, exercising, or even talking in your mask. How widely you open your mouth for speech may also be helpfully minimized, or any specific behavior that tends to cause nose slippage for you, if it is appropriate in the situation to minimize it.

2. **Developing perceptiveness about leaks**.
   If you learn to **notice clues that a large leak is developing**, you may be able to interrupt it early. Signs of a leak developing are different for different people, but might include: How a mask's edges feel when they are snugly positioned on your cheekbones, chin, or cheeks; how much of a gap your fingertip detects around a mask's edges; the sensation on your skin of air flowing in or out of an edge; tell-tale changes in the sound of your breath or voice (when a very large leak develops, voice and breath may grow clearer and louder, with sharper "s" sounds, for example); or a feeling that air is flowing much more easily inside the mask. However, keep in mind that even experts report being unable to detect some leaks without fit-testing.[89] So practicing perception skills may help to catch some large leaks—not necessarily all leaks.

3. **"Test-driving" enough masks to choose a better-fitting model**.
   Research strongly suggests that comparing the fit of several different masks before deciding

[88] The *best* protection is to *avoid* such air. Whenever possible, don't inhale poorly ventilated shared air, *no matter what kind of mask you have*.
[89] Roy McKay, a noted respiratory-protection scientist, observes that even he cannot always detect leaks by observing the fit of a respirator on a worker's face (**link**). His warning underscores that checking fit can be a valuable way to reduce large leaks—so long as a good check isn't interpreted as a guarantee of *no* leaks.

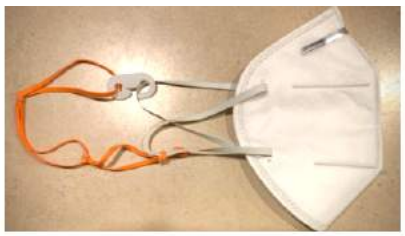
which one is the best fit for you can improve the final fit. Different sizes, shapes, and styles of disposable respirator fit people *really* differently, much the way shoes do. And also like shoes, it can pay off in the long run to be choosy at first about how well your respirator fits.

4. **Considering behavior techniques recommended by manufacturers or regulators**. Different masks may perform best with different techniques. So manufacturers, especially domestic ones, sometimes provide very specifically relevant information about how to safely use a specific model, such as a more-specific method for checking its fit or sizing. Some even offer free online training videos. CDC, NIOSH, or OSHA may also offer relevant resources (but keep in mind that much of their advice was written with regulated workers as the intended audience, so it may or may not apply to you).

4. Anti-Slippage Techniques

Sometimes a mask fits really well except that it gradually slips down the nose, or it is just a bit too loose on the face overall. Slippage can be an especially serious fit problem, because once a mask has slipped out of position, it may leak profusely until noticed and corrected. If you have this problem, several ideas may be of interest:

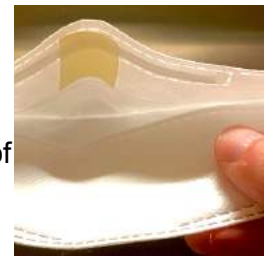
- ❑ **Creating something similar to an N95's elastic tether around the head:** It may enhance fit to tether a mask with a strap made out of short, high-quality rubber bands that go around the head. The reason this may help is that earloops are usually relatively inelastic, so a strap made instead of high-quality rubber might more effectively pull everything back up into position as it begins to slip over and over throughout the day. The loops and knots also may provide grip on the back of the head so that you can position the band higher without it sliding down—and that higher position can help tug the mask slightly upward back into position. This accessory can be combined with a short earloop connector, for convenience (see photo).



Above: KN95 with rubber-band headstrap and an earloop connector

- ❑ **Applying grippy foam medical tape inside of your mask, across from the nose:** A small patch of 3M's MicroFoam (a grippy, hypoallergenic closed-cell foam medical tape) on the inside surface of a mask directly opposite the nose may control slippage of non-sweaty skin. Additional common ideas include using only one layer, keeping it away from the face-seal (see photo), and pressing the tape to the mask firmly for several seconds to activate the adhesive. By some reports, even a very small amount may solve many slippage problems.

- ❑ **Many nose-strips are too flimsy to hold their shape. If yours keeps flexing away from your nose, a sturdier, self-adhesive replacement model may serve better:** A source is listed in the footnote.[90] Nose-strips may fit best when positioned far up on the nose bridge, away from the lower, softer sides of the nose. Compressing a nose-strip too forcefully while on the face can cause injury. They can be shaped mainly while off the face.



If you are still experiencing slippage:

- ❑ **Respirators with two high-quality elastic headbands** often have an advantage in terms of staying in position on the nose. If you try such a respirator, **the upper headband is typically designed to be worn on the crown of the head, not back**. It is sometimes helpful to make sure that the upper headband isn't too loose overall by temporarily shortening it by an inch and checking again for slippage while talking. If shortening the headband helped, it can be tied shorter with a permanent knot—but care may be needed to not shorten it so much that the elastic presses into your flesh.

[90] One team of mask scientists has used this sturdy brand (**link**), which can be cut to length . Cited in this study (**link**).

5. "Knotting the Corners" Technique

see cautions re: sizing and corner gaps

A surgical mask with a knotted corner. Note the leak the technique created.

Knotting the corners is a technique that narrows the sides of a surgical-style mask dramatically, potentially closing off major gaps along the cheeks. The technique is not yet established as a high-performance modification, but it has some limited evidence of effectiveness. See video in footnote.[91] **Knotting corners has the complicated side-effect of downsizing many surgical-style masks by a size or more**. When a surgical-style mask becomes too small for a face it can tend to slip up or down, especially during speech. One strategy is to begin with an oversized surgical-style mask before knotting its corners. **Knotting the corners can also create a gap at the center of each side of the mask, which can be folded in and taped closed.** Elsewhere advice is given to just fold the mask material inward to close those gaps, but such closures can open up during use, and the new opening is unlikely to be sensed by the wearer. The gap can instead be easily closed with cloth medical tape.

Fastening a surgical-style mask more tightly around the entire head with an earloop connector is an alternative fit-tightening technique that does not make a mask smaller.

6. Double-Masking Technique

See cautions re: extended wear

Above: *Double-masking. Note fogging of the right glass lens which indicates a persistent leak along the right side of the nose. Leaks along the top edge do not commonly occur with a well-fitted mask fitter.*

In double-masking an outer cloth mask is customarily used to seal down the edges of a surgical-style[92] mask. Research is preliminary. A pilot fit-testing study with three participants found the largest reductions in edge-leakage for a stretchy gaiter-style mask worn over a surgical-style mask,[93] an arrangement illustrated in the nearby photo. Non-stretchy outer cloth masks did not cause the same amount of improvement.
Double-masking raises three interrelated concerns:

1. Pairing certain cloth masks with certain surgical-style masks can add up to a great deal of breath resistance—potentially enough resistance in some cases to exceed federal rules for respirator breathability. So if you choose to double-mask, consider using an extremely breathable outer layer.

2. Based on preliminary research, a stretchy gaiter seems likely to provide better edge-sealing *and* breathability than a conventional cloth top layer. However, because a gaiter is not tightly tied around the crown of the head and normally lacks a nose-strip, it is unclear how reliably it can be expected to maintain its position on the nose during extended wear. If you choose to double-mask with a stretchy gaiter—or any other top

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[91] Mask researcher Emily Sickbert-Bennett demonstrates the technique in this video (**link**).
[92] A respirator worn properly should not need this kind of fit-enhancement, and some limited research exists to suggest that tightly fastening a mask over some respirators may compromise their seal. The CDC currently advises against double-masking of respirators by the public (see section entitled 'Do Not' at this **link**).
[93] See Sickbert-Bennett et al.'s report (**link**), and this press release describing some of their findings (**link**). Photo: A. Solomon.

layer—one idea is to begin with an hour-long "test drive" at home, as described earlier, to investigate how well your double-mask combination remains in position during a long conversation and other common daily activities, and also how comfortable it remains to breathe through.

3. A tightly worn top layer can force an underlying mask onto the wearer's mouth (see photo), potentially causing excessive breath resistance. For more about this problem, see "The Problem With Facepiece Collapse."

In summary, a stretchy gaiter worn carefully over a high-performance surgical-style mask seems likely to provide a better faceseal than a surgical-style mask worn without any fit-enhancements. But a leading mask-fitter provides a better-tested leakage-control method, while avoiding concerns described above.

7. Nylon Stocking Technique

see cautions re: extended wear

In this method, a length of nylon stretch stocking is worn over the entire head to seal an underlying mask's edges. But as the inventor of the method warned, a stocking can press an underlying mask directly onto the wearer's face, or even lips, which can create inappropriately high breath resistance, up to orders of magnitude higher than is customary.[94] A leading mask-fitter is a better-tested technique, and it can leave the center of the facepiece uncompressed. See "The Problem With Facepiece Collapse."

See *Special Topics*, Next Page

[94] Cooper et al. (1983) invented this method and drew attention to this concern. See footnote, next page.

➤ *Special Topic:* The Problem of Facepiece Collapse

Certain edge-sealing techniques can press a mask continually onto the mouth or cause the mask to be sucked on and off the mouth with every breath. Pressing a mask onto the mouth, such as may happen with a tightly worn overlayer, makes the breathing area of the mask much smaller, which reduces breathability.

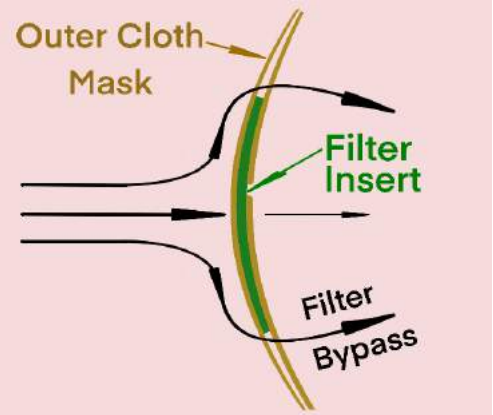
To get a sense of how much smaller the breathing area can become, press a mask tightly across your lips and try to breathe in and out. A researcher did this with manikins and found that the mask's breath resistance became "unacceptably high," as much as 100 times higher.[95] Sustained high breath resistance is of concern, and getting sucked onto the mouth repeatedly is not ideal for a filter's performance, nor is it hygienic.[96]

Mask brackets are an accessory that fit inside a surgical mask in order to keep the mask away from the mouth. Unfortunately, many of them interfere with a mask's face-seal. Check with your mask-fitter company for updates to find out if any have been approved for use.

Concerns about the possible effects of facepiece collapse are one reason that we focus so much on masks that are unusually breathable and that are structured or shaped so as to stay clear of the mouth. It is also among the reasons that we are cautious about double-masking and stretch-stocking overlayers. Finally, it is among the reasons that we rely on challenging, higher-velocity filtration tests whenever possible.

➤ *Special Topic:* The Problem of Filter Bypass

Many two-part masks are sold with replaceable filters that fit into a pocket or sleeve inside a cloth mask. These filters often fit loosely or imprecisely. Mask scientists have warned that when this kind of filter doesn't span the entire cloth mask, or doesn't remain in a precisely correct position during use, a lot of contaminated air can get inside the mask by passing *around* the filter. It is not clear how wearers would even detect such a defect, since the filter is hidden from view inside the cloth mask. See footnote[97] for a few sources that have raised concerns of this kind.



Similar concerns can arise with unregulated masks that resemble elastomeric respirators.

It may be best for each unregulated design of this kind to be submitted to an accredited laboratory for specific analysis of the risk of filter bypass, and for the results of the testing to be made publicly available. At this time, we have more confidence in conventional masks in which all layers are securely fused together.

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[95] See Cooper (1983): "Under conditions in which the nylon hosiery pulled the fabrics against the lips of the manikin, the filtration area was greatly reduced and the flow resistance became unacceptably high (10 to 100 times higher)" (**link**).

[96] For an exploration of how mask filtering fabric may be expected to perform worse during repetitive, forceful reversals of airflow, see Bourouiba et al. (**link**) and, especially, Dbouk & Drikakis (**link**). Hygienic concerns related to increased moisture, contact with the mouth, and viral transfer across the filter are explored in Nikiforuk et al., (**link**) and Yi, Fengzhi, & Qingyong, (**link**), and Rengasamy & Niezgoda (**link**). Photo: A. Solomon

[97] See discussion of filter bypass in Duncan et al. (**link**), Cherrie et al. (**link**), and Volckens et al. video (**link**) (see the 58'53" minute mark in the video). Some two-part masks appear to be very well-designed, and we expect that they will pass relevant safety tests. Figure this page R. Wilson. Photo A. Solomon.

➤ *Special Topic:* Mask-Fitter (Mask Brace) Solutions

Mask-fitters may feel awkward to wear. If you aren't persuaded by the first one you try, consider trying another, because different types feel really different. If you can't find a good match, these ideas may be of help:

1. Switching to a more breathable mask: Before you began using a mask-fitter, the leaking edges of your mask were providing a lot of free airflow that was helping to keep your mask cool and dry. If that reduction in airflow with your mask-fitter bothers you, take a look at our earlier recommendations for especially breathable high-performance masks and respirators.

2. Just wearing your mask-fitter like a necklace most of the time: You can pull a mask-fitter up into position on your face quickly whenever air quality becomes questionable (e.g., a smaller or crowded room, a vehicle), and leave it tucked in your shirt collar or just dangling around your neck most of the day. (See **right photo.**)

3. If you find the appearance of mask-fitters unacceptable: A homemade mask-fitter may blend in better with your existing mask. Find a cloth mask with sturdy, stretchy outer trim[98] that matches the color of your high-performance mask. The **simplest approach** is just to cut away the center portion of the donor mask (**left photo**). An approach that should yield **a closer fit** is to cut away everything except the stretchy trim (**lower right photo**), knot both corners to create a V-shape at the outer cheeks, apply a deluxe adhesive nose-strip,[99] and add an elastic strap to go around the crown of the head. If the mask-fitter feels too loose, padding can be sewn into its edges, it can be tied more tightly around the head, or a smaller donor mask can be used. But keep in mind that there are no studies of any home-made mask-fitter. The commercial mask-fitters that have been standardized and studied are the only kind with evidence to support their use at this time, and we recommend avoiding less-standardized, less-tested modifications when possible.

4. If you experience facepiece collapse:

- A larger surgical-style mask or KF94 may allow you to create a longer pouch that stays further away from the mouth, as shown in the lower nearby photo.
- A more breathable surgical-style mask should not pull in as sharply during inhalation.
- If any *mask bracket* has been tested and found suitable for use with your mask-fitter, that could also solve the problem.
- A more-structured mask can resist collapse, but as of this writing specific KF94 and KN95 models had not been extensively tested with mask-fitters; check with manufacturers or relevant expert sources such as the CDC for updates on whether any such respirators have been tested and found safe and effective with their fitter.

[98] The one shown here is Hanes cotton-mask model MASKN2.
[99] A source is provided in "Anti-Slippage Techniques." Photos: A. Solomon.

➤ *Special Topic:* The Problem of Beards

Beards aren't sealed properly by masks.[100] Masks don't seal properly over beards because the invisible gaps among beard hairs are enormous compared to microscopic airborne particles. Because those gaps among beard hairs are invisible, it's easy to think a mask has created an airtight seal over a beard when it hasn't. Beards also slow airflow down, which means the warning sensation of a leaking puff of air is lost. Because of this, various experts agree that staying closely shaved is necessary when wearing a tightly-fitted mask or respirator. But for those who *can't* shave their beards for religious or medical reasons, certain strategies may[101] help:

For those who can only trim or shave partially:

- **Keep whiskers as short as possible.**
  Short whiskers typically cause less leakage.[102] The worst leakage may often begin after a week or more of growth.

- **A new respirator with a "squishy"[103] gel face-seal might be considered.**
  The Envo Mask's face-seal (see photo) has two hypothetical advantages when worn over very short beards: First, research on gel pads used to prevent pressure injuries suggests that gel facepieces might be comfortably worn more tightly than conventional facepieces.[104] Second, a preliminary research report[105] suggests that gels may be the best of many materials at sealing a short beard because they can partially enclose short hairs—although even the squishiest of such materials was not judged as effective as shaving. Note that this respirator's NIOSH classification raises an unresolved question about its overall fit performance.[106]

For those who must maintain a full beard:

- **A thin rubber sheet can be used to create a good face-seal.**
  A method has been invented[107] that appears to be capable of producing an excellent face-seal over full beards. The method involves covering the beard with a thin, stretchable synthetic rubber sheet (see nearby figure). Successful fit-testing was documented in a small study of men with several different facial types, using several different kinds of respirator. This technique is new; only one study has documented the effect so far; and we do not know of any training available online yet.

For those with whiskers of any length:

- **Wear your mask as tightly as is safe for you.**
  The more you compress your whiskers, the less leakage may occur. However, overtightening a mask increases the risk of pressure injuries to the skin, so pay attention to the condition of your skin and take more frequent breaks to allow your face to decompress. A highly elastic mask-fitter may help distribute pressure more evenly.

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[100] For discussion of the problem and some data, see Meadwell et al. (**link**), Frost & Harding (**link**), and Sandaradura et al. (**link**).
[101] You would need to get fit-tested to know whether these methods are actually helping.
[102] For discussion of how short beards or whiskers compare to full beards, see Meadwell et al. (**link**), Frost & Harding (**link**), and Sandaradura et al. (**link**).
[103] The type of material the Envo Mask relies on for its face-seal was first engineered for ventilation and CPAP masks, as explained **here**.
[104] Some gels and foams are validated for prevention of pressure injuries in immobilized patients, and as facepiece seals to limit skin pressure in ventilation masks (**link**).
[105] See this report (**link**). Note the discussion and data regarding a face-seal made of "Non-Newtonian Fluid Sample 1." It is unclear how similar that gel is to the Envo Mask faceseal.
[106] NIOSH classifies the Envo Mask in an unusual respirator category called "quarter masks," which fit *on* the chin rather than *under* it. To simplify somewhat, quarter-mask respirators are assumed by NIOSH to exclude half as much particulate contamination as other N95 respirators in "worst case" situations. The Envo Mask's particular design might perform much better than NIOSH's general assumption about quarter-masks, but we have seen no data to resolve that question yet.
[107] See Singh et al."s pioneering report on the "under-mask beard cover" (**link**). Photo: A. Solomon. Illustration: R. Wilson.

➤ *Special Topic:* Younger Children's Masks

Many parents are considering what they can do to protect unvaccinated children against airborne transmission, as reports emerge of variants that may produce serious illness in some children. Advice is changing rapidly, so check for updated guidance from your pediatrician and from the CDC. See the footnote[108] for CDC guidance regarding how caretakers can ensure safety for young children in masks and what level of supervision is required. As that CDC document notes, masks are not appropriate for children under two, nor for people of any age who have certain disabilities. The World Health Organization recommends masks only for children over five, but also recommends following regional authorities.[109] We highlight only a couple issues related to young children's masks below:

Breathability and easy removal: Concerns have been raised about high-resistance, tightly sealed, or hard-to-remove face-coverings for younger children. One concern is that it is important for vomit to be able to flow away from the child's mouth quickly rather than being inhaled. Young children's breathing patterns and lungs are also fundamentally different from adults, with less capacity to breathe against restricted airflow.[110] Overall, children are more likely to wear a mask consistently if it is breathable. For such reasons it has been suggested that comfort, breathability, and easy removal be prioritized for children's masks, especially for younger children.

Contact with the mouth: Some younger children habitually mouth or chew any mask that is close enough to the lips, which is unhygienic and could compromise the filter. A mask that has enough structure so that it does not contact the child's lips may be helpful. For example, some **KF80** earloop respirators in children's sizes resist collapse *and* are especially breathable. However, cup volume of young childrens' masks should be kept low, according to one expert review.[111] Your pediatrician could provide guidance on appropriate cup volume.

Lost masks: Young children tend to misplace their masks, and whenever that happens they will be unmasked for a while. **Mask lanyards** are available that permit a mask to be worn like a necklace when not worn on the face.[112] Younger children may need **breakaway lanyards** (designed to safely disconnect whenever strained).

Checking for poor material breathability: Parents may be able to exclude especially unbreathable masks from consideration by holding a mask very tightly around their own lips and noting any that are especially resistant to breathing through it. This method is not validated, however.

Checking the child's experience: It can be important for parents to confirm that a child is comfortable in a mask, understand the source of any discomfort, and confirm that the child is able to quickly and reliably get their mask off.

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[108] See the document section entitled: "Certain groups of people who may find it difficult to wear a mask", at this CDC advice page (**link**).
[109] This document (**link**) and this detailed Q&A (**link**) summarize the WHO's expert advice.
[110] For a scientific review of protective masks for children, including some explanation of how children''s relevant physiology and anatomy differs from adults'', see Roberge (**link**).
[111] See Roberge 2011 (**link**).
[112] An example is shown in this newspaper article about mask accessories (**link**).

➤ *Special Topic:* Eyeglass Fogging

Overview: Fogged eyewear can be hazardous.[113] Sometimes fogged eyewear is a warning that *unfiltered* air is leaking out along the top edge of the mask, which is of concern because an **edge leak** allows contaminated air in and out of the mask. But fogging doesn't always come from an edge leak. That's because **warm *filtered* air** also travels upward after you blow it out through your mask, much the way the 'steam' rises outward and then upward from your mouth on a cold day. As that warm air flows upward from your mask, it can also become trapped behind your eyeglasses.

To figure out which problem you have, it may help to press on your mask's top edge along one side of the nose, with the tip of a pencil eraser in order to temporarily seal that side's leak. For an edge leak, that lens will commonly stop fogging while the other one will continue to fog. If no change is observed, the problem be the other kind. Of course, the problems often occur together.

Several strategies have been suggested to help with *any* cause of fogging:

1. **Coating the inside of lenses with a non-irritating, liquid dish detergent and then polishing them until just clear—but not rinsing them.** Sharma et al. reported that this controlled fogging for up to twelve hours in an operating room.[114] Kumar et al.[115] reported partial success for approximately two hours when a detergent solution was permitted to dry passively on lenses without polishing. In some research, detergent residue outperformed some commercial anti-fog products. The ideal liquid detergent would be non-irritating and free of oily additives or moisturizers, so that lenses don't smear.

2. **Wearing eyeglasses further forward on the nose.** This may solve an unexpected episode of fogging by quickly diluting the hot, humid air that is trapped behind the lens. For longer use, ask an eyecare professional about an adjusted prescription.

3. **Reducing the temperature difference between your exhaled breath and the air around you.** In colder air, glasses fog much more easily.

4. **On worksites, wearing fog-resistant safety goggles with rubber edges.** The rubber edges are designed to limit the flow of air into the goggles.[116]

If your fogging is caused only by upper-edge leakage, two suggestions are often emphasized: **Using a mask-fitter**, or **taping the mask's top edge**. Both of these can seal a top edge very effectively. But **taping can result in skin injury**, especially if it is done without adequate training or with the wrong kind of tape. See the next section for more information about the risks of taping.

If the main problem is warm filtered air rising off the face of the mask and getting trapped behind the glasses, then it may help to **apply a narrow strip of medical-grade adhesive tape to the outside highest half-inch of a mask.**[117] If you try this, cover only a very small fraction of your mask's breathable surface. Any clingy, thin medical tape should work. This technique is not helpful for edge leaks.

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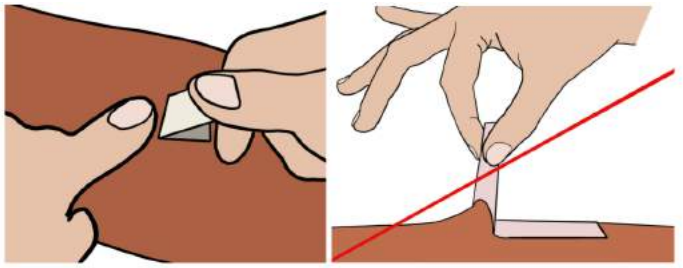
[113] Fogged glasses can make it impossible to see safely. It is also a leading reason offered by workers for not wearing protective eyewear (**link**).
[114] Sharma et al. (**link**).
[115] Kumar et al. compared three methods to control fogging of glasses (**link**).
[116] An example is shown at this **link**.
[117] See Karabagli et al. (**link**).

➢ *Special Topic:* Taping

see cautions

Overview: Taping the face can cause mild to serious skin injuries. Problems can arise because some tape adhesives bond to skin increasingly tightly over minutes to hours, so that the adhesive, which seemed only weakly bonded, becomes extremely difficult to remove after minutes to hours have passed. Skin under or around the eyes, and face skin of older adults or young children in general, can be very thin and fragile. Skin can be torn off if tape is too strongly adhered or removed at the wrong angle or speed. Repeated or prolonged use can have much worse effects on skin than brief or single use. Skin can be injured if it is stretched before taping. Residual rubbing alcohol on the skin can cause certain adhesives to become *more* adhesive.[118]



Above: Two examples of why safer tape application and removal requires expert training: On the left, skin is being stabilized at the peel line with one hand while tape is removed "low and slow" with the other. Notice how the tape is kept closely parallel to the skin while slowly pulling. On the right, removing tape in this way has a high risk of causing delicate skin to tear. The sensitive skin around the eyes is much more vulnerable than the arm skin depicted here, and can require other techniques. Illustrations based on instructional materials from 3M.

A new generation of soft silicone-gel adhesives are especially gentle.[119] Unfortunately, such tapes generally have weaker adhesion than conventional medical adhesives, and not all tapes with “silicone” in their description are gentle.[120]

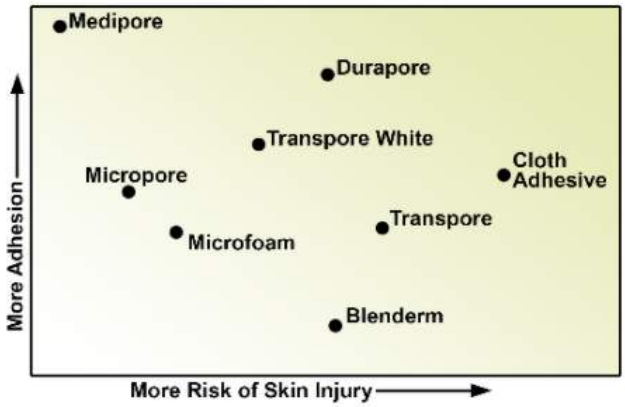


Figure based on 3M's data comparing its most common surgical tapes. Better tapes for sensitive uses have very low risk of injury. Medipore and Medipore H have had identical adhesive formulations since 2012 per 3M.

For these reasons and others, we recommend consulting with a knowledgeable healthcare professional before using tape, to understand how to apply and remove medical tape most safely, which tapes provide the best adhesion with the lowest risk of skin injury[121] (see examples of the very wide range in a nearby figure[122]), which kinds of tape should always be avoided on delicate skin, and how to remove tape without tearing off skin in event of unexpectedly tight adhesion (e.g. how best to apply moisturizer to the “peel line” to loosen it, while pulling slowly at a certain angle).

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[118] The examples of problems and techniques included here are not completely explained.
[119] For example, 3M’s Kind Removal Silicone Tape, now rebranded as Micropore S, is reportedly the gentlest of their commonly used medical tapes. For more information about Micropore S, see 3M’s informational brochure (**link**).
[120] For an explanation of these and related issues, see the 3M white paper, "Selecting the right medical adhesive tape: Challenges facing the medical device designer" (**link**).
[121] A widely circulated social-media post by a surgeon recommends using 3M Micropore to seal the top edge of masks. But 3M’s data favor reformulated Medipore or Medipore H over Micropore for lower risk of skin injury with better adhesion. 3M reports that since 2012, Medipore H and Medipore have had the same adhesive formulation: "In 2012,we eliminated the difference between Medipore [and] Medipore H [so that] both tapes provide the higher level of adhesion while maintaining the gentleness to the skin." (**link**).,
[122] Data were estimated for this plot from a figure in 3M’s guide to surgical adhesive tapes (**link**). Top figure by R. Wilson and bottom figure by M. Cammer.

➢ Cautions and Disclaimers

The Content provided by N95DECON is for INFORMATIONAL PURPOSES ONLY and DOES NOT CONSTITUTE THE PROVIDING OF LEGAL OR MEDICAL ADVICE and IS NOT INTENDED TO BE A SUBSTITUTE FOR INDEPENDENT PROFESSIONAL LEGAL ADVICE OR MEDICAL JUDGMENT, ADVICE, DIAGNOSIS, OR TREATMENT. Use or reliance on any Content provided by N95DECON is SOLELY AT YOUR OWN RISK. Review the full N95DECON disclaimer at: https://www.n95decon.org/disclaimer

➢ Disclosures

N95DECON strives to provide objective information grounded in scientific evidence. As a volunteer organization composed of scientists, health professionals, researchers, and other experts in the field, one or more of our members may on occasion have professional relationships that could give rise to an apparent or actual conflict regarding the information we provide. We believe in transparency and have asked our members to disclose any relevant relationships to allow our audience to evaluate potential conflicts. Our members disclosed the following relationships for High-Performance COVID-19 Masks: (1) a former N95DECON member is a founder of 4C Air, Inc. but was not a member at the time this report was conceived or drafted and (2) an N95DECON member is affiliated with a separate nonprofit which received a donation of masks from Powecom. The listing of masks or accessories in this document does not constitute a recommendation from N95DECON. The N95DECON consortium is a 501(c)(3) nonprofit.

➢ Other suggestions for use of your mask or respirator

Consider any of the following suggestions that apply to your situation: ➢ **When selecting and wearing a respiratory device, consider health concerns:** ● Wearing a tightly fitted mask or respirator places an additional load on the body. Individuals with a known or suspected cardiovascular, respiratory, kidney, or anxiety disorder, or any other potentially relevant conditions should consult a medical expert. ● For some individuals, such masks may be difficult to breathe through. Your initial evaluation may need to be done seated with minimal exertion until you are confident that you are experiencing no respiratory symptoms ● If you experience a change in your breathing pattern or other symptoms like breathing discomfort, pain, headaches, dizziness, nausea, grogginess, or malaise while using a tightly worn respirator, it may be necessary to take a fresh-air break and consider seeking the advice of a health professional; symptoms may be due to CO_2 buildup, hyperventilation, anxiety, and other factors; consider the CDC's advice here. ● Pressure on the face from a tightly worn respirator or mask may be high enough to cause skin pressure injuries or other sensitivity reactions, especially with long, uninterrupted wear, and especially around the nose and cheekbones. It may be important to check often for skin irritation or breakdown, take breaks to decompress the skin, and consult a medical expert if skin discomfort or skin changes occur. See CDC advice here. Any respiratory, skin, age, or other precautions that apply for N95 respirator use may also apply to a braced face mask or an international respirator ● Avoiding using force when fitting your device. The skin and blood vessels in the face are delicate. Tighten the straps gently, avoid binding your ears, and press gently on the nose-strip. ● Links herein to third-party resources are not endorsements of any advice that they provide. Products mentioned in this document may be appropriate for use only during the declared COVID-19 public health emergency, and never in place of federally approved workplace protection where available; if uncertain, consult a medical expert.

➢ **Also consider device performance:** ● Elastic tethers lose their strength over time, and weakened tethers can cause a poor fit. ● These respirators or masks may not filter as well after exposure to soap, detergent, alcohol and other aromatic solvents, disinfectants, paint, fumes, oils, acids, alkalis, or certain other chemicals. ● Intermittent wetting has not been found to rapidly compromise the filtering ability of most respirators and face masks, but the effect could be variable from device to device. ● Most or all of the above-mentioned respirators and masks were designed only for a single use, and their performance may worsen with extended use. Information about the cautious reuse of face masks and respirators is available elsewhere on our website. ● Performance may be worse for expired respirators and face masks; it may be necessary to check the date code on the package. ● Falsified, expired, or mishandled products may sometimes be sold, especially by unauthorized resellers ● No guarantee of safety or performance is possible for many reasons, including because device quality varies from sample to sample, falsified products exist, and fit will vary from person to person and over time. Overall performance as a filter system is likely to be poor if the device's fit is poor. ● The fit-checks and some other behavioral techniques described above have not been validated for community use; some or all of them simply resemble challenges used in federal workplace testing to reveal leakage problems in respirators during head and face movement. They may be relevant to enhancing fit, but have not been proven to be so. ● Most or all of these devices have not been approved or evaluated as appropriate for the prevention of specific diseases or infections, or for the filtering or control of viruses, bacteria, smoke, fumes, hazardous liquids or splashes; flammability; or for use in community, workplace or healthcare settings. ● Manufacturers and distributors are responsible for ensuring compliance with all applicable laws and regulations. ● The manufacturer and relevant regulatory agencies should be consulted for guidance on safe and effective use of such devices. ● No particular brand or model of device is endorsed or vouched for as suitable for any general or specific use. ● The colloquial use of the term *respirator* above does not mean that the referenced device has been approved or defined as a workplace or medical respirator by U.S. or foreign regulatory authorities. ● These instructions do not guarantee protection against transmission of any diseases. ● Clean your air-filtering device only as recommended by the manufacturer or other experts. Most such filters are damaged by soap, alcohol, and other chemicals. ● Beware of online sellers providing misleading information. A reseller's advice about how to fit, operate, clean, or maintain a device may not be reliable. A reseller's website may only pretend to be operated or authorized by the manufacturer. ● It can be important to read all safety information provided by the manufacturer, and consider any updated CDC guidance for the public on mask fit and leakage. ● Replace your device at appropriate intervals. Replace it within the manufacturer's recommended maximum hours of wear, or sooner if it shows significant wear or if you notice worsening fit or decreased breathability. ● Most disposable respirators and disposable masks were originally designed for a single use. They are supposed to be reused only during the public health

emergency by following CDC guidance. ● Read authoritative information about your specific device's care and use. Other information, including information presented here, may not apply to your device and may be outdated. ● Homemade and non-regulated masks and accessories do not meet regulatory guidelines and should be used only during the COVID-19 public emergency when no better option is available. ● Masks and accessories may not have been approved or cleared by any regulatory agency; any approvals or clearances cited above may have lapsed or been revoked, rescinded, or withdrawn since this document was published ● Homemade and other accessories are to be used at your own risk. Due to variability of materials and construction, a non-regulated or homemade accessory's safety or effectiveness is not proven and cannot be assumed. ● Information and instructions reproduced in this document and elsewhere are not guaranteed to be complete, accurate, or up-to-date.