**Supplementary material**

# Forgotten technology. Filtration properties of cloth and cloth masks: a narrative review

**Supplementary Figure 1.** Definitions and relationship between filtration efficiency, protection factor and total inward leak. For consistency, we calculated filtration efficiency from data provided in the original work, rather than presenting the data in the units chosen by the authors. Protection factor and fit factor are synonyms. Modified and reproduced with the permission of the American College of Physicians.[1] Q factor as described by WHO updated guidance 2020 June 05,[2] and Podgórski and colleagues.[3] When calculated as defined below, WHO guidance states that expert consensus recommends a minimum Q factor of 3 (as well as other criteria) for mask material. Other authors[4] use $\log_{10}$ rather than ln to define Q; results need to be interpreted differently.

There are several types of experiments described in the literature. Some experiments test flat cloth samples, and others test masks worn by volunteers or on manikins (figure 1). For the latter two cases, some experiments test how well the mask protects the wearer from external particles, and some test how well the mask stops a wearer from transmitting particles to the environment.

In all cases, the experiments compare particle concentrations on both sides of the mask or cloth sample. We use the term *filter* below to refer to either a mask or a cloth sample depending on the type of experiment.

Let $c_{high}$ be the concentration of particles on the source side of the filter. The source side is the upstream side for tests of cloth; the outside for tests of masks as a means of protecting the wearer, and the inside for tests where the wearer is the source of the infection.

Let $c_{low}$ be the concentration of particles on the protected side of the filter. This is the opposite of the source side.

When measuring the filtration properties of filters, there are two contributions to particles on the protected side: particles that have passed through the mask (*penetration*), and particles that have leaked around the edges of the mask (*edge leak*). Experiments on cloth samples use equipment designed to exclude edge leak. With masks on manikins and volunteers, edge leak can be a significant factor.

The definitions below can be applied in all types of experiments. Of course, the measured efficiency of a piece of cloth would not be the same as the efficiency of a mask made of that cloth because in the latter case, edge leak would reduce the measured efficiency.

The *filtration efficiency* (*FE*) of the filter is the ratio of particles removed by the filter; this is a number in the range 0 < FE < 1. This is calculated by the formula:

$$FE = \frac{c_{high} - c_{low}}{c_{high}}$$

The *protection factor* (*PF*) of the filter is the ratio of particle concentration high to low; this is necessarily at least 1, and the higher the number, the better protection afforded by the filter. As a formula:

$$PF = \frac{c_{high}}{c_{low}}$$

These are related:

$$FE = \frac{c_{high} - c_{low}}{c_{high}} = 1 - \frac{c_{low}}{c_{high}} = 1 - \frac{1}{PF}$$

We also define the *total leakage* (*TL*) to be proportion of particles admitted by the filter. This is also in the range $0 < TL < 1$. In the literature, the name *total inward leakage* (*TIL*) is often used for this quantity.

$$TL = \frac{c_{low}}{c_{high}}$$

Since a particle is either admitted by the filter or removed by the filter, it is apparent that

$$TL + FE = 1$$

so

$$FE = 1 - TL$$

Furthermore,

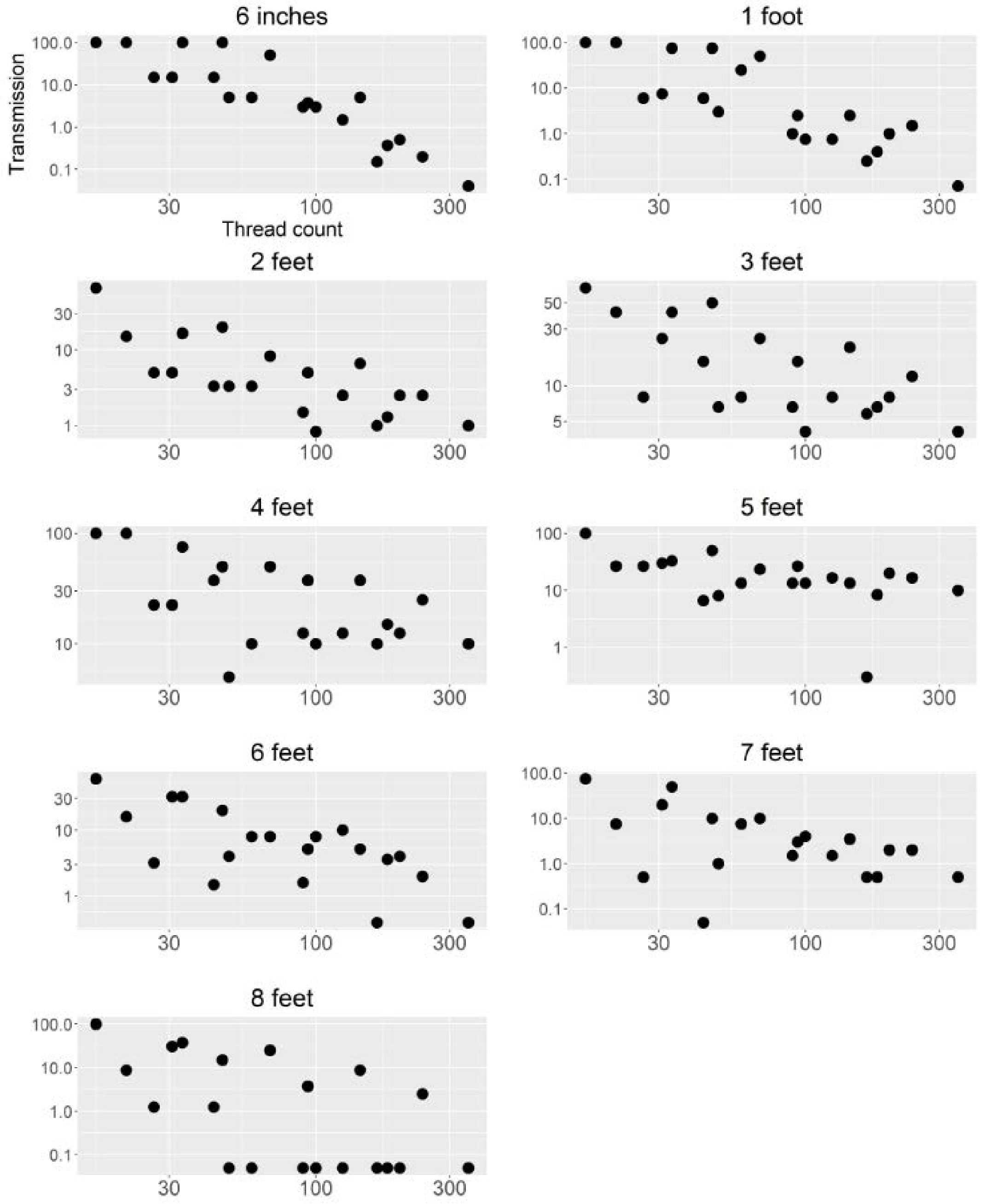
$$PF = \frac{1}{TL}$$

Let $\Delta P$ be the pressure drop across the material (under standard conditions of area and air flow), in kPa. It is a measure of breathability: the higher the pressure drop, the more the work of breathing increases to maintain flow, and the lower the breathability.

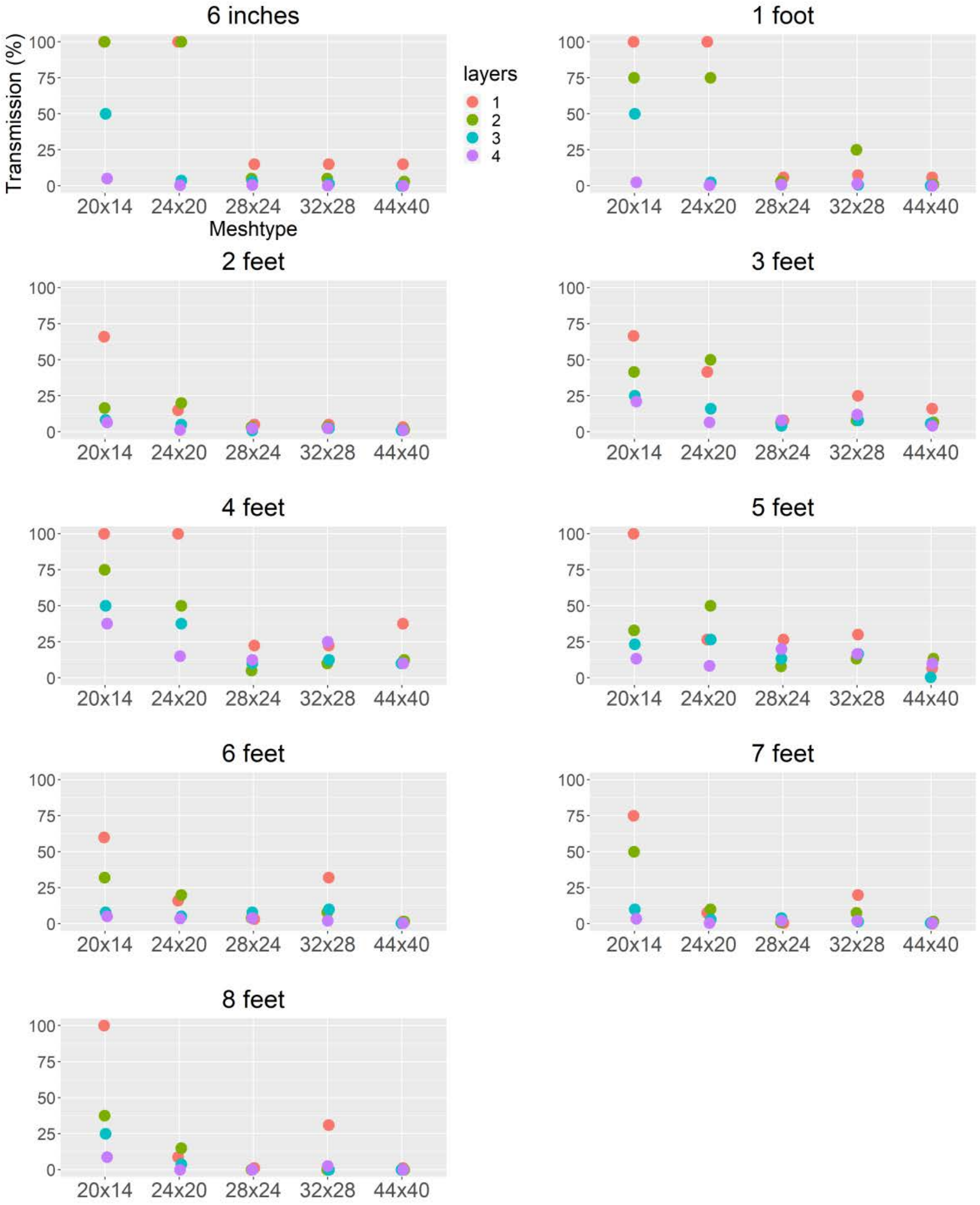
The quality factor, Q, is used to describe the trade-off between efficiency and breathability for a given material, and is defined as

$$Q = \frac{-\ln(1 - FE)}{\Delta P}$$

**Supplementary figure 2.** Data are from Table 3 in Weaver 1919.[5] In this experiment, the transmission of bacteria through material was studied using woven gauze with varying thread count and number of layers, for example, 3 layers of 24x20 gauze. We calculated thread count as the mean of the warp and the weft, multiplied by the number of layers. The relationship between transmission and thread count is shown for each of the distances studied. Transmission decreases as thread count increases.



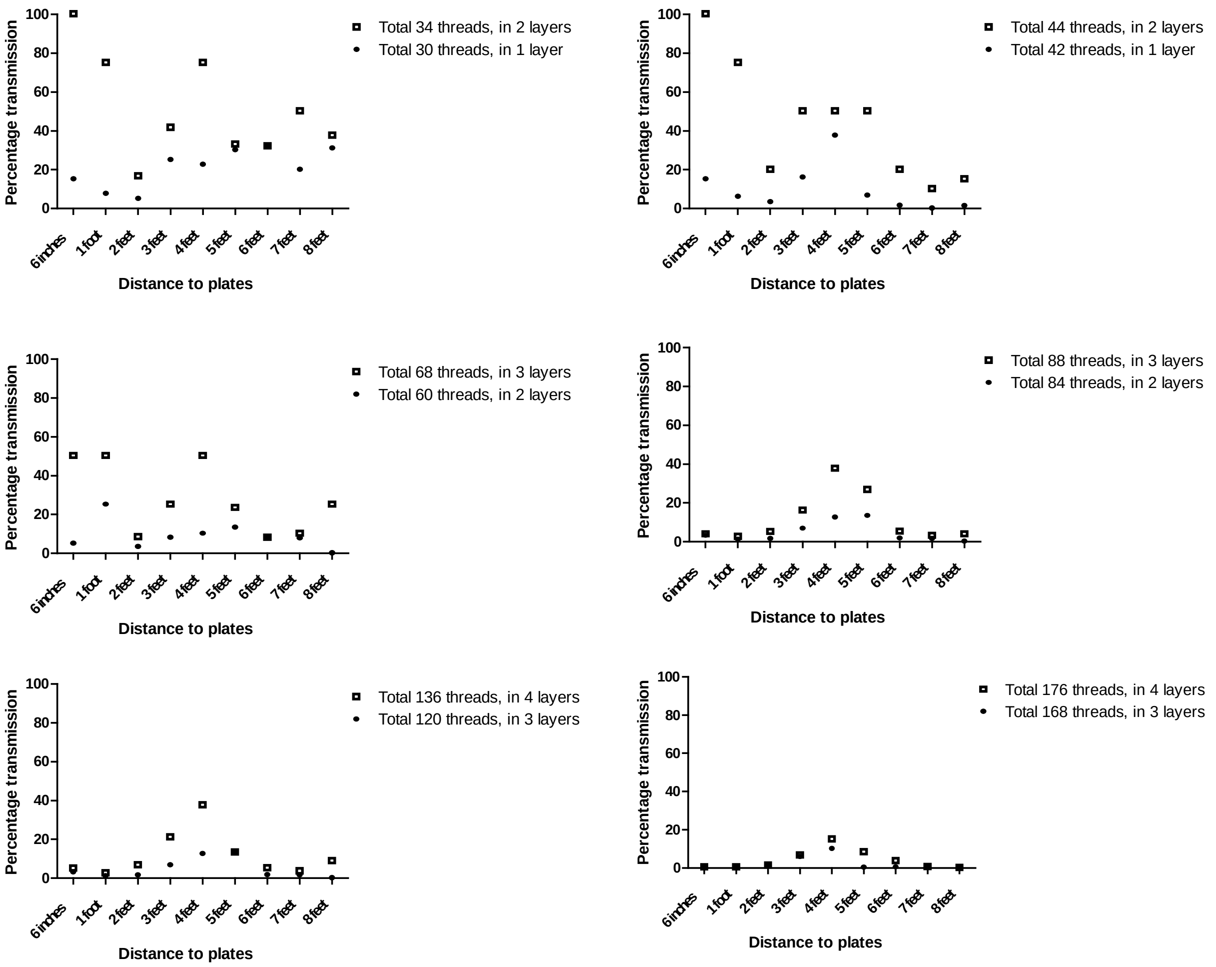
**Supplementary figure 3.** Data are from Table 3 in Weaver 1919.[5] In this experiment, the transmission of bacteria through material was studied using woven gauze with varying thread count and number of layers, for example, 3 layers of 24x20 gauze. We show the relationship between number of layers and transmission, for each type of gauze, at each distance studied. Transmission decreases as number of layers increases.



**Supplementary figure 4.** Data are from Table 3 in Weaver 1919.[5] In this experiment, the transmission of bacteria through material was studied using woven gauze with varying thread count and number of layers, for example, 3 layers of 24x20 gauze. We calculated thread count as the mean of the warp and the weft, multiplied by the number of layers. The relationship between transmission and thread count is shown for each of the distances studied. Transmission decreases as thread count increases.

We selected, a priori, all pairs of data in which similar total thread counts were achieved with varying numbers of layers. 6 pairs were identified and graphed. In each case, achieving the same thread count with a smaller number of layers resulted in less transmission. This extended to the case of 1 vs 2 layers: 1 layer with mean thread count 42 (1 layer of 44x40) resulted in less transmission that 2 layers of mean total thread count 44 (2 layers of 24x20).

To convert this to the modern unit, threads per inch (TPI), the warp and the weft are added together. For example, 24x20 gauze would now be described as 44 TPI. Total thread counts of 168 (in 3 layers) and 176 (in 4 layers), bottom right, would convert to 336 TPI and 352 TPI respectively.



## References

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3. Podgórski A, Balazy A and Gradoń L. Application of nanofibers to improve the filtration efficiency of the most penetrating aerosol particles in fibrous filters. *Chem Eng Sci* 2006; 61: 6804-6815.
4. Zhao M, Liao L, Xiao W, et al. Household Materials Selection for Homemade Cloth Face Coverings and Their Filtration Efficiency Enhancement with Triboelectric Charging. *Nano letters* 2020; 20: 5544-5552. DOI: 10.1021/acs.nanolett.0c02211.
5. Weaver GH. Droplet Infection and Its Prevention by the Face Mask. *The Journal of Infectious Diseases* 1919; 24: 218-230.