

Author's Note:

This report describes an experimental facemask that might protect wearers from COVID-19 and other respiratory viruses. However, the mask has not been tested for that specific purpose and—because it may be classified legally as an unapproved medical device—it is not authorized for use.

This report includes internal hyperlinks. To return from a hyperlink destination to the hyperlink origin use the key combination Alt+◀.

Although the report is 216 pages in length, it consists mostly of illustrations. If all illustrations and captions are removed, its length is only 30 pages.

Toward an Anti-COVID-19 Facemask That Can Be Made from Materials That Are Readily Available Worldwide

by Geoff Graham

Version 2021-10m-07d_1

October 7, 2021

Questions? Comments? Anything left out? Anything you disagree with? I'd love to hear your thoughts. Email me at gjgraham4health@protonmail.com.

Follow me (forever free) on Substack at <https://geoffreyjgraham.substack.com/>

Summary

Purpose: To provide a method to remove SARS-CoV-2 and other respiratory viruses from inhaled air using materials that are widely available around the Earth. The method is intended for use by people who lack other protections such as vaccination and effective conventional facemasks.

Accomplishments: The techniques discussed here can produce a facemask from materials that are cheap and widely available. Alternatives are suggested for key steps in which desired materials or

tools may be unavailable. The key facemask's key ingredient, cellulose acetate filter material, can immobilize dissolved food color from an inhaled aerosol of droplets whose sizes are biologically relevant. To my knowledge, every step of these techniques is in the public domain and is not the intellectual property of anyone. The facemask is provisionally named the "Bugeye Facemask" because of its appearance.

Drawbacks: The techniques are time-consuming. The facemasks produced have not been tested against SARS-CoV-2 or any other respiratory virus and are not yet legally authorized for use anywhere. Large amounts of aerosolized liquid in inhaled air can defeat the facemask by capillary action (wicking). The mask might benefit from the addition of a one-way air valve(s).

Contents

Introduction	3
Materials and tools used	6
Cellulose acetate can trap substances in aerosols of respiratory size	.9
The main components of a facemask	24
Create a device to test air intake through a filter matrix	26
The Bugeye facemask template	33
Construction of a filter matrix using non-corrugated cardboard, 2-sided carpet tape, and a hole punch with a two-inch reach	43
Creating a matrix to hold cigarette filters	51
Creating a matrix using glue instead of 2-sided carpet tape	96
What if cardboard and a 2-inch hole punch are not available?	105
The rare usefulness of electric drills	127
Adding extra protection to the filter matrix	130
Construction of the mask frame	137
Creating the mask air space	139
Construction of the mask nosepiece	142
Padding of the facemask for contact with human skin	174
Adding of rubber band straps	179

<u>Attachment of filter matrix to the mask frame and finishing touches</u>	194
<u>Adding a test for mask failure caused by wicking</u>	208
<u>Further development of the CAF facemask</u>	215
<u>Appendix – Printable Template</u>	216

Introduction

A brief description of a novel facemask. This report describes tests of an improvised facemask (the Bugeye Facemask) whose key component, cellulose acetate cigarette filters, was able to filter out color-labeled aerosol droplets of the same size as the human respiratory droplets that spread COVID-19 and other respiratory viruses. Although cellulose acetate is a promising air filter, it is commonly available only in inconvenient forms: as round cigarette filters of about 5/16 inch (7.9 millimeters) diameter or as the longer filter rods of the same diameter from which individual filters are derived.

The amount of air that a person could inhale through a single cigarette filter is far too little to sustain that person. Hence, a mask that uses cigarette filters to purify inhaled air must necessarily pass that air through many cigarette filters in parallel. For this to succeed, the filters must be held in an artificial matrix that is impermeable to air and which grips the filters tightly enough that air can enter the mask only by passing through the filters and not by passing through the junction between filters and the matrix that holds them. A description of the materials by which such a filter matrix can be made and of the techniques involved is presented in this report. There are several materials from which a filter matrix can be made, but each requires special techniques.

The cigarette filters used in these tests were 3/4 inch (19 millimeters) in length when purchased. According to tests described in this report, it is not necessary to use such a long tube of cellulose acetate to remove aerosol droplets from air. Truncated filters of about 8 millimeters will suffice. This is important because a cellulose acetate filter's resistance to the passage of air increases in proportion to its length. Thus, a filter matrix that contained 75 filters, each being only half the length of an unshortened filter, would allow in 150 times as much air for the same effort as would a single unshortened filter.

In order to form a useful facemask, a filter matrix (including the filters) must be joined with an airtight seal to a structure that creates the mask air space. As this

report explains, plastic food cartons and their plastic covers can be modified to create a suitable airspace with the filter matrix sealed to it.

The most important cause of facemask failure is probably that many facemasks [do not fit the wearer's face](#) and, thus, unfiltered air enters the mask air space from around the edges of the mask. Weather stripping, which is soft and pliable, can be used to line the edges of the facemask and create a tight junction with the wearer's skin. This and methods to reshape a plastic food carton so that it accommodates the mask wearer's nose are also described in this report.

Tests explained in this report show that cellulose acetate filtration of aerosol particles can be overcome by capillary action (wicking) when too much liquid is present. A method to detect when this has happened is also discussed.

The future of the Bugeye Facemask. It is not known for certain that cellulose acetate filters can trap SARS-CoV-2 virus particles, and this point must be settled first. Assuming that the filters do trap the virus, and that the novel facemask design is shown to be sound, it makes sense to petition appropriate government officials in countries around the world to promote this novel facemask to be constructed on an improvised basis.

As of today (September 22, 2021), winter is coming in the Northern Hemisphere. If adequate anti-COVID vaccines are not available, or vaccine-resistant variants spread through the population, the world may be in for a very hard six months. Therefore, it may make sense for people to manufacture this novel facemask any way that they can.

In the future, however, obvious improvements will be needed. If cigarette filters continue to be used, then the current filter matrix and mask airspace should be replaced by stamped plastic that fits the filters perfectly.

Even better would be to replace the cylindrical filters by larger rectangles of cellulose acetate filter tow, if this is feasible. Filter tow is sold in large blocks from which flat rectangles could be cut, but it is not certain that large rectangles of filter tow would remain free of cracks, even if the rectangles were supported by a rigid matrix.

Society has put surprisingly little effort into devising facemasks that protect people from airborne respiratory diseases, but this should change. Inexpensive, easily obtainable facemasks with replaceable filters should be the norm in every country, and this facemask might be a first step toward that.

COVID-19 is still dangerous. On August 8, 2021—the latest date for which information is available—there were more than 628,000 new COVID-19 cases, worldwide. On July 1, 2021, also the latest reporting date, there were almost 9,000

deaths. Although large fractions of the populations of some advanced countries have been vaccinated against COVID-19, most of the world remains unvaccinated and vulnerable to the pandemic. In some countries, few people have received even a single dose of vaccine.

With so many people infected with COVID-19, [new variants](#) may arise that will evade the vaccines. This could force many countries into another lockdown, which might throw the world into a global depression. Moreover, although the new delta variant of COVID-19 does not evade the vaccines, it infects unvaccinated people (the majority worldwide) at [very high rates](#).

News / **CONSEQUENCE**

Feedback

'Dangerous period' of COVID-19 pandemic, says WHO chief after Delta variant found in 98 countries

World Health Organization Director-General Tedros Adhanom Ghebreyesus said in countries with low vaccination coverage, terrible scenes of hospitals overflowing are again becoming the norm.



Invest in the future of kids like Smyrna.

[Find Out How](#)



10-year-old Smyrna



The Delta variant of SARS-CoV-2, and perhaps other variants, increase the danger of the COVID-19 pandemic. Posted on July 3, 2021 [at this URL](#):

The world needs effective facemasks. As discussed above, facemasks can protect people from respiratory diseases, including COVID-19. There is an urgent need for effective facemasks that can be constructed from materials that are plentiful worldwide.

Materials and Tools Used

The following materials and tools were used in these investigations. Each link below leads to a passage in this report where use of a given material or tool is described. Some materials or tools serve the same purpose as others, which means that it is probably necessary to acquire only one of them. For example, non-corrugated cardboard, silicone rubber sheets, and the soles of some discarded shoes are all materials from which a filter matrix can be made. Similarly, long-reach hole punches and cork borers are both tools to create holes in different types of filter matrix, and one or the other, but not both, will be needed.

Items followed by an asterisk are present in more than one category.

Test of cigarette filter suitability

[Vacuum cleaner](#) (household)

[Nebulizer](#) (Mesh brand)

[Funnel and plastic container](#) (both small)

[Tea bag material](#)

[Food color](#) (blue) *

Filtering inhaled air

[Cigarette filters](#) *

Printing of template for filter matrix construction

[Internet connection](#)

[Computer](#)

[Printer](#)

[Printer paper \(at least one sheet\)](#)

Construction of filter matrices

[Breathing tube](#) (short)
[Cardboard](#) (non-corrugated)
[Carpet tape](#) (two-sided)
[Cigarette filters](#) *
[Cork borer with an outer diameter of 1/4 inch](#)
[Cork borer sharpener](#)
[Glue \(rubber cement\)](#)
[Glue \(Arts-and-crafts, e.g., Elmer's Glue\)](#)
[Glue \(Superglue, e.g., Brand 401\)](#)
[Hole punch with a 2-inch \(5.08 cm\) reach](#)
[Metal snips](#)
[Plastic cartons used to store marketed foods such as cottage cheese](#) *
[Putty \(molding putty\)](#)
[Razor blade \(industrial\)](#)
[Razor blade \(for shaving\)](#)
[Reinforcing rings for notebook paper](#) *
[Clear plastic wrap \(e.g., Saran wrap, Glad wrap\)](#)
[Silicone rubber sheets](#)
[Soldering iron](#)
[Soles of old tennis shoes](#)
[Surgical tape](#)
[X-Acto knife](#)

Construction of mask air space

[Plastic cartons used to store marketed foods such as cottage cheese](#) *
[Scissors with sharp points](#)

Creation of mask nosepiece

[Candle](#)
[Cans \(empty\) of tuna or other food](#)
[Cans \(empty\) of a soft drink](#)
[L-braces \(small\) for bookshelves](#)
[Sardine tins \(empty\)](#)

Padding of the mask

[Paper towels](#) *
[Tape \(duct tape\)](#) *

[Tape \(vinyl electrical tape\) *](#)
[Weather stripping](#)

Sealing of the mask

[Tape \(duct tape\) *](#)
[Tape \(masking\)](#)
[Tape \(vinyl electrical tape\) *](#)

Safety of filter matrix

[Nylon scouring pads *](#)
[Furnace prefilter](#)
[Stiff wire screen](#)

Detection of mask failure

[Coffee filter](#)
[Food color](#) (preferably blue) *
[Netting \(flexible\)](#)
[Nylon scouring pads *](#)
[Paper towels *](#)

Adding of support strap to mask

[Office stapler with staples](#)
[Paper clips \(preferably large\)](#)
[Reinforcing rings for notebook paper *](#)
[Rubber bands \(preferably large\)](#)
[Squeeze fasteners and squeezing pliers](#)

Cellulose Acetate Can Trap Substances in Aerosols of Respiratory Size

Summary. Coughing, breathing, and ordinary speech produce respiratory droplets that can spread SARS-CoV-2, the virus that causes COVID-19. Similar aerosol droplets can be produced mechanically and, if the droplets are produced from a strongly colored aqueous solution, the fate of the droplets can be monitored.

Tests with such artificial respiratory droplets indicate that when they are propelled by a stream of air into the cellulose acetate of a cigarette filter, that the colored substances dissolved within the droplets remain at or very near the point where they first contact the cellulose acetate. This has been shown for several different chemical colorants. Thus, there is reason to hope that viral particles—which are also dissolved in respiratory droplets, but which are much larger than chemical dyes—might also remain where they first contact the cellulose acetate of a filter.

Characteristics of respiratory droplets. Respiratory droplets that can spread COVID-19 are generated by coughing, by speech, and by ordinary breathing. Such droplets range in diameter from less than one-tenth of a micrometer to as much as a millimeter, although the larger droplets quickly settle out of the air and become harmless. The most numerous droplets, which remain in the air for minutes or even hours, have diameters of about 2 micrometers. See Figure 1 of the review article by Michael Jarvis, [at this url](#).

Cellulose acetate cigarette filters. A substance called cellulose acetate is the main ingredient in 95% of cigarette filters. **Cellulose acetate cigarette filters** are good candidates for material that could remove aerosolized droplets from inhaled air. They are manufactured to trap smoke components while allowing air to pass through and squeezing the filters interferes only slightly with the passage of air through them. Cellulose acetate filters can be purchased as components of cigarettes, but they can also be purchased alone. One brand of filters sold over the Internet is TOP brand, which I used for all of my tests, but other brands may be equally suitable.



(Above) TOP brand filters are available for purchase over the Internet in the USA. The filters are composed mainly of cellulose acetate, have a diameter of $\frac{5}{16}$ inch (7.9 millimeters), and are about $\frac{3}{4}$ of an inch (1.9 centimeters) in length. These filters, or shortened pieces of them, were used for all tests of cigarette filters reported here.

The need to use many filters. A single filter does not allow enough air to pass through to sustain a person. Cutting a filter in half crosswise increases the air flow, presumably by about two-fold. Using the air flow through 75 full-length filters increases the total air flow by 75-fold relative to a single full-length filter. Using the air flow through 75 half-length filters would be predicted to increase the total air flow by 150-fold.



The above photograph shows an intact TOP brand filter (left) and a similar filter cut in half transversely (right). The cut filter transmits more air under suction than does the full-length filter. The cut filter is long enough to completely occupy one hole in a 9-layer cardboard filter matrix.



The above photograph shows a 75-filter array seen from the front. The filters in the holes are half the length of an uncut TOP brand filter. When part of a facemask, the array should allow 150 times as much air to enter the mask as would a single uncut TOP cigarette filter.



The above photograph shows the 75-filter array displayed in the previous photograph but seen from what would be the inside of the mask.

Manufacture of biologically relevant aerosols. “Mesh” brand **nebulizers** create aerosols whose droplets have virologically relevant sizes. The literature that comes with a nebulizer gives the size range as being from 2 to 20 micrometers diameter, with a peak at 4-5 micrometers. I have no independent way to verify this, but I can confirm that the mist is very fine and does not appear to fall toward the floor. (Human respiratory aerosol droplets [range in size](#) from 0.1 micrometers diameter to 1000 micrometers diameter, with the smaller droplets persisting longer in the air).



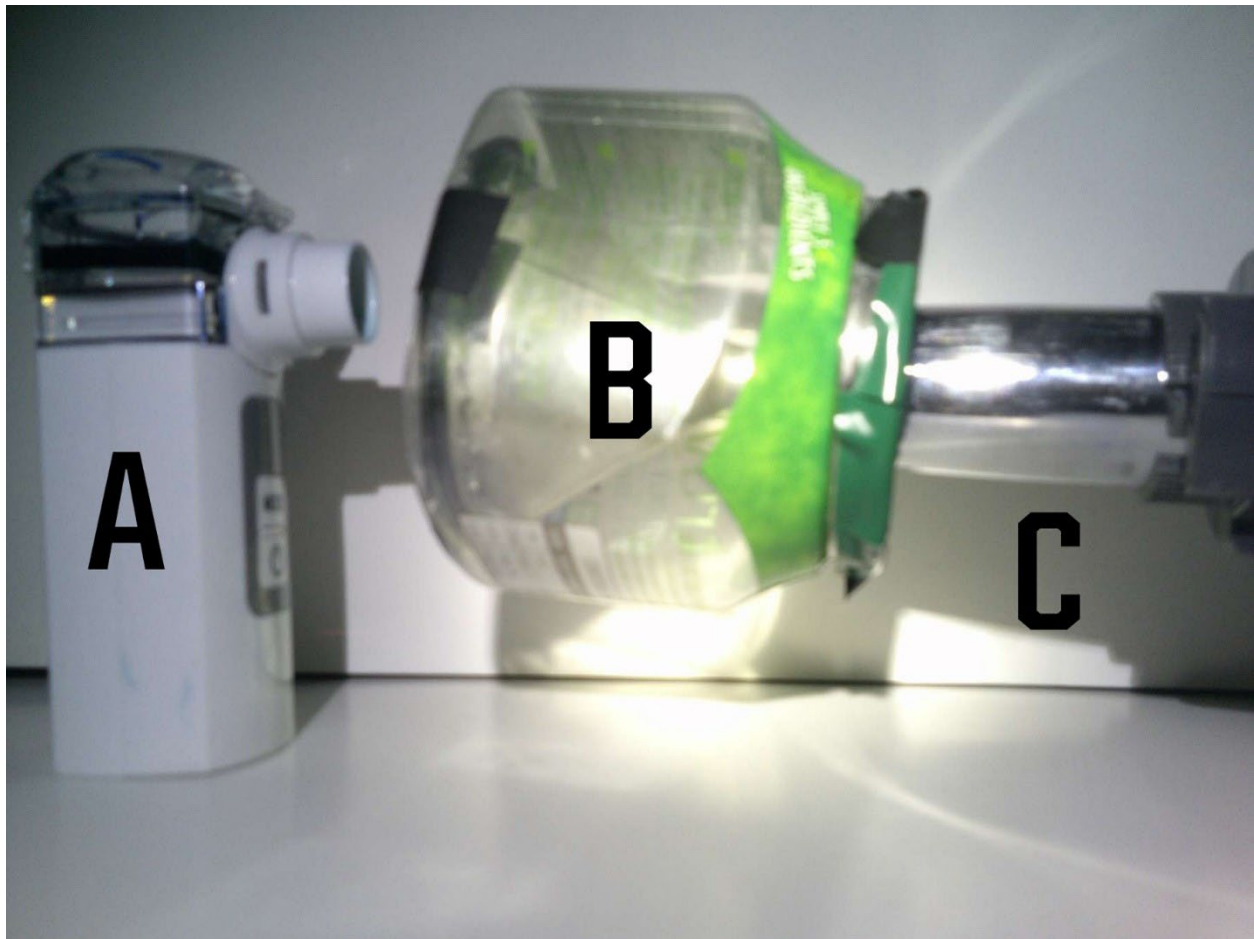
The above photograph shows a Mesh nebulizer seen from the front. The nebulized spray would travel toward the reader.



The above photograph shows a Mesh nebulizer, seen from the side. The spray from the nebulizer would exit toward the left in this picture.

The method by which Mesh nebulizers turn a solution into an aerosol requires that there be ions in the solution. **Commercial preparations of food color** do not contain such ions, and so ions must be added for the Mesh nebulizer to function. Typically, I dissolved one tablespoon of table salt, NaCl, in one cup of tap water, and mixed the solution thoroughly. Then, I added 5 drops of this solution to 5 milliliters of blue food color, mixed the solution, and added it to a Mesh nebulizer.

Testing of cigarette filters' ability to trap aerosol droplets. The ability of cigarette filters to trap nebulized droplets was tested using a Mesh nebulizer, a filter assembly, and a household vacuum cleaner. These are components A, B, and C, respectively, in the photo below.



In the above photograph, a Mesh nebulizer (A) is positioned to send a nebulized aerosol toward a filter assembly (B), which has air drawn through it by a household **vacuum cleaner** (C). The purpose is to test the degree to which the cigarette filter in the filter assembly will immobilize the aerosol.

The Mesh nebulizer generated a colored aerosol that was used to bathe the filter assembly for 2 seconds or longer. However, 2 seconds was always enough to produce a heavy stain on the side of the filter that was nearest the nebulizer. Air was drawn through the filter array by the vacuum cleaner, which was then allowed to run for up to 5 minutes. My vacuum cleaner has a “Performance Indicator” light which showed that air flow into the vacuum cleaner was largely blocked by this procedure; this indicates that there were no air leaks great enough to weaken the suction on the filter.

The filter assembly was constructed as follows. A cigarette filter was wrapped with tape (usually vinyl electrical tape) and inserted into the funnel. Enough tape was used to ensure that the filter fit the funnel snugly and a slight overhang of tape

was created on one side of the filter so that the wrapped filter could be manipulated with tweezers.

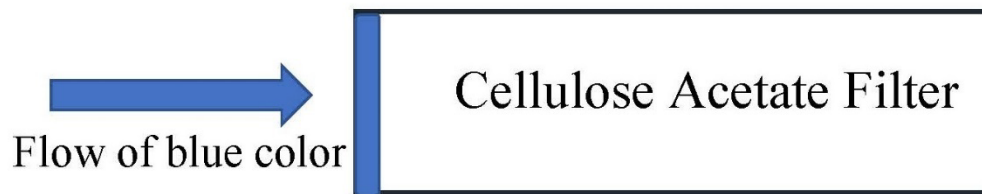
The **funnel was then inserted into the small plastic container** that was open at both ends, but which had a sieve at one end, to prevent the filter from being sucked into the attached vacuum cleaner. The pieces of the filter assembly are shown below. Note that the below photo shows both an unwrapped and a wrapped filter, but only the wrapped filter was inserted into the filter assembly.



(Above) The filter assembly (Item B in the previous picture) shown disassembled. To the extreme left is a cigarette filter of the type that will be tested in the filter assembly. Second from the left is a similar cigarette filter that has been wrapped with vinyl electrical tape so that it will fit snugly into the funnel, which is the third item from the left. Only the wrapped filter was inserted into the funnel; the unwrapped filter was not. The fourth item from the left is a wire screen that restrains the filter and prevents it from being sucked into the vacuum cleaner. The far side of the wire screen (not visible) has been modified so that it fits over the end of the vacuum cleaner

used and forms a tight seal. The rectangular piece of masking tape which is on the front of the wire screen, and which has a hole in its center, is a guide to anchor the stem of the funnel. On the extreme right is a plastic container that houses the filter assembly. When operating, the arrangement is made airtight with vinyl electrical tape so that air enters the filter assembly only through the wrapped filter.

Food color is immobilized by cellulose acetate. The results of these experiments show that the blue food color remains at or very near the point at which it first contacts the cellulose acetate filter. My camera does not have the resolution to show this, but below is a drawing.



The nebulized blue food color remains at or very near the point where it first contacts the cellulose acetate filters.

As noted (and misspelled) above, the nebulized blue food color remains at or very near the point where it first contacts the cellulose acetate **filters**.

Red, yellow and green food color behave the same way. This is important because the dyes used in the food color preparations are chemically different. The list below shows what was used. The abbreviation FD&C stands for the Food, Drug, and Cosmetic Act of 1938:

The supposition is that if four different chemicals are immobilized by the cellulose acetate, then viral particles—which are much larger—will be prevented from moving, also. This has not been proven, but it has a better chance of success than, for example, an ordinary handkerchief used as a mask.

Chemical Components of Food Colors:

Blue color: FD&C Blue #1 and FD&C Red #40

Red color: FD&C Red #40 & #3

Yellow color: FD&C Yellow #5

Green color: FD&C Blue #1 and FD&C Yellow #5

The above placard lists the chemical components of blue, red, yellow, and green commercial food colors. Multiple food colors are immobilized by cellulose acetate filters.

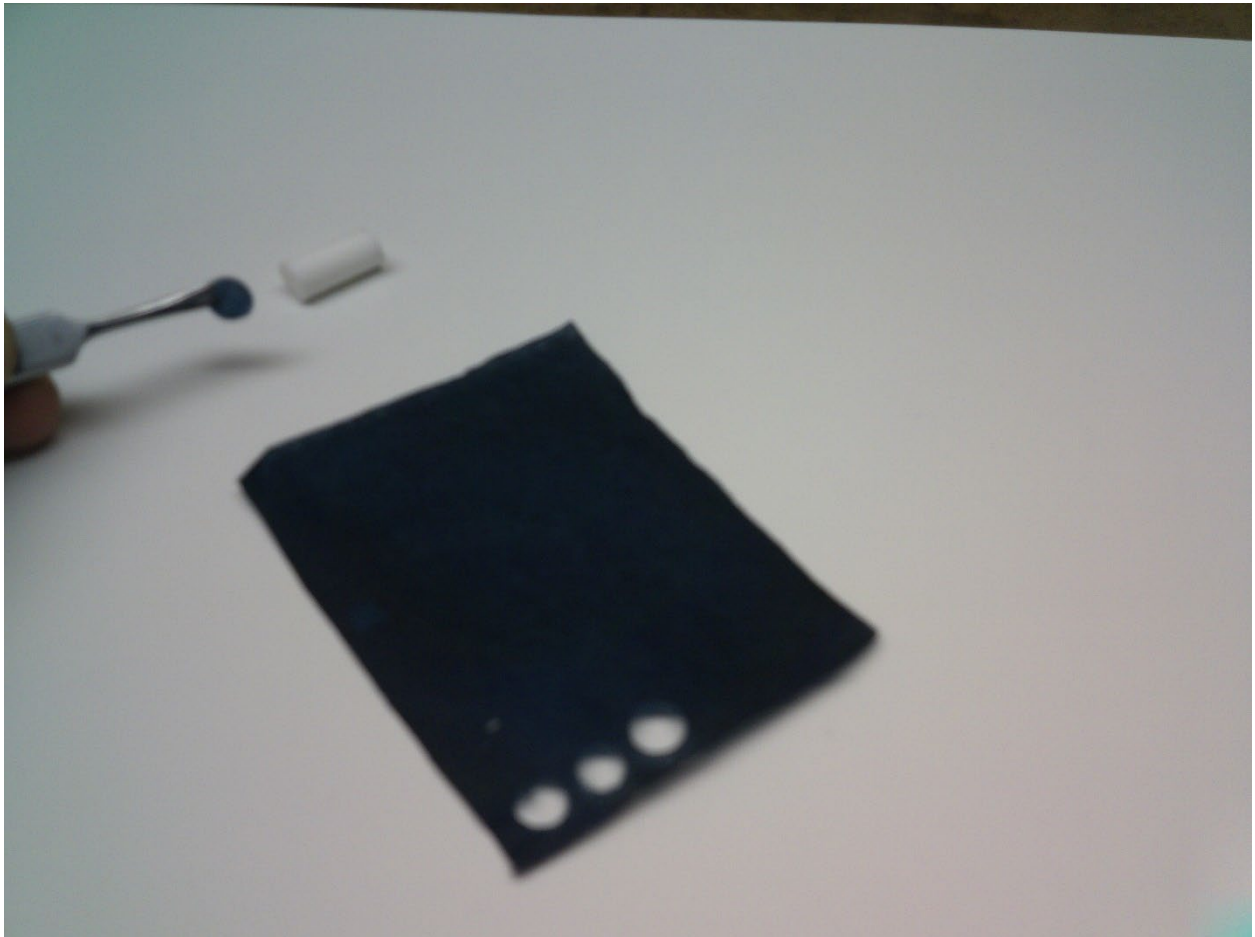
Large amounts of liquid can breach the filter due to wicking. When large amounts of water are present, the water can breach the filter due to capillary action, also known as “wicking.” Capillary action is the tendency of a liquid to flow in narrow spaces due to attractive interactions between the liquid and the solid material through which the liquid flows. (A more thorough description of capillary action, also called “capillarity”, is given [here](#).)

When enough water is present, wicking will carry the blue food color through the filter, and it will appear on the end of the filter that is inside the mask.

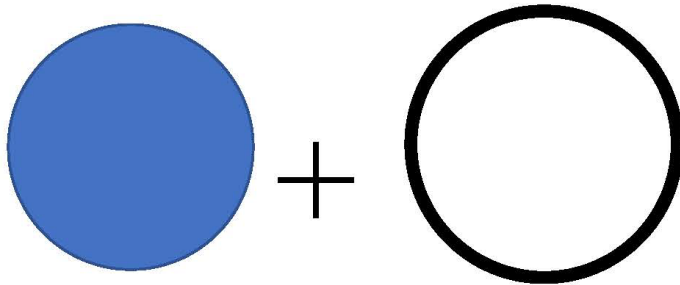
This was tested in an experiment where blue food color was applied to the “front” part of a filter that was under vacuum suction as described above, and then the filter was subjected to 2 minutes exposure to a stream of nebulized (i.e., aerosolized) tap water, and simultaneously to 2 minutes of vacuum suction, as described [above](#).

The blue food color was applied to the filter using a membrane that had been soaked in blue food color and then dried. Applying food color to the front or

outside end of a filter using the Mesh nebulizer or a cotton swab would create a sloppy patch of blue color that would vary from instance to instance. Instead, in order to ensure more reproducible conditions, I soaked a membrane cut from an **empty tea bag** in blue food color, then dried the membrane, and used a hole punch to remove a blue-colored disk from the membrane. Then, I used tiny pieces of tape to attach the blue-colored disk to the front or outside end of a cigarette filter. The process of making a membrane soaked with food color is described [below](#) in this report.

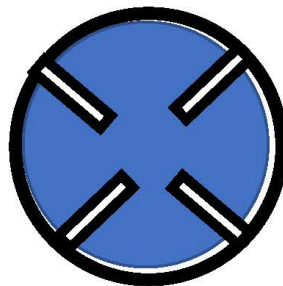
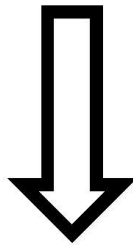


Above: A porous tea bag was cut into two halves. One half (shown above) was soaked in blue food color and then dried. A hole punch was used to excise a small circle of blue-colored material from the tea bag. This colored circle was used in the test described below.



**Blue dot
consisting of
porous paper
soaked in
blue food
color**

End of cigarette filter



Blue dot attached with small pieces of tape to front of cigarette filter. Direction of vacuum suction is away from the viewer.

The diagram above shows how a dot of porous, blue-soaked paper was attached to the front end of a cigarette filter. The dot was then used in a

test to determine the effects of large amounts of nebulized water on the filter.

The result was that all of the blue food color was washed from the layer into the cigarette filter. Some blue food color appeared at the inside end of the filter, although the color was a very light blue.

The filter was removed from the adapter and cut with a razor blade into five roughly equal cross sections. These showed that the blue color had migrated along the filter through a central channel of perhaps 2 mm diameter. The blue material was distributed along the length of the channel and, hence, was light blue.



The cigarette filter was cross-sectioned into 5 roughly equal pieces, which were then dissected. The dissection showed that blue food color had followed a channel near the center of the filter, and appeared at what would be the inside of the mask.

This result indicates that excess moisture can cause the filtration to fail, at least with respect to blue food color, which we use as a proxy for SARS-CoV-2. It also suggests that a layer of porous material soaked in blue food color might provide a warning of mask failure due to moisture accumulation.

The Main Components of a Facemask

This report explains how to use cigarette filters to filter the air the enters a facemask. Because cigarette filters have an inconvenient size and shape for this purpose, we must create a way to direct air intake through 75 separate filters, arranged in parallel. The figures below show me wearing a prototype.



The above photograph shows a prototype of the facemask with 75 cellulose acetate filters arranged in parallel.



The above photograph presents a side view of a prototype of the facemask.

The basic components of a Bugeye facemask are the filter matrix, the frame (which encloses the air space), the nosepiece (which shapes the frame to accommodate the wearer's nose), and the elastic strap or straps that hold the mask against the wearer's face. In improvised masks, the elastic straps are likely to consist of chained rubber bands.

The photograph below shows a Bugeye facemask prototype with the parts labeled. Two straps of chained rubber bands are present, which increases the pressure between the facemask and the wearer's face and enables the facemask to continue to function even if one strap breaks. If the facemask were in service, the junction between the filter matrix and the mask frame would be sealed with tape to make it airtight.



The above photograph shows a Bugeye facemask with the filter matrix, the nosepiece, and the rubber band straps labeled.

Create a Device to Test Air Intake Through a Filter Matrix

Construction of a Bugeye Facemask, as described in this report, always involves the creation of a filter matrix through which air is inhaled. If too little air to sustain a person enters through the filter matrix, the resulting facemask will be useless. Moreover, because rubber cement or arts-and-crafts glue is used to seal the boundary between each filter and the hole that contains it, and because insertion into a hole can pinch a filter, filters may transmit less air than expected. Hence, it is a good idea to test each finished filter matrix for its capacity to transmit air.

A simple device to perform such a test can be created with some **moldable putty**, a **short tube** to serve as an air conduit, and a commercial plastic food

carton. As the short tube, I used a Cardiopulmonary Resuscitation (CPR) training valve that allows air to pass in both directions. [CPR Savers and First Aid Supply One-Way Disposable Training Valves for Micromask CPR Training. 50 valves.

Sold by: CPR Savers & First Aid Supply LLC. Serial Numbers:

AZ:EAUS1N9MMRH67BAHMAT8DWN93U].

The valve used and the device that it is part of are shown in the photographs below. The purpose of the device is to assess how much air will traverse the filter matrix in response to a person's inhalation. To verify that no air is leaking into the device except through the filter matrix, cover the filter matrix with plastic wrap and attempt to inhale through the inhalation valve.



The above photograph shows a side view of a valve that allows the passage of air in both directions. The valve is 6 centimeters (2.36 inches) in length.



The photograph above shows the same valve as shown in the previous photograph but seen from one end.



The photograph above shows an inside view of the test device.



The photograph above shows the test device with a filter matrix attached to it by an airtight seal of green vinyl tape.



(Above) The filter matrix attached to the inhalation testing device is covered with clear plastic wrap. With this arrangement, a person should be unable to inhale air through the inhalation valve, showing that air only enters the device through the filter matrix.

Larger test devices. This report describes the construction of filter matrices with whose diameter is about 10.2 centimeters and which have 75 holes that can each hold a single filter. The reason for this size limit is to allow the filter matrices to fit onto plastic carton covers that are common in the United States of America. Because only 75 holes are present in the filter matrix, there is enough space between the holes that small errors in positioning the holes will not cause them to overlap. My experience is that when the filters are shortened in length to 9 millimeters, 75 filters can transmit enough air to sustain a person comfortably.

However, it should be noted that filter matrices can be both larger in diameter and have holes that are more densely packed. Below are photographs of a test device made from a metal can and attached to a filter matrix containing 94 filters.



(Above) A test device can be made from a metal can, an inhalation valve, and some soft putty.



(Above) The above filter matrix holds 94 filters and was tested using the device shown in the previous photograph.

The Bugeye Facemask Template

The most important component of a Bugeye facemask is the filter matrix, and the first step toward constructing a filter matrix is to print a template to guide the holes that will be created in the matrix material. The most promising matrix material is non-corrugated cardboard, but other materials may be used as well (e.g., [see below](#)).

The template's purpose. We want the facemask to filter air through as many cigarette filters as possible, but we need to limit the circular filter array to a diameter of about 10.2 centimeters, so that it can fit onto the plastic cover of a food carton. If each filter occupies a circle of 1.0 cm, we want to fit as many such circles as possible into a larger circle of 10 centimeters diameter.

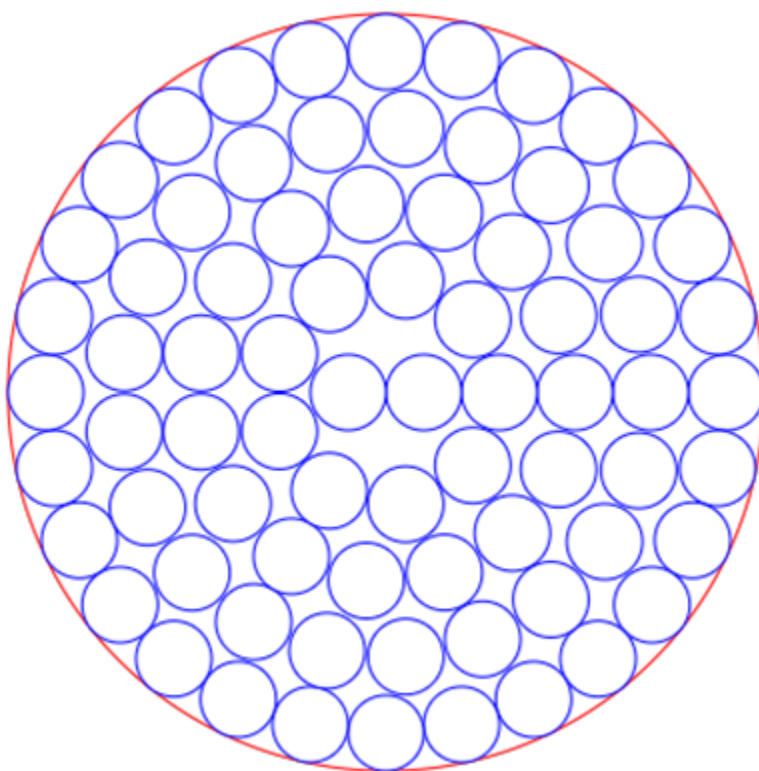


The above photograph shows the plastic cover of a cottage cheese carton with a cardboard filter matrix attached. The 75 holes in the matrix are filled with cellulose acetate filter segments. The cover is seen from the top and what would be the front of the mask. The dark-colored area is a remnant of commercial artwork that adorned the plastic cover of the cottage cheese carton.

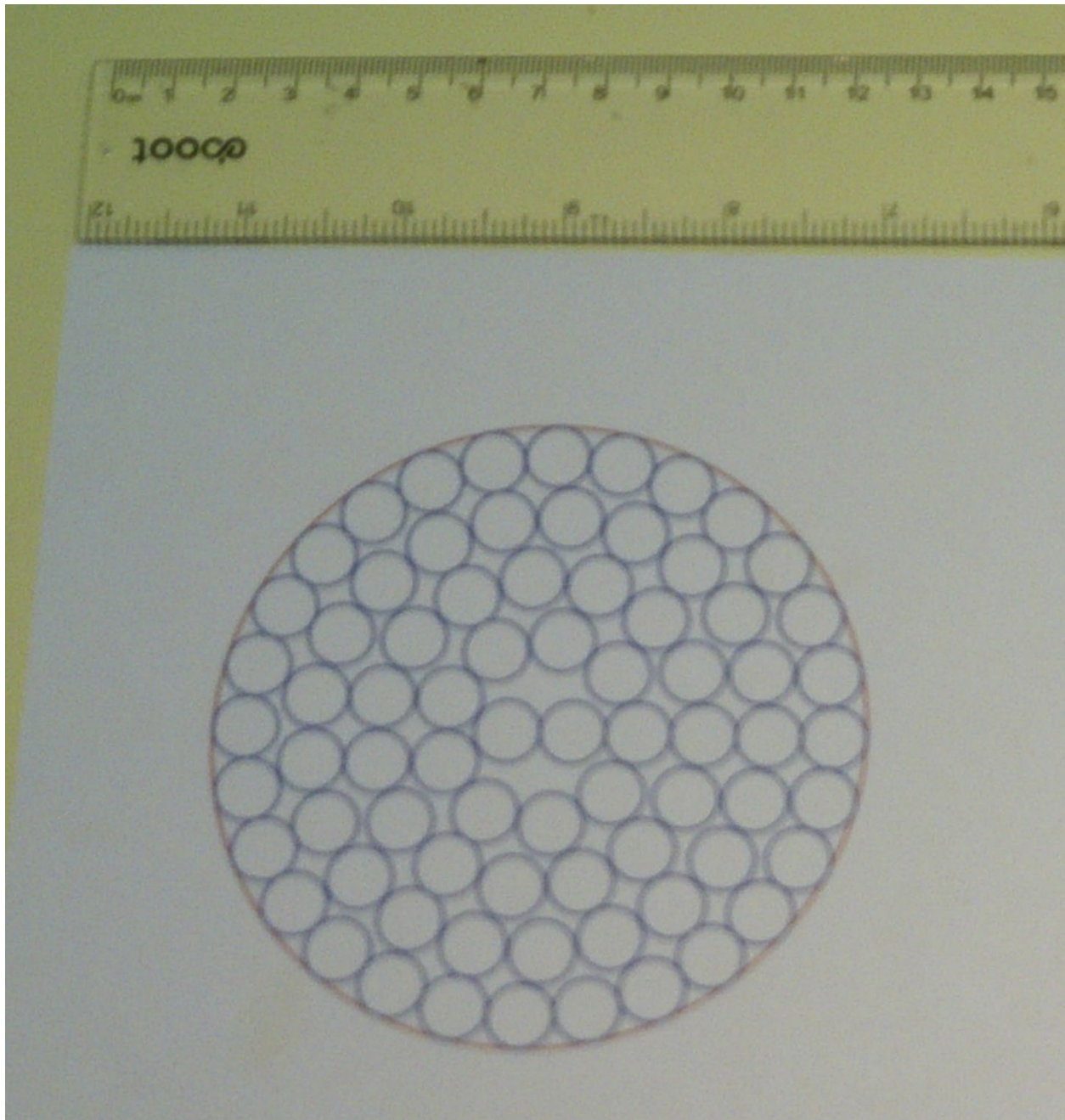


The above photograph shows the previous figure seen from below the plastic carton cover and what would be the inside of the mask.

Using resources at a website called The Engineering Toolbox ([see below](#)) I have created a template where this problem has been solved. Immediately below, and also on the final page of this report, is an image that, when printed, should create a template with 75 holes and a diameter of 10.0 centimeters. In addition, the same image can be downloaded from the [link](#) “[Print Template](#)”.



The above template indicates where 75 holes should be created in a cardboard matrix. This figure can be printed to create a template 10.0 cm in diameter.



The results of printing the previous figure, shown along with a ruler.

Create, and then print, a template. If the above fails for some reason, there is [an online website](#) (The Engineering Toolbox) where a similar template can be created. At that website, in the dialog box “inside diameter of large outer circle”, enter the number 10. In the dialog box “outside diameters of inside smaller circles”, enter the number 1. Then, click the “Calculate” button. Here is a screenshot of what you will see.

Input

- the inside diameter of an outer larger circle (or pipe, tube, conduit, connector), and
- the outside diameters of small circles (or pipes, wires, fiber)

The default values are for a 10 inch pipe with 2 inch smaller pipes - dimensions according [ANSI Schedule 40 Steel Pipes](#).

inside diameter of large outer circle (in, mm, m ...)

outside diameters of inside smaller circles (in, mm, m ...)

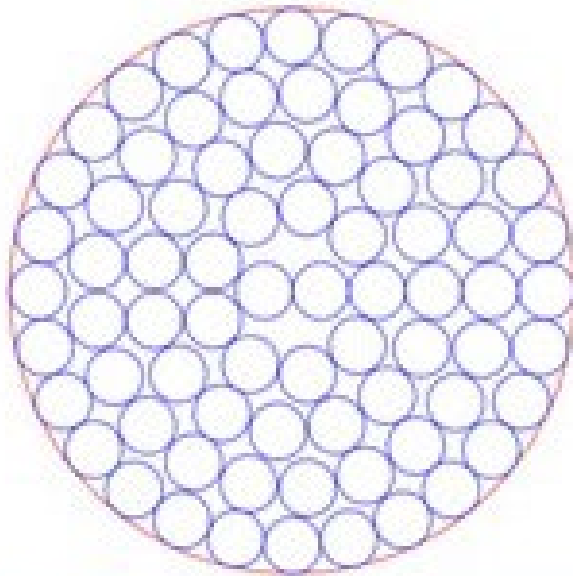
Maximum number of smaller pipes or circles inside the larger one: **75**

Area large Circle (in², mm², m²): **78.5**

Area small Circle (in², mm², m²): **0.785**

Area all Circles (in², mm², m²): **58.9**

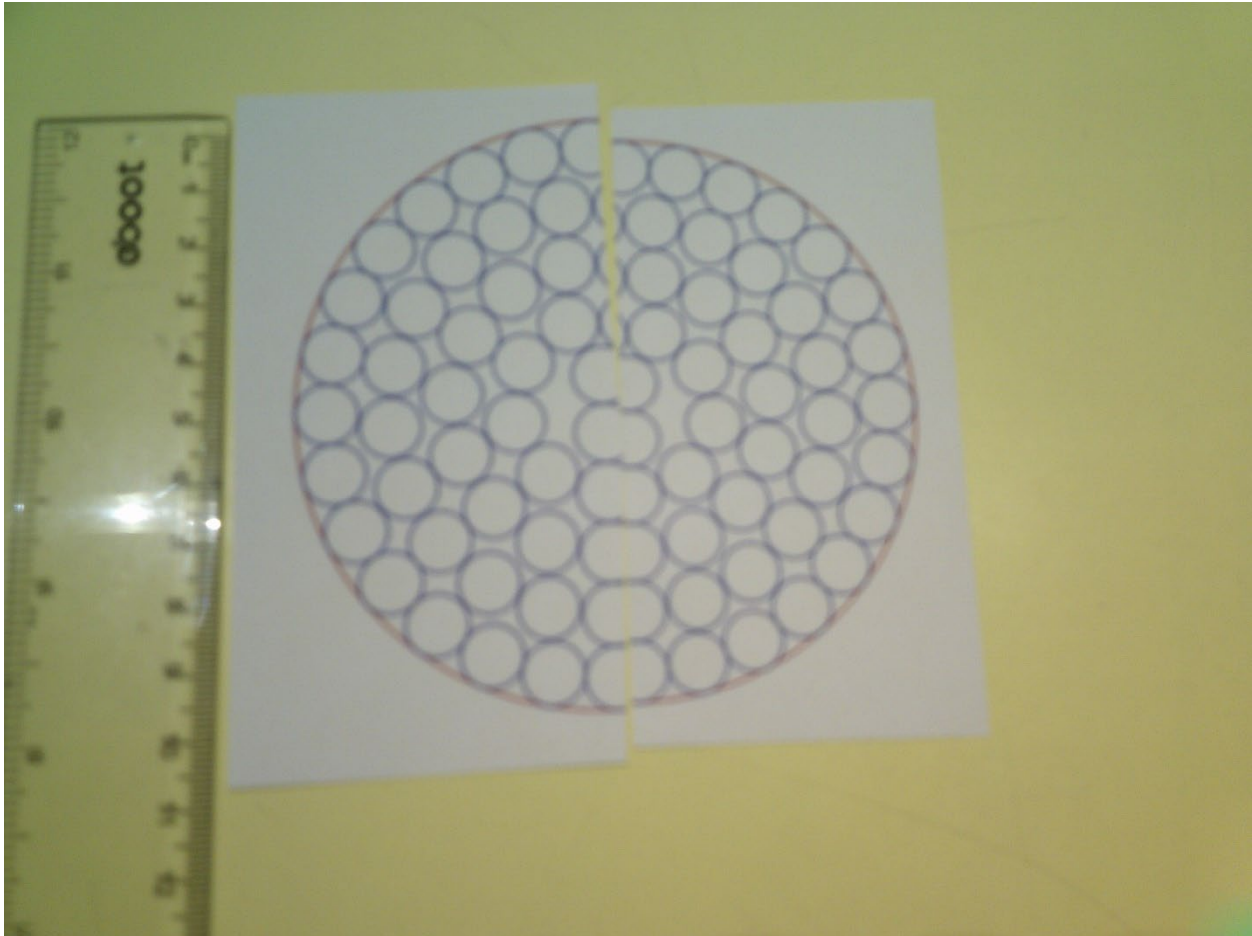
Small Circles to Large Circle Area Ratio (%): **75**



(Above) A screen capture from the Engineering Toolbox website calculator for “smaller circles within a larger circle.” For “Inside diameter of large outer circle” enter the value “10”. For “Outside diameter of inside smaller circles” enter the value “1”. Then, click the calculate button.

The website that I refer to, The Engineering ToolBox, produces an image that prints a large circle whose diameter is only 9.5 cm. Although the difference between 9.5 cm and 10.0 cm may seem small, a 10.0 cm diameter makes the

template less crowded and the process less prone to mistakes. So, you should prefer the template whose diameter is 10.0 cm.

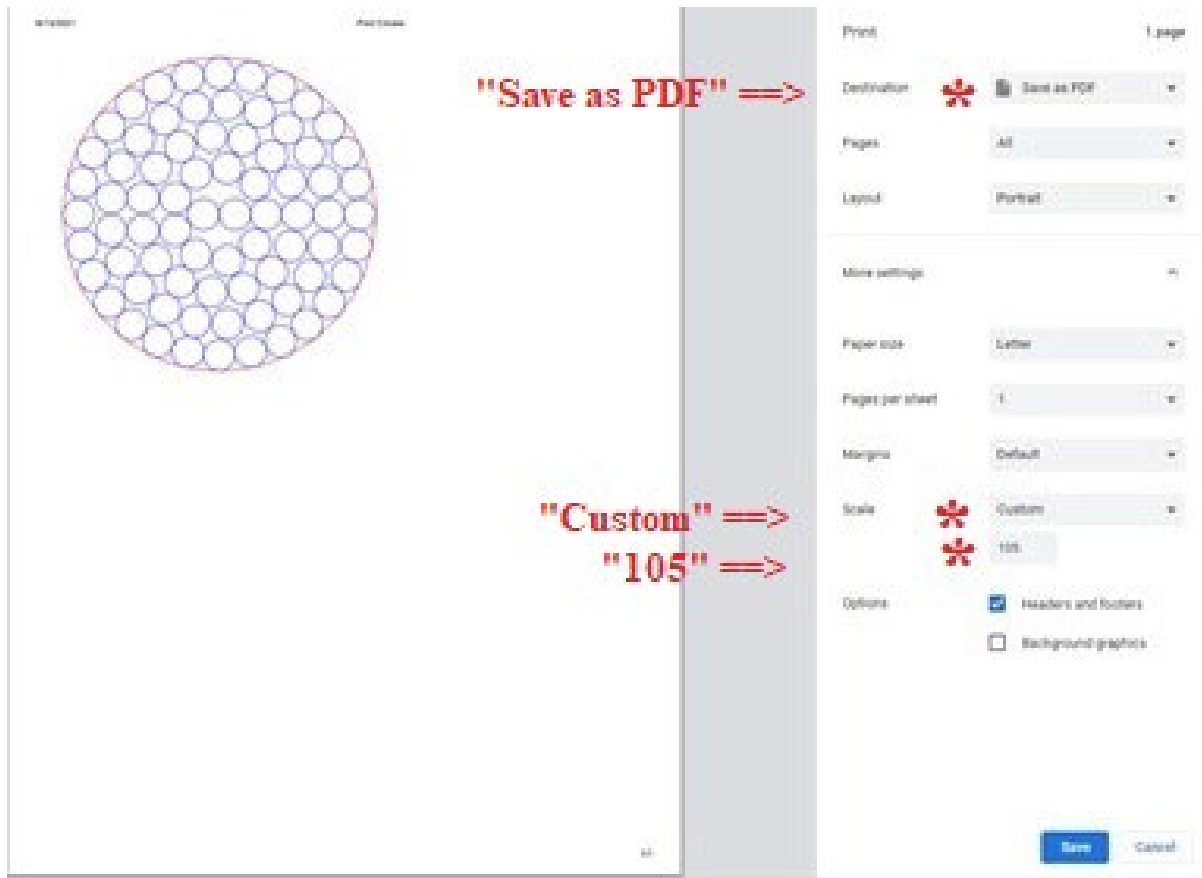


The above photo shows half of a template whose diameter is 10.0 cm compared with half of a template whose diameter is 9.5 centimeters. Although the difference may seem insignificant, a template whose diameter is 10.0 cm is easier to work with and the work is less prone to mistakes.

To convert a diagram that would print as a circle of diameter 9.5 centimeters to a diagram that will print as a circle of 10.0 centimeters, follow these steps: At the lower right of the Engineering Toolbox webpage, there will be a button that read “Print circles!” Click on this button. A printer control dialog box should appear.

For the “Destination” entry in the dialog box, select “Save as PDF.” Use the default settings for the entries “Pages” and “Layout” Select the “More Settings” entry, then select “Scale”, then “Custom,” and then enter a value of “105” in the entry box that appears. Then, click the “Save” button.

This should create a PDF file that will print a template whose diameter is 10.0 centimeters.

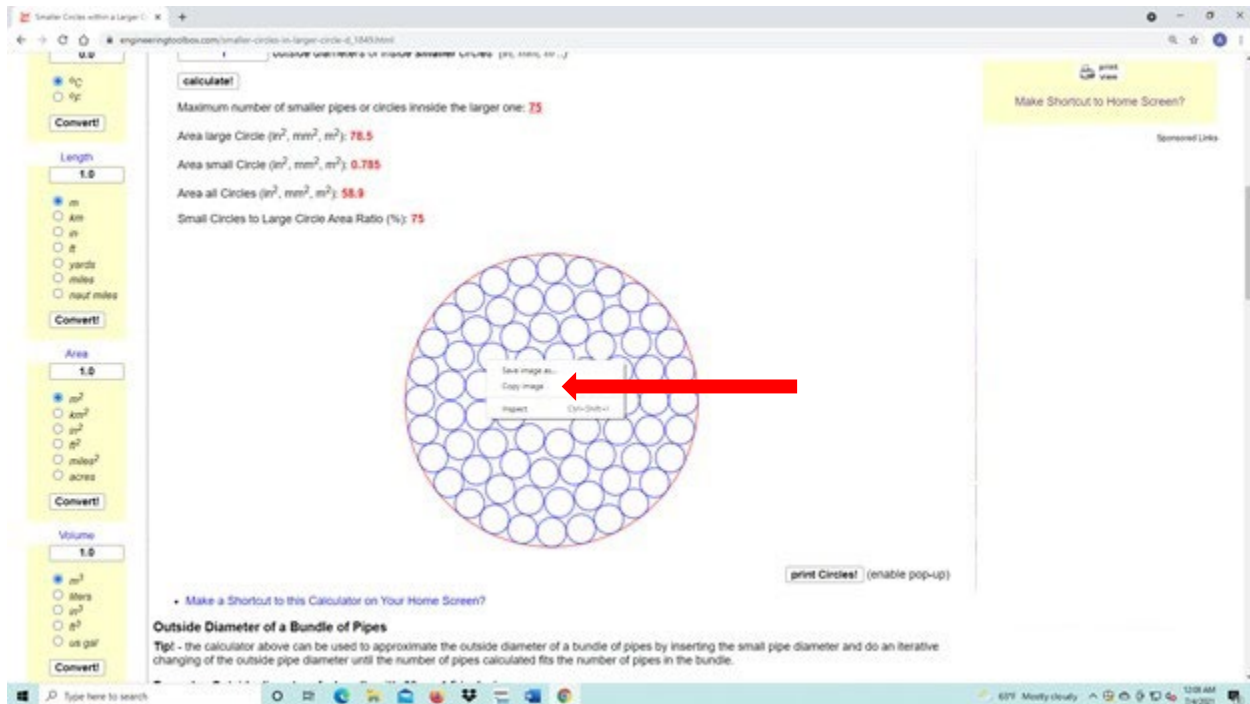


(Above) The dialog box used to alter the template presented at The Engineering Toolbox website so that it prints a circle of diameter 10.0 centimeters.

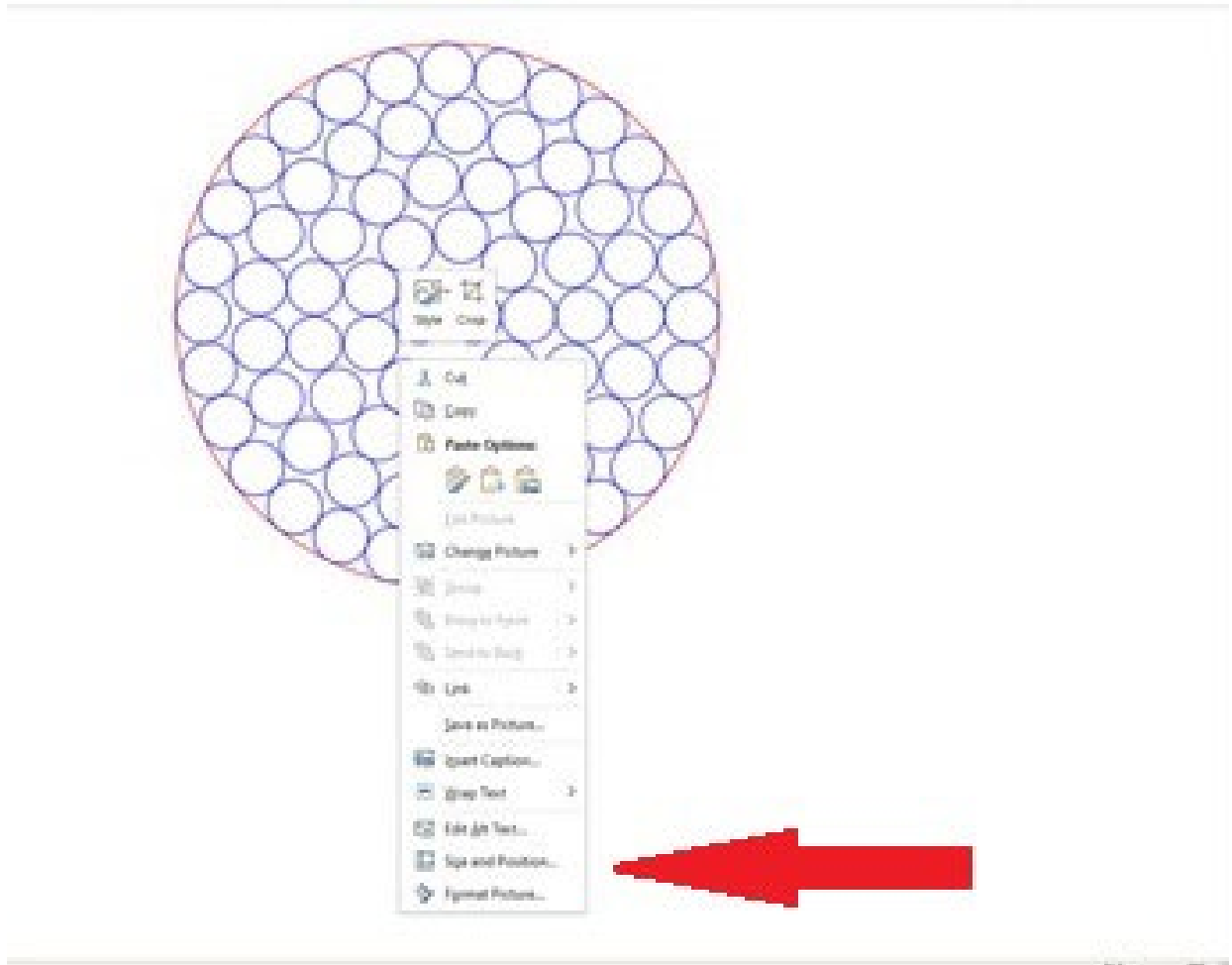
If you use Microsoft Word, you can also right-click on the diagram presented by The Engineering Toolbox, choose “Copy Image” from the popup menu that appears, and paste the diagram into a Word document. Then, right-click on the image in the Word document to summon another popup menu. From this, select the “Size and Position” option. The “Layout” dialog box will appear. In the “Scale” area of the Layout dialog box, in the “Height” text box, enter “105%”. Before doing this, be sure that the “Lock Aspect Ratio” and “Relative to Original Picture Size” boxes are checked.

Then, select the picture using the cursor. As a final step, use Microsoft Word’s Print function to print just the picture. The steps are shown in the three photos

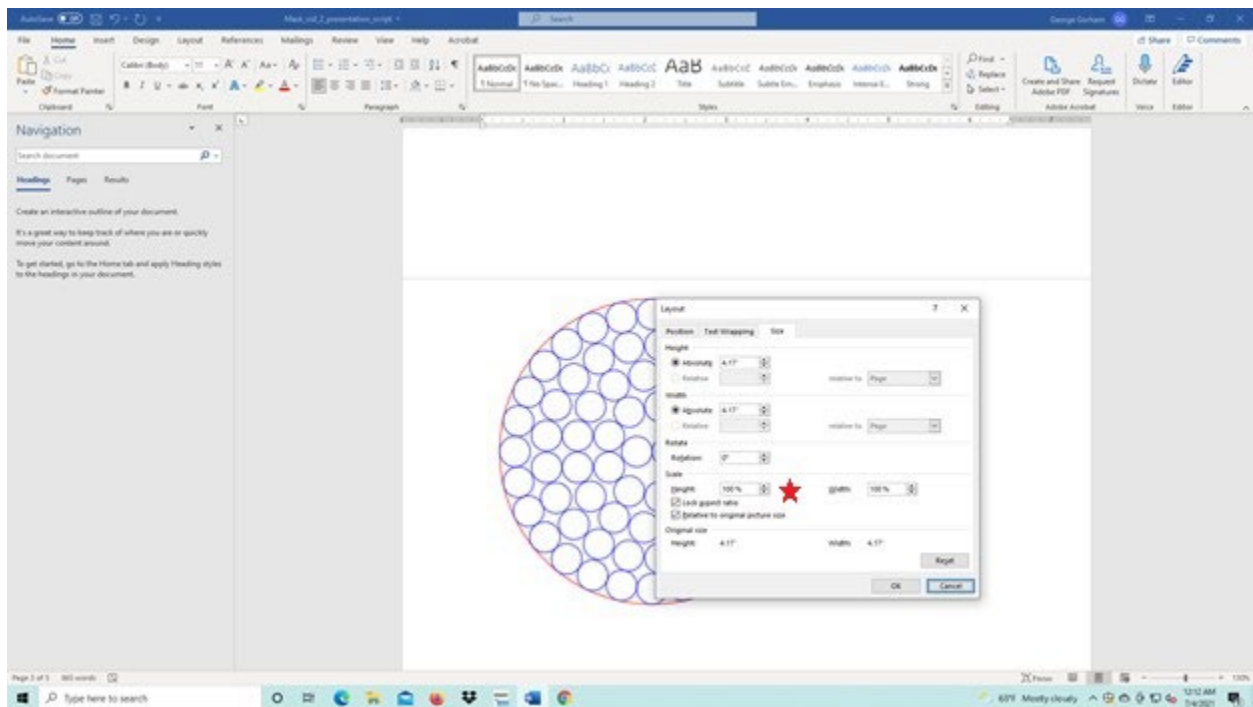
below:



As the above screen capture indicates, right-click on the large circle that contains 75 smaller circles. From the popup menu that appears, select “Copy Image”.



(Above) Paste the image into a Word document. Then, right-click on the image in the Word document. From the popup menu that appears, select the item “Size and Position.”



(Above) The “Layout” dialog box will appear. In the “Scale” area of the Layout dialog box, in the “Height” text box, enter “105%”. Before doing this, be sure that the “Lock Aspect Ratio” and “Relative to Original Picture Size” boxes are checked.

Then, select the picture using the cursor. As a final step, use Microsoft Word’s Print function to print just the picture.

Construction of a Filter Matrix Using Non-Corrugated Cardboard, 2-Sided Carpet Tape, and a Hole Punch with a Two-Inch Reach

The best method to construct a filter matrix employs non-corrugated cardboard, 2-sided carpet tape, and a hole punch with a two-inch reach. The method is described immediately below.

A hole punch with a 2-inch (5.08 cm) reach. Most hole punches have a reach of slightly less than one inch; in other words, the hole punch can create a hole whose center is a bit less than one inch from the edge of a stiff piece of paper. A hole punch with a 2-inch reach can punch a hole in the cardboard whose center is 2 inches from the edge. The 2-inch reach of the hole punch enables the mask creator

to punch out all or nearly all of the 75 holes to be created in a filter matrix. The brand of hole punch that I used was a McGill 2" Reach Punchline Hole Punch, 5/16 Inch Round, Chrome/Purple.

The diameter of the holes should equal the diameter of the filters to be used. I used a hole punch that creates holes of 5/16 inch (7.9 mm) and I used TOP brand filters, which were shown above. Before starting to construct a filter matrix, investigators should check that the holes made by the hole punch are the right size to accommodate the filters. The fit between hole and filter should be snug, but not snug enough to crinkle the filters.



The ruler in this picture is 12 inches (30.5 centimeters) in length

(Above) This hole punch creates holes of 5/16-inch (7.93 millimeter) diameter. The punch can create a hole whose center is 2 inches from the edge of a stiff piece of paper.

Scissors and a razor blade of the kind used for shaving. Scissors are needed to cut the paper template and the cardboard sheets that will compose the filter matrix. A shaving razor blade is needed for cutting filters crosswise to fit the holes in the mask.



The photograph above shows **scissors with sharp points** and a razor blade of the type used for shaving.

As stated above, the most promising method to construct a filter matrix involves lamination of several layers of non-corrugated cardboard using 2-sided carpet tape. Typically, 2 half-matrices are constructed. The first half-matrix includes 5 layers of cardboard interspersed with 4 layers of 2-sided carpet tape. The second half-matrix includes 4 layers of cardboard interspersed with 3 layers of 2-sided carpet tape. The second half-matrix is also laminated to a plastic carton cover, with 2-sided carpet tape being the adhesive.

Holes are created in the individual layers of cardboard or plastic using a 5/16-inch hole punch with a 2-inch reach. However, creation of a few holes in the plastic carton cover may require use of a hot soldering iron instead of a hole punch.

Materials Needed

Cigarette filters. About 40 cigarette filters (an absolute minimum of 37.5 filters) are needed. These can be supplied by 2 packs of cigarettes or by a retail vendor of filters. I used TOP brand filters, which are sold in bags of 200, but which may not be available in all countries. TOP brand filters have a diameter of 5/16 inches (7.9 millimeters) but some cigarette filters have a smaller diameter, such as 0.24 inch (6 mm):

<https://www.mistersmoke.com/en/conseils-mistersmoke/filtres-cigarette-choisir/>

<https://www.mistersmoke.com/en/produits/filtres-et-tips/filtres-mousse/sachet-de-450-filtres-smk/>



The above photograph shows cigarette filters that are sold separately from cigarettes. This brand, TOP, is composed mainly of cellulose acetate.

Non-corrugated cardboard. This method of constructing a filter matrix requires about three sheets of non-corrugated cardboard, provided that the sheets measure at least 20 centimeters X 20 centimeters and are about two-thirds of a millimeter in thickness. I used cardboard from boxes of Carbquik, a commercial brand of low-carbohydrate flour, but cardboard from cereal boxes would probably suffice. The cardboard of soft drink can cartons is about 0.46 millimeters in thickness, and so more layers of cardboard from that source are needed.

The cardboard is used to create a matrix of 75 holes that will each hold a plug of cellulose acetate. It is essential that the cardboard be non-corrugated in order to prevent connections from forming between the holes.



The above photograph shows sheets of cardboard from boxes of a brand of low-carbohydrate baking flour.



The above photograph shows sheets of thinner cardboard from a box used to hold soft drink cans.



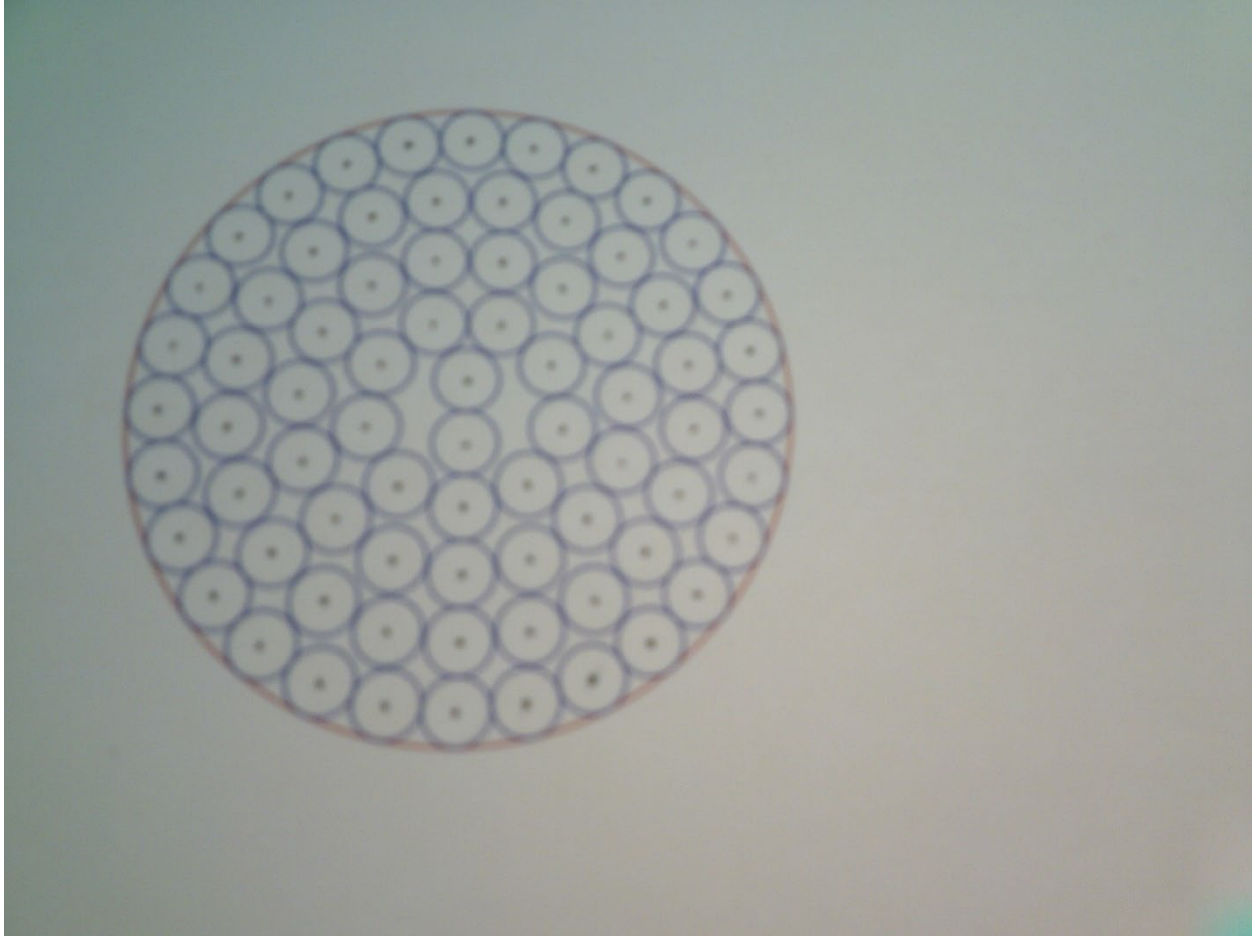
(Above) Corrugated cardboard is NOT suitable for use in this project because connections will form between holes drilled in the cardboard.



Two-sided carpet tape (two rolls are shown at the center and right of the above photo) is used to hold layers of cardboard together to create a filter matrix. If carpet tape is unavailable, glue (seen at the left of the photo) can substitute as described [in the text](#).

Creating a Matrix to Hold Cigarette Filters

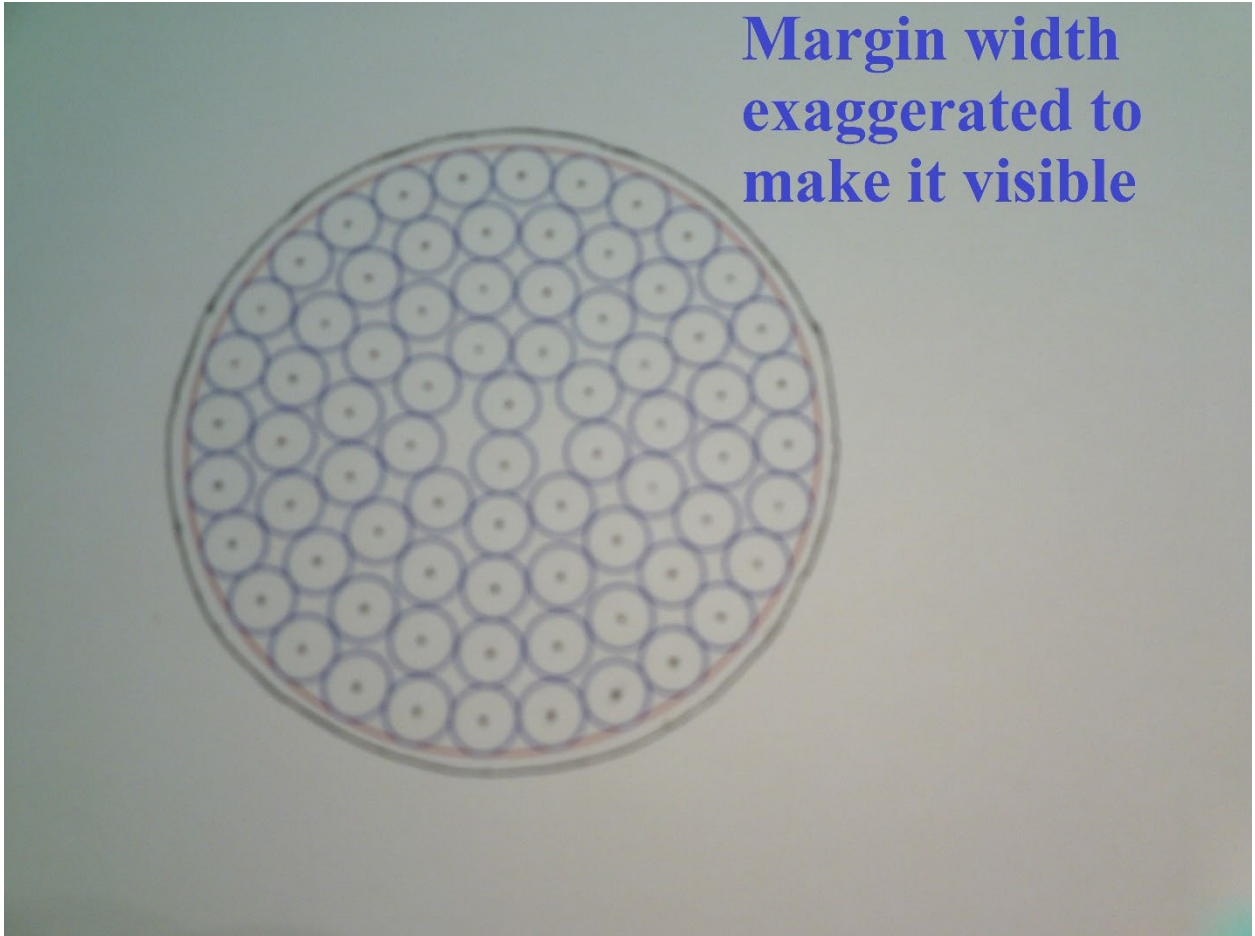
Mark the centers of template circles. Next, after printing a template of diameter 10.0 cm, mark the center of each small circle as accurately as possible. The purpose is to help you position the hole punch when you use the template to punch holes in the first layer of cardboard.



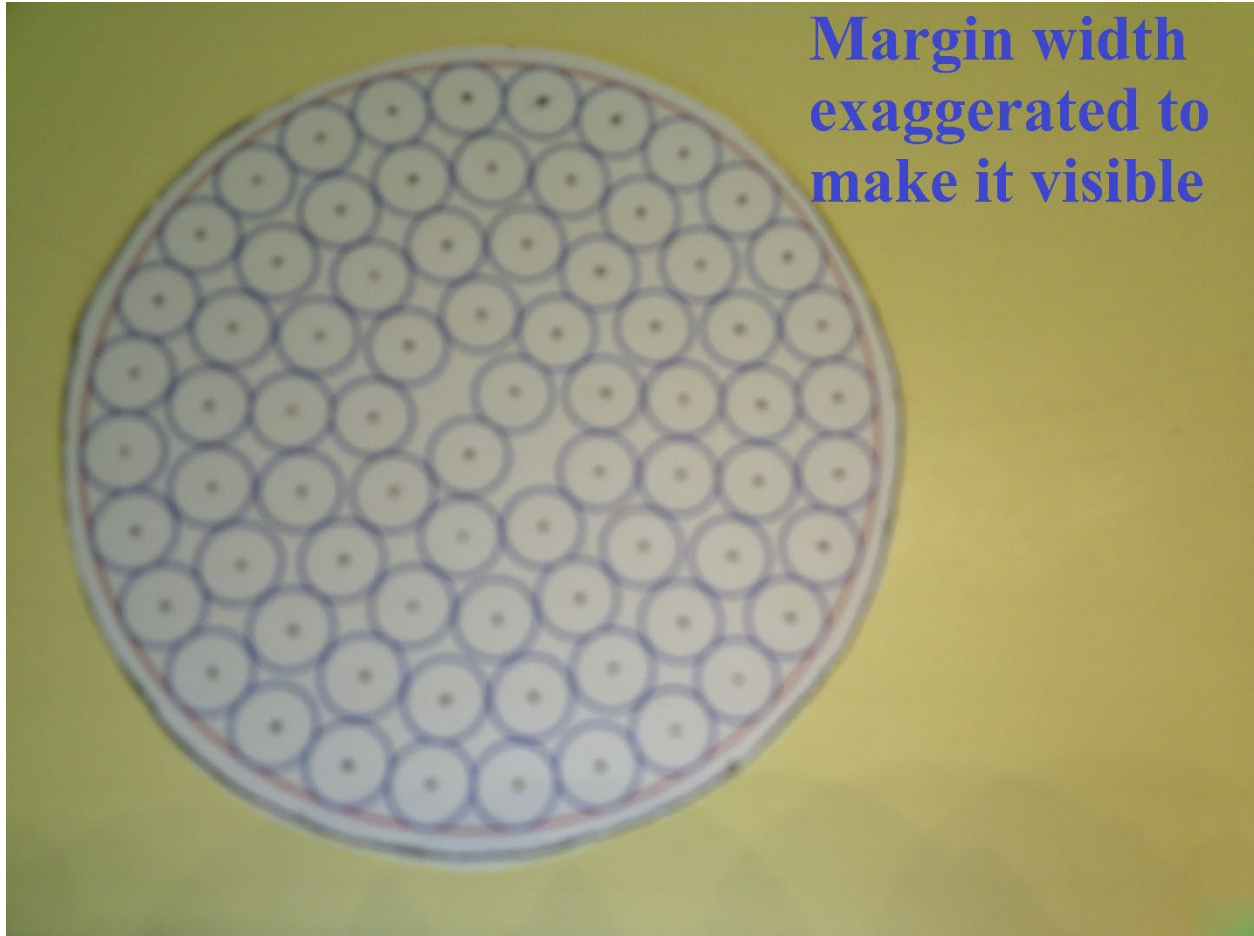
The above photograph shows a printed template with a dot penciled in at the approximate center of each circle. The dots will help guide the hole punch used to create the first cardboard circle with 75 punched holes. It is surprisingly easy to punch holes that are off-center and which may overlap with other holes.

Add a margin to the large circle and cut out the large circle. Mark an additional 1 mm ($1/25$ inch) around the template circle and cut the circle out. The margin's purpose is to give you room for error in constructing the filter array.

**Margin width
exaggerated to
make it visible**

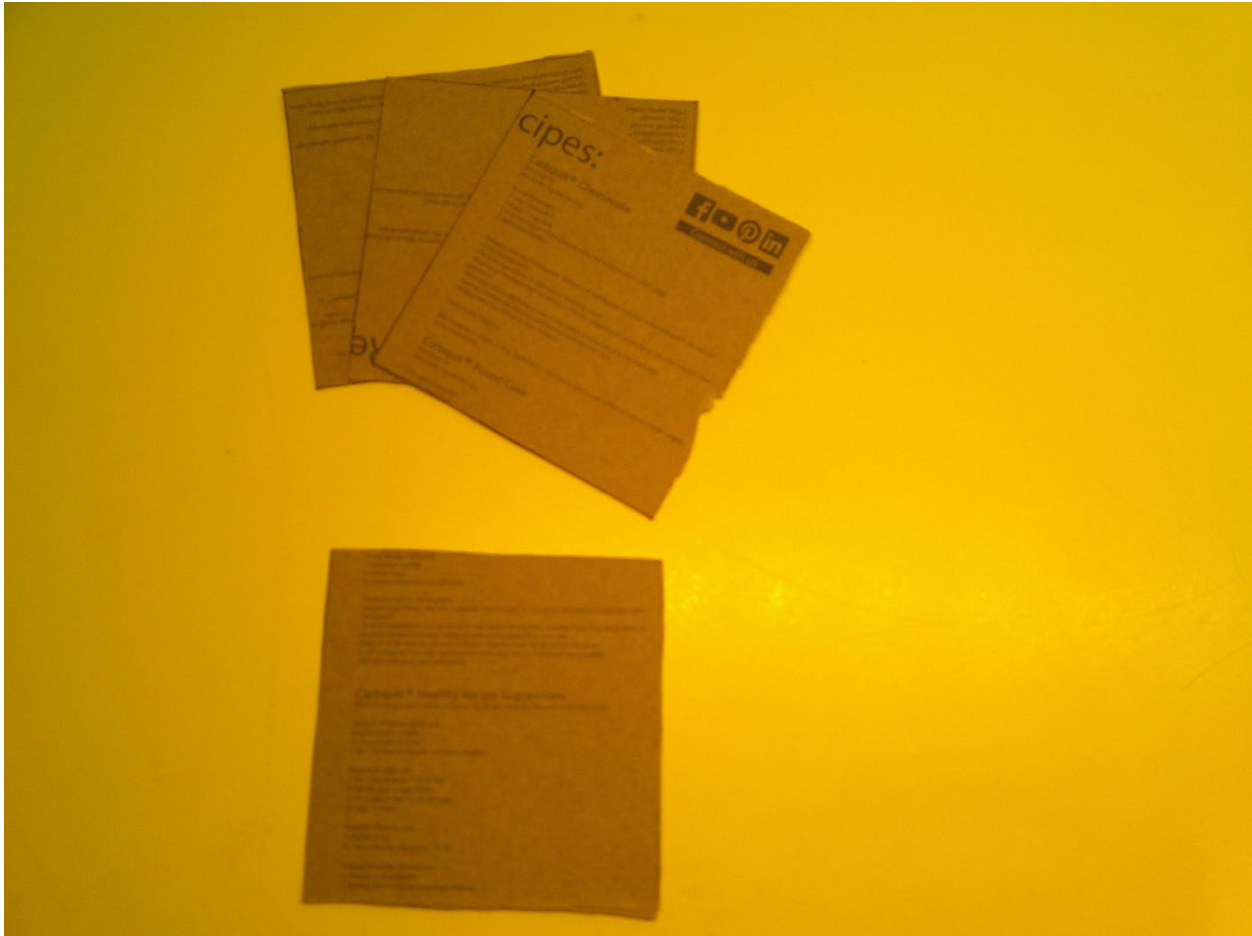


Before cutting the template out of the paper that it is printed on, draw a 1-millimeter margin around it, as shown above. As the printing on the photo indicates, the width of the margin has been increased beyond 1 millimeter in order to make it visible.



(Above) This is the same template as shown in the previous picture but cut out of the paper that it was printed on and resting on a yellow background. As noted, the thickness of the margin has been increased to make it visible.

Create the first cardboard matrix layer. Cut cardboard into squares whose sides are at least 10 cm in length. Cereal boxes, boxes of canned soft drinks and other cardboard sources can all be used. However, as discussed above, the cardboard **MUST** be non-corrugated.



The above photograph shows squares of cardboard cut from a box that originally stored low-carbohydrate flour. The squares are slightly more than 10.0 centimeters on each side. The cardboard is about 0.67 millimeters in thickness and is non-corrugated.

Next, use a transparent or translucent tape to attach the template to a cardboard square. Mark places on the template and on the cardboard square to align them.



The above photograph shows a printed 75-hole template, with a dot in the center of each small circle. The paper template is taped to a cardboard square whose sides are slightly greater than 10 centimeters. Although it is difficult to see in this picture, both the paper template and the cardboard square beneath it have a single black ink mark at the top and a double black ink mark at the side.

Next, draw a circle close around the template, except where there is tape. The circle is difficult to see in the photo below but is drawn in black ink around the paper template.



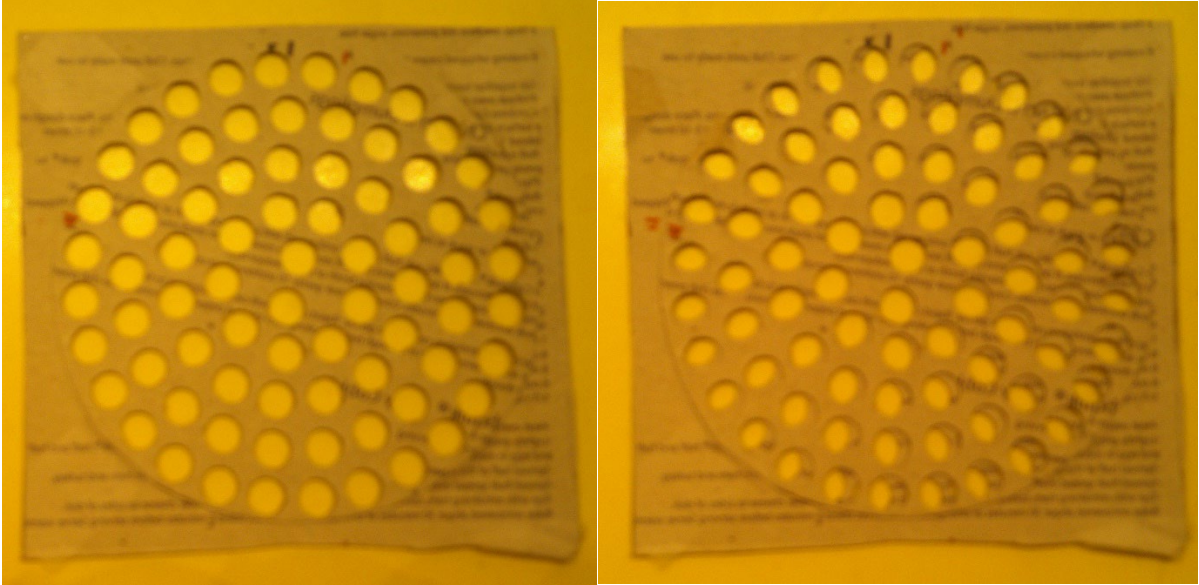
In the photograph above, a black circle has been drawn with ink around the paper template. This will serve as a guide when the punched out cardboard circle is cut away from the remaining cardboard.

Then, use a hole punch to punch out holes that are within reach of the edge. If you have the kind of hole punch that I have, you may be able to punch out all of the holes without trimming the cardboard. If not, you may first have to trim the cardboard somewhat.



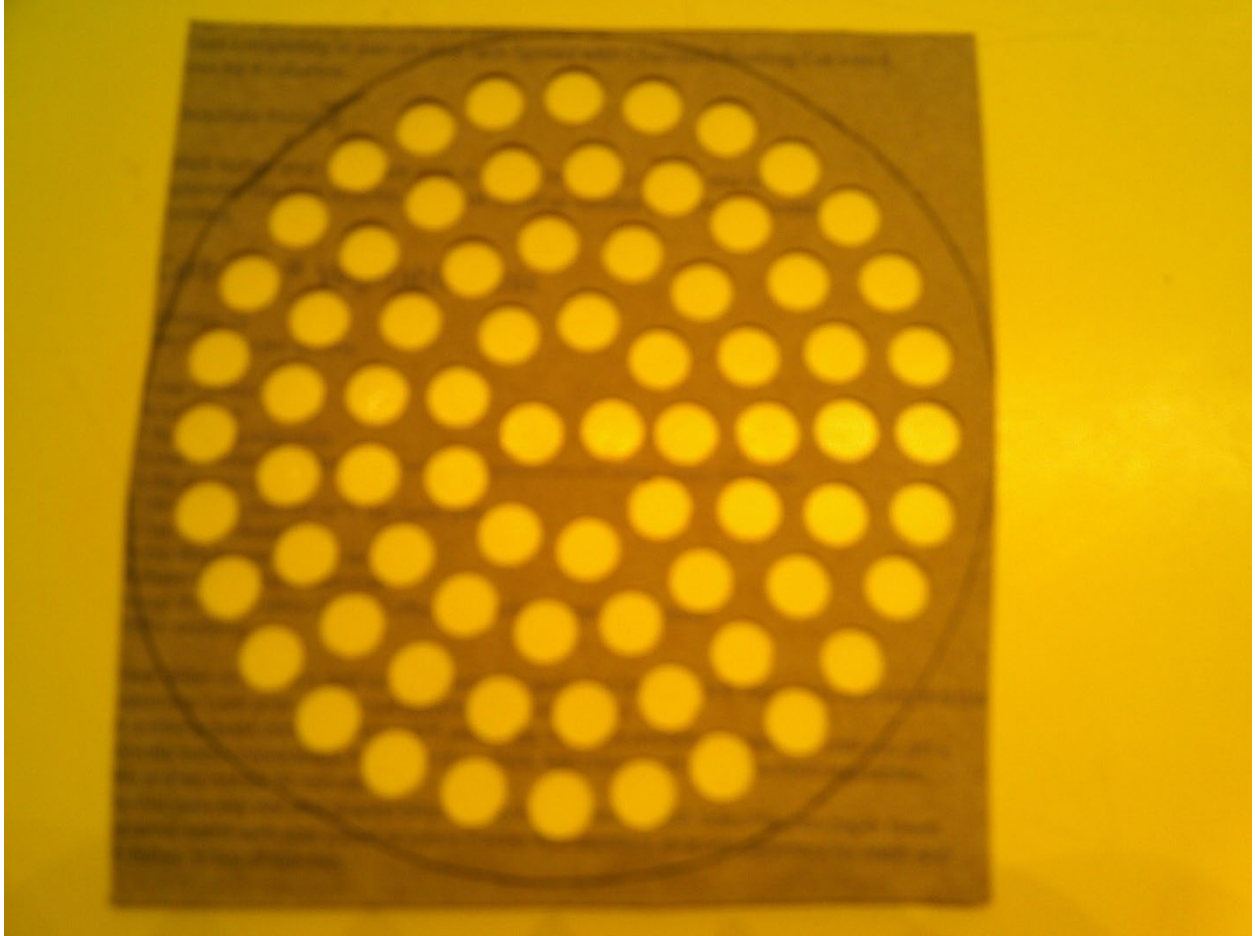
In the above photograph, all 75 small circles in the template have been punched out with a hole punch that created holes of diameter 5/16 inch.

Create a second cardboard matrix layer. The next step is to tape the punched-out cardboard circle to a cardboard square and repeat the above step, using the punched-out cardboard circle as a template. The holes in the cardboard circle are a good guide for the hole punch.

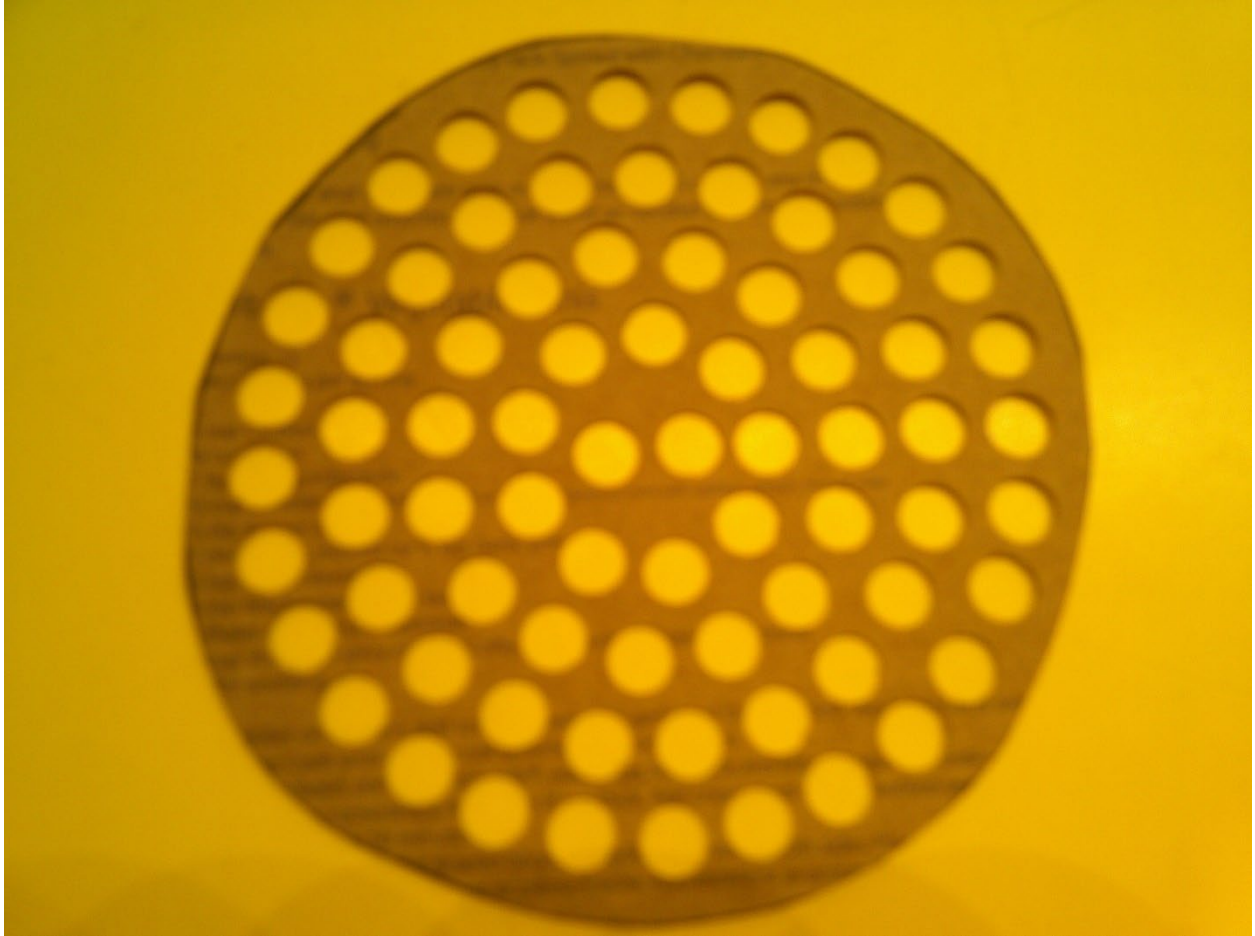


To create the photographs above, a cardboard circle with 75 holes punched in it was taped to a second cardboard layer and used as a guide to punch holes in the second cardboard layer. The photograph on the left shows the holes of the two layers perfectly aligned. The photograph on the right shows the upper circle slightly twisted with respect to the lower circle.

Then, use a pen to trace the outer edge of the punched-out circle onto the cardboard square. Following this, trim the cardboard square to form a circle.



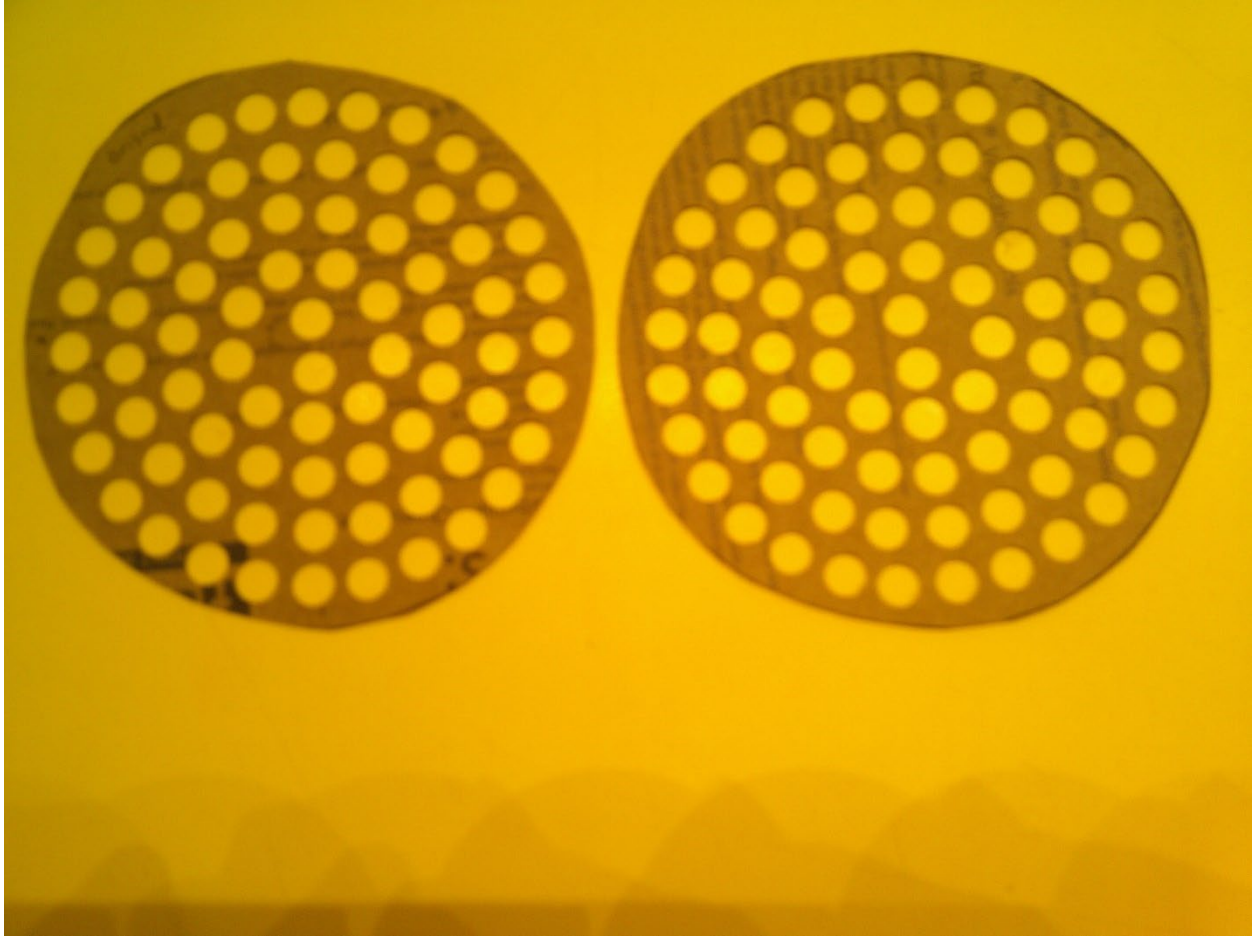
The above photograph shows a lower cardboard layer with all 75 holes punched out, but before trimming.



The above photograph shows a lower cardboard layer after trimming. Compare it with the previous photograph.

The result of the above manipulations is to create two identical cardboard circles, each with 75 holes. If one circle is placed atop the other, the pattern of 75 holes will align perfectly.

Two such circles are shown below. Each of these two circles will become the starting layer of a half-matrix.



The above photograph shows two identical circles, created by the procedures described above. Each will become the template for a half-matrix. Marking each circle with a single ink mark at the top and a double ink mark at the right makes it easier to align them. If this is not done for some reason, the two central holes in each circle can be used to align the circles.

Add a second cardboard layer to the first half-matrix. The next step is to **add carpet tape** to a square of cardboard and to remove the protective sheet. I used two rolls of two-sided carpet tape of different widths, but which together were adequate to cover a cardboard square. The tapes dispensed by the two rolls were equally thick.

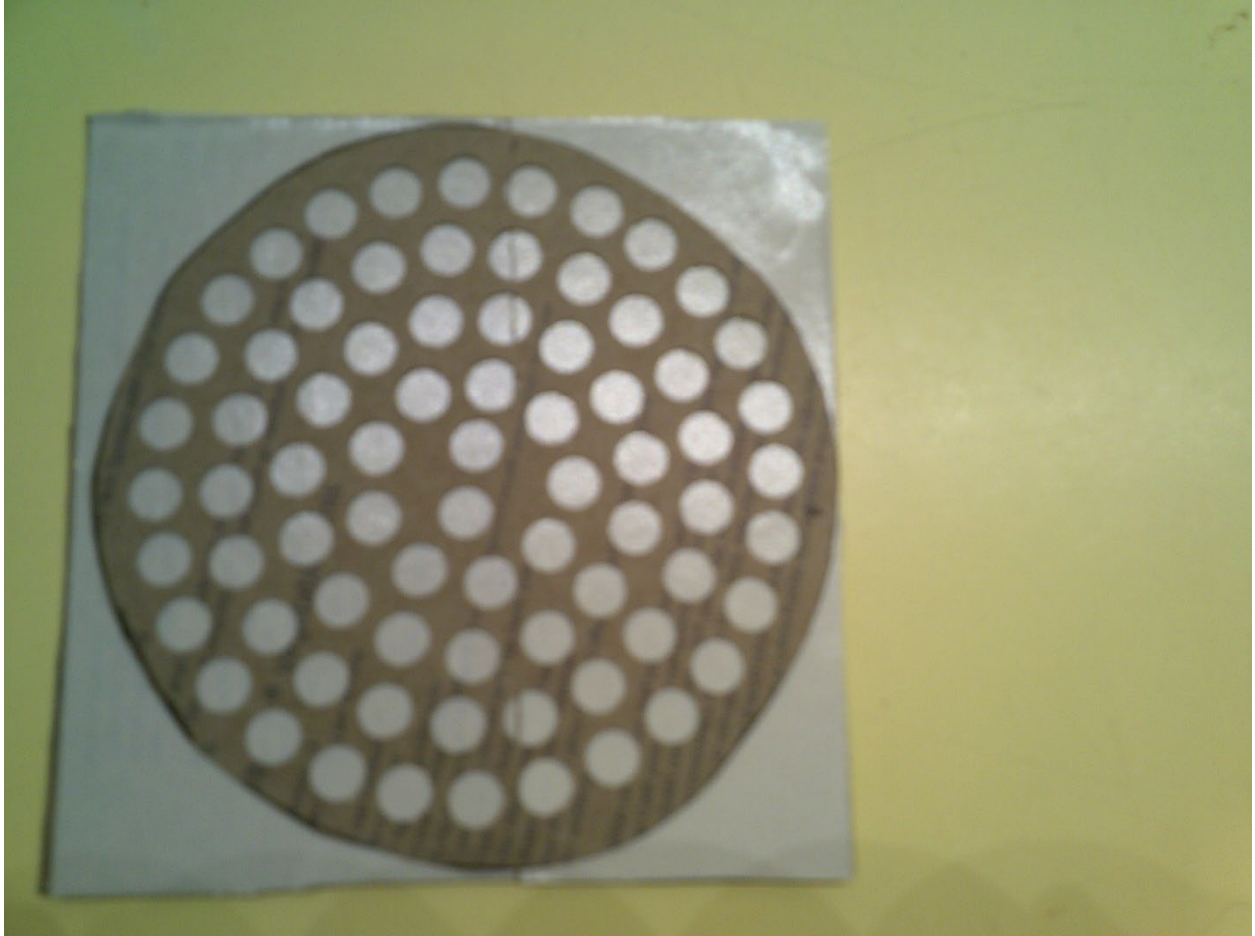


In the above photograph, a square of cardboard is covered by (and hidden by) two pieces of 2-sided carpet tape. In this picture, the side of the carpet tape that faces the camera is covered with plastic sheet (yellow on the left, white on the right).

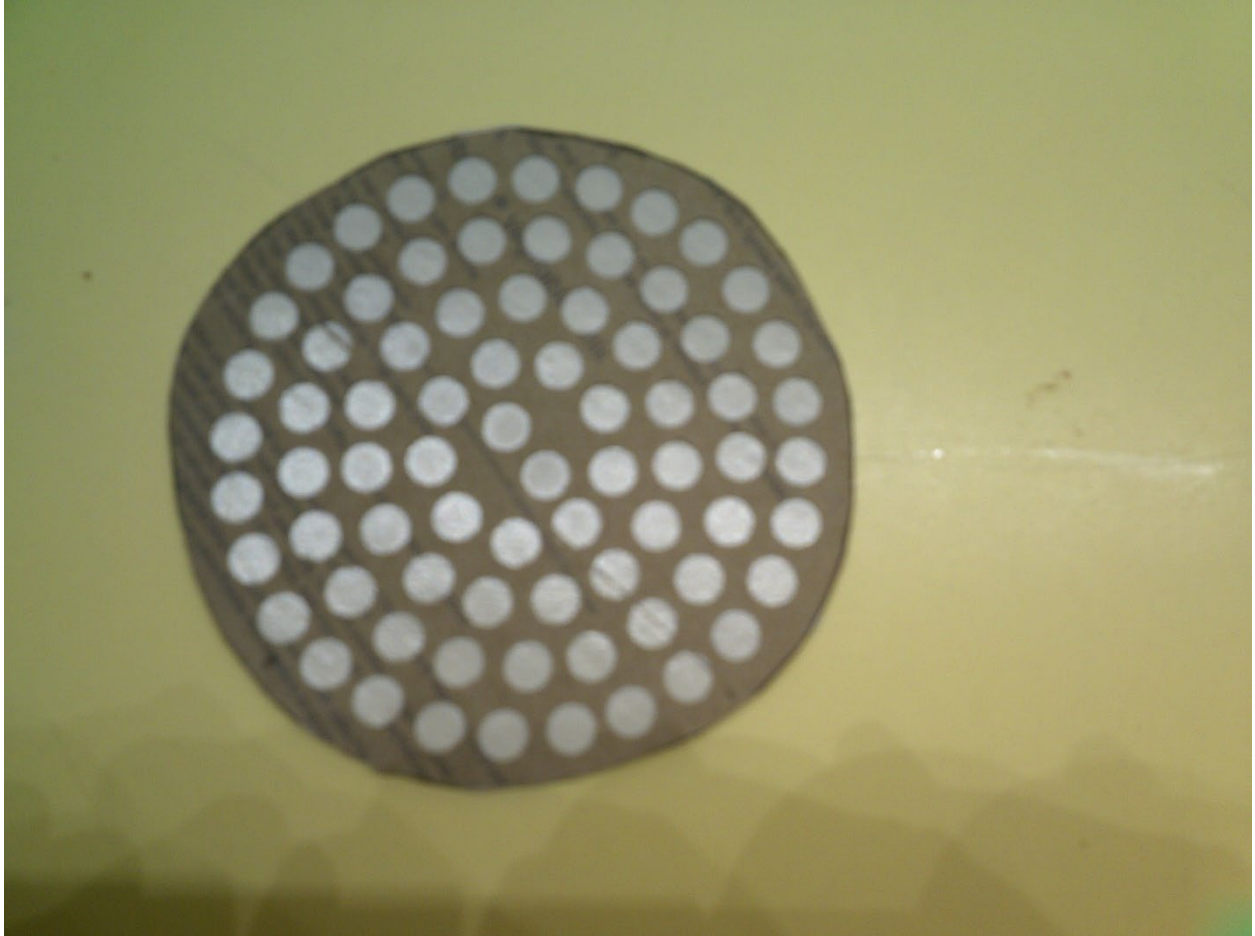


In the above photograph, the plastic sheet has been removed from the tape strips shown in the previous picture, leaving the sticky surface of carpet tape facing the camera.

Then, press one punched-out cardboard circle onto the cardboard square that is covered with carpet tape. After that, trim the cardboard square using scissors.



In the above photograph, a circle with 75 holes has been pressed onto a cardboard square that is covered with sticky carpet tape.

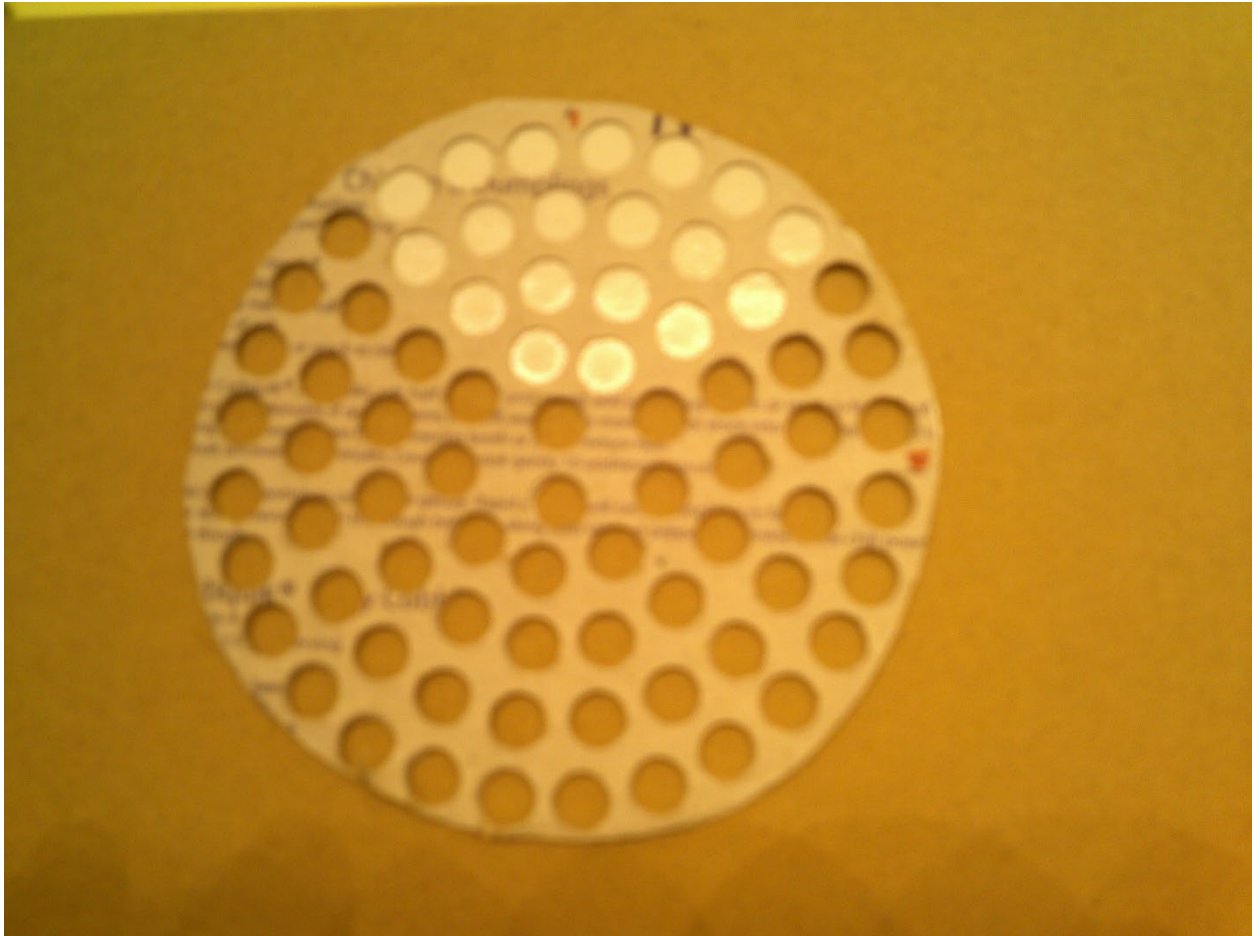


In the above photograph, the excess cardboard and carpet tape present in the previous photo have been removed with scissors.

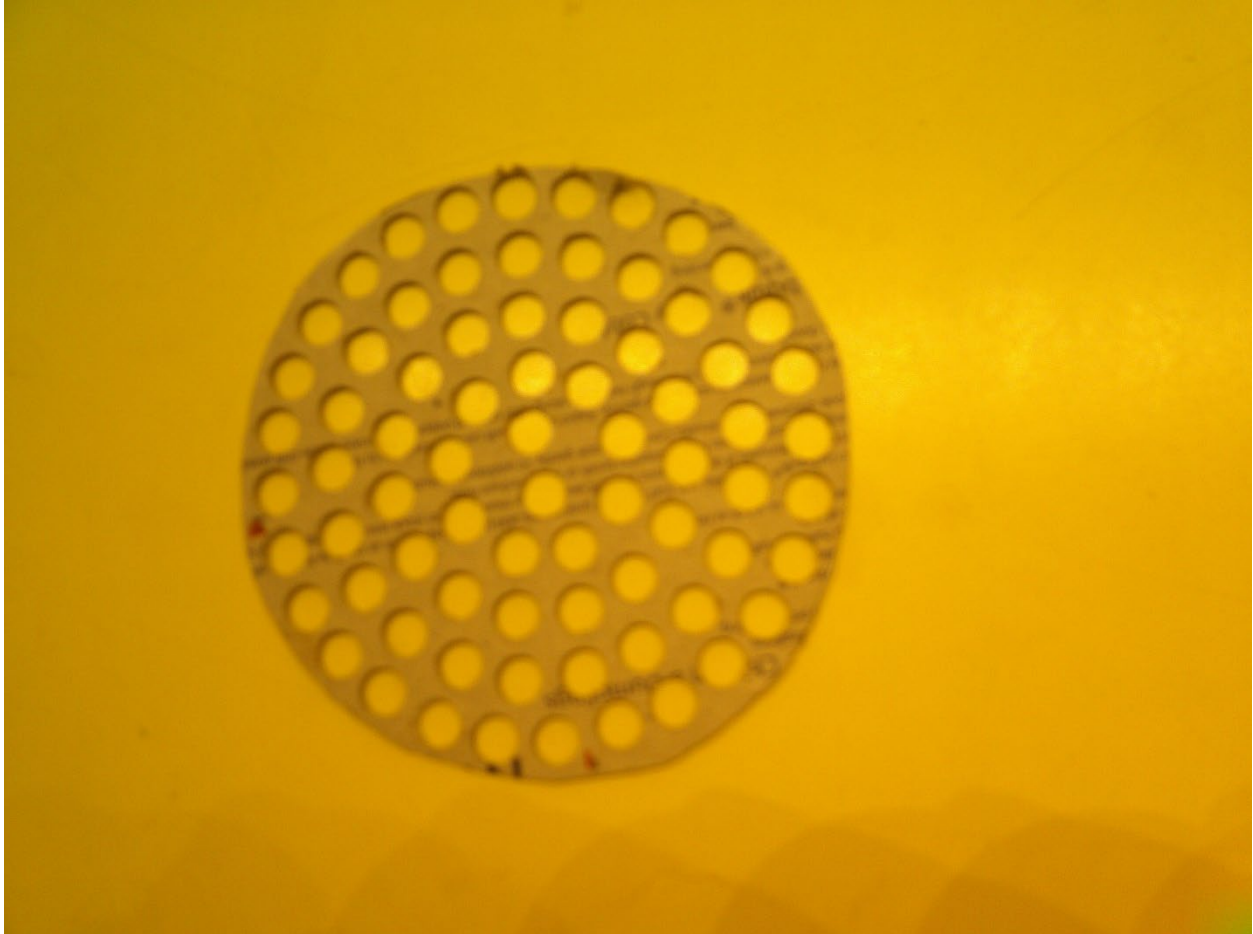
Finally, punch holes in the cardboard with a hole punch, as shown in the three pictures below.



In the above photograph, 15 holes at the bottom of the cardboard circle have been completely punched through with the use of a hole punch. The holes have a diameter of $\frac{5}{16}$ inch (7.94 millimeters). The growing cardboard half-matrix, above, consists of a cardboard layer, then a layer of 2-sided carpet tape, and then a second cardboard layer.



In this photograph, all but 19 holes at the top of the cardboard circle have been punched through. As in the previous photo, the growing half-matrix above consists of a cardboard layer, then a layer of 2-sided carpet tape, and then a second cardboard layer.



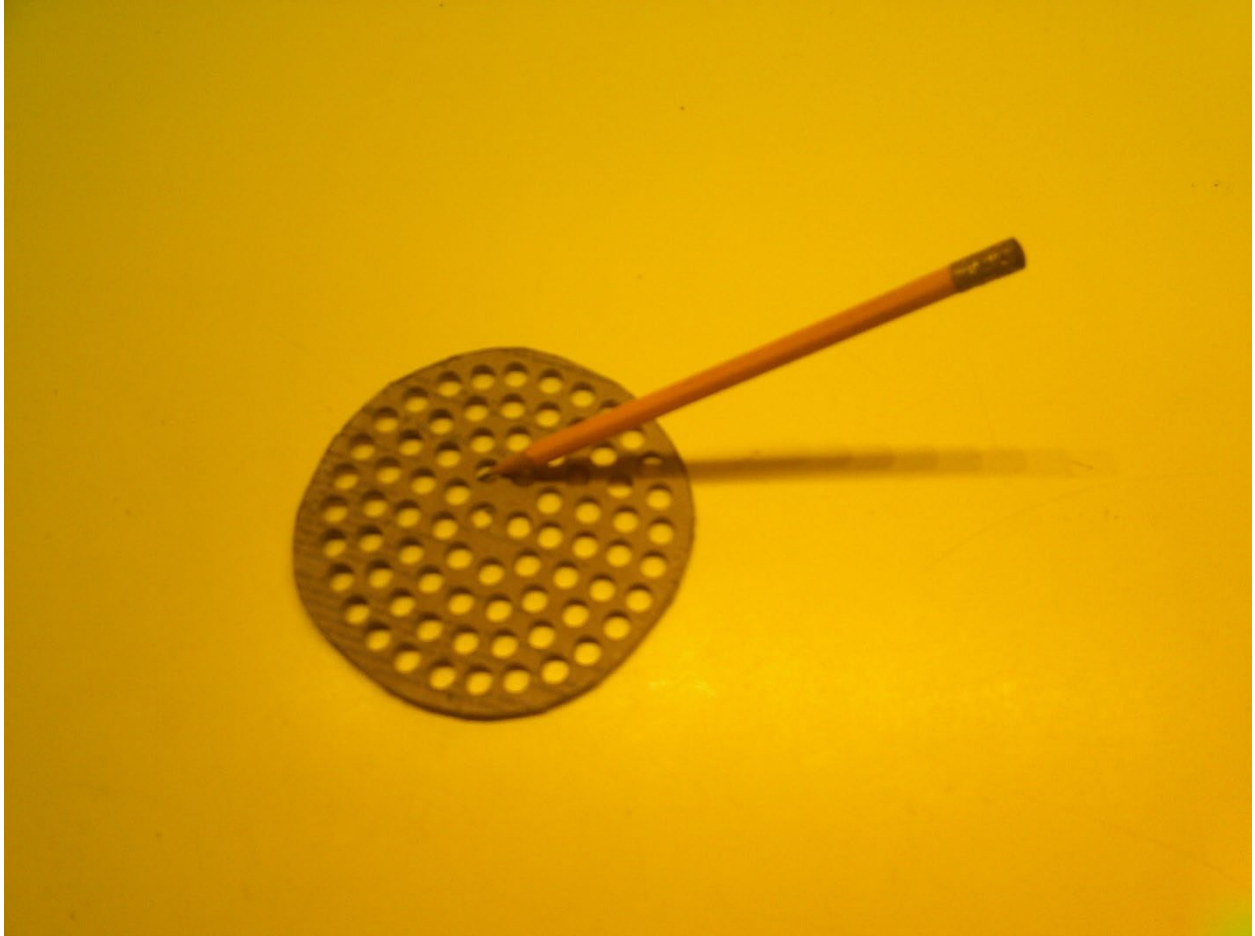
The above photograph is the same as the previous photograph except that all holes in the growing matrix have been completely punched out.

Add three more cardboard layers. Repeat the preceding steps in order to add a third cardboard layer to the growing cardboard half-matrix. Then, add a fourth and a fifth layer. Additional layers become easier to add, up to a limit of five, when the growing half-matrix becomes thick enough to prevent the hole punch from closing.

The finished half-matrix consists of 5 cardboard layers interspersed with 4 layers of two-sided carpet tape. Two photographs of a finished 5-layer cardboard matrix are shown below. (Layers of cardboard, but not layers of tape, are counted in the numbering system).



The above photograph shows a 5-layer half-matrix that consists of 5 cardboard layers interspersed with 4 layers of 2-sided carpet tape. I was unable to create half-matrices thicker than 5 layers because the hole punch was obstructed by thicker half-matrices.



As the above photograph shows, the 5-layer cardboard half-matrix shown in the previous photo is thick enough to support a pencil

Create a second half-matrix. Using the second punched-out cardboard template described [above](#), repeat the preceding steps to create another half-matrix, that has only 4 layers of cardboard, interspersed with 3 layers of two-sided carpet tape.



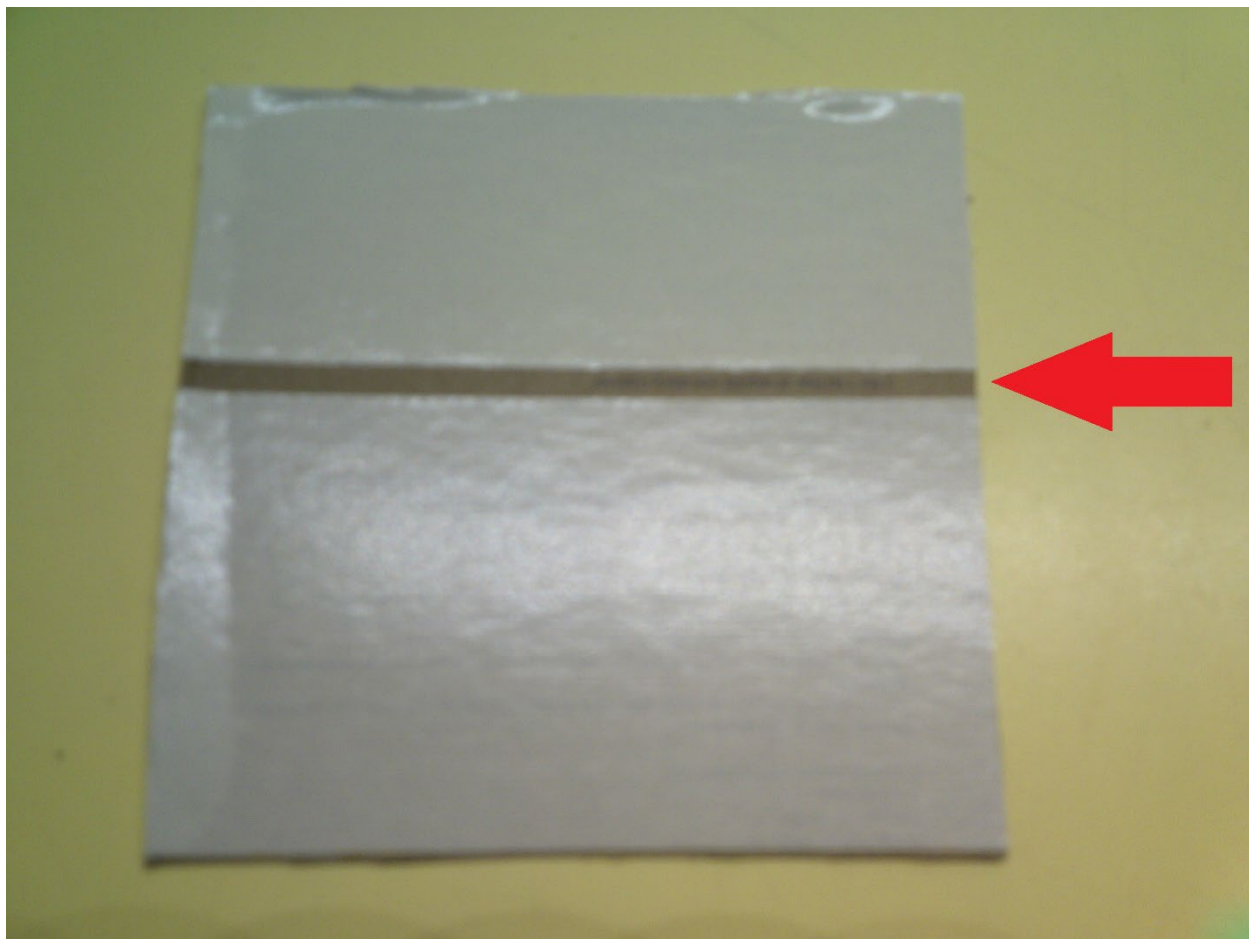
The above photograph shows a 4-layer half-matrix consisting of four cardboard layers interspersed with 3 layers of carpet tape.

Seal any accidental lateral channels. Because the two-sided carpet tape is extremely sticky, placing two pieces exactly adjacent to each other on a layer of cardboard is difficult. If the pieces overlap, the layer of cardboard should be discarded and a new layer started.

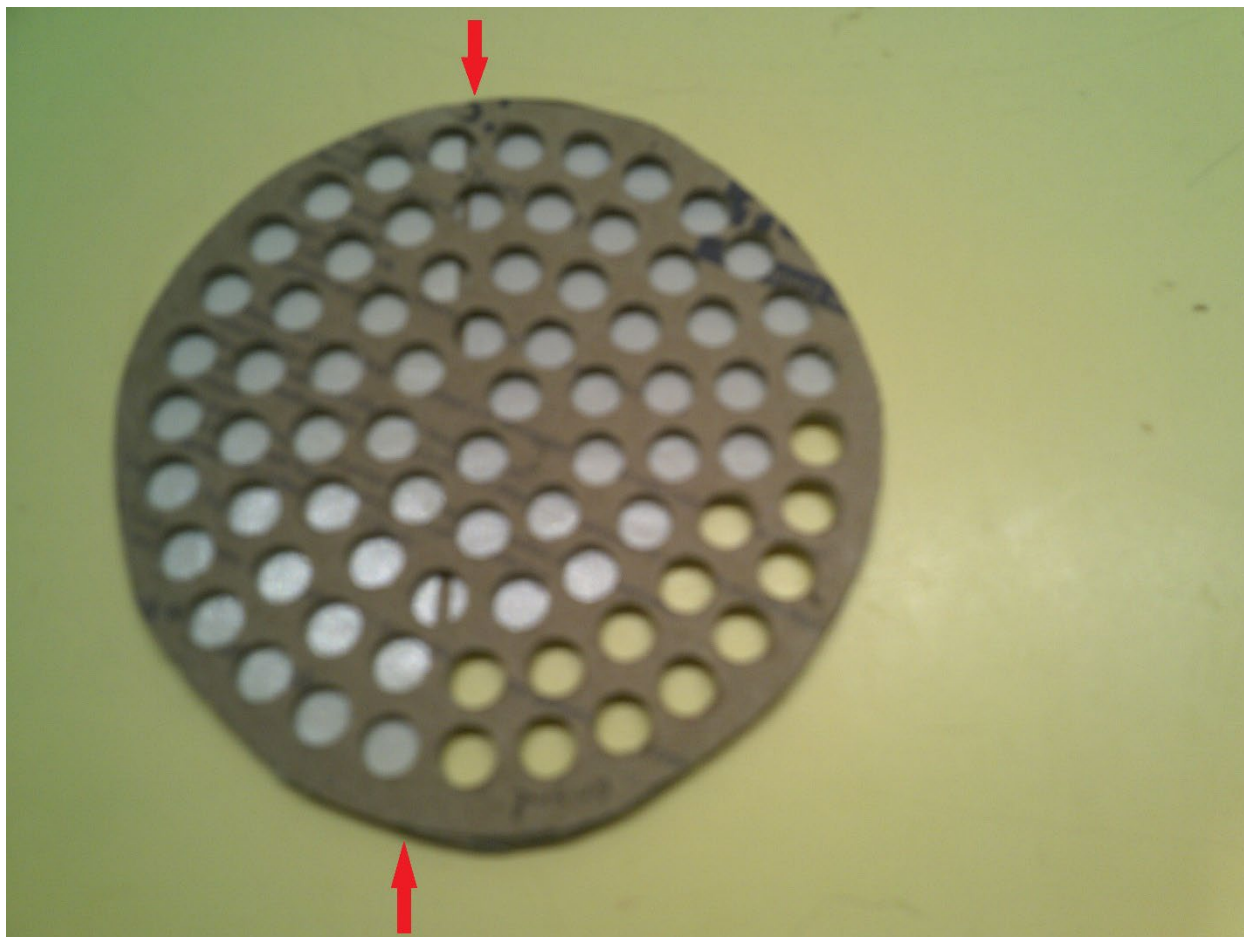
If there is a gap between the pieces of tape, a small lateral channel might form in either half-matrix. Although such channels would begin and end within the inner airspace of the facemask and, thus, would probably not expose the mask wearer to COVID-19, it is safer to use tape to block the ends of the gap. Mark the ends of the gap and then block them when construction of the half-matrix is complete.



The above photograph shows a space between two pieces of 2-sided carpet tape that have been added to a fresh layer of cardboard. Although a space this wide can probably be avoided, placing of the tape often produces narrower spaces. The red arrow points to the space.



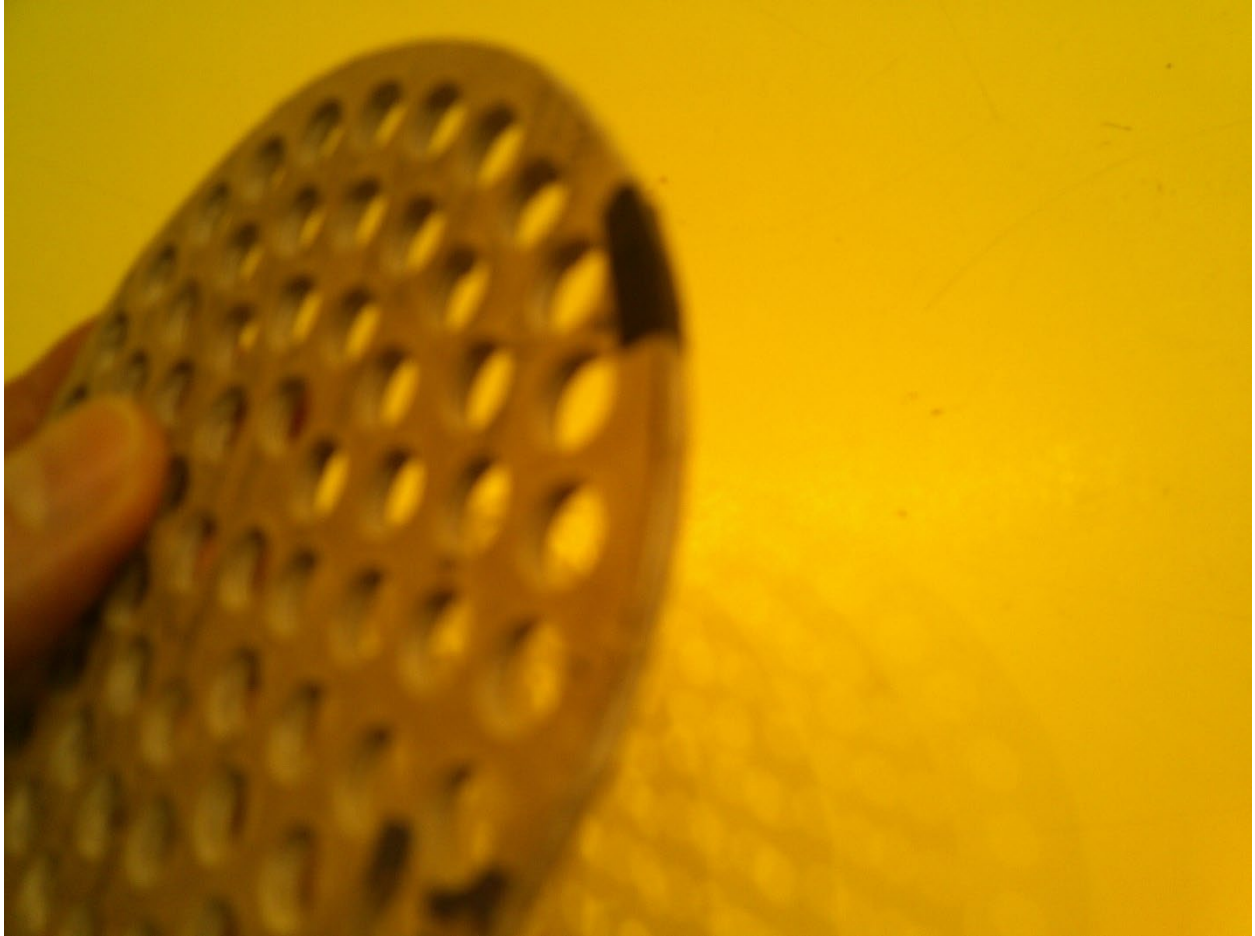
(Above) The same as the previous photograph, but with the plastic sheet coverings of the tape removed.



The above photograph shows a partly punched-out half matrix with a gap in the layer of tape that is being punched out. Note that this forms a channel in the matrix. The red arrows indicate the ends of the channel at the half matrix's edge.



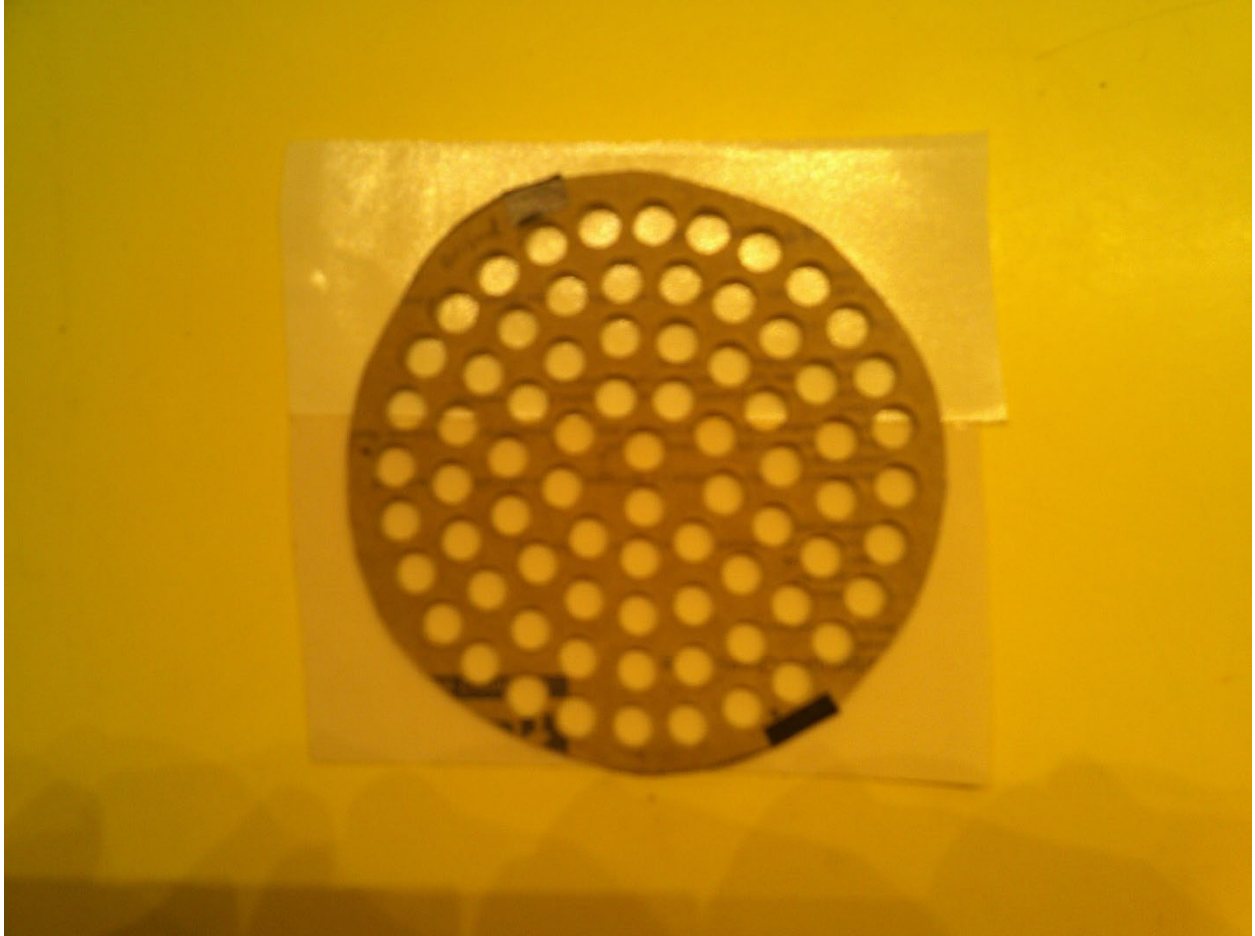
The above photograph shows the same half-matrix as shown in the previous photograph, but with the ends of the channel taped. The channel will also connect holes within the half- matrix. Individual filters are surrounded by an impermeable membrane which prevents particles from entering the mask via one filter and then migrating laterally. Although the channels do not allow unfiltered air into the mask, it is better to avoid creating them.



(Above) Another view of a half-matrix with the end of a channel blocked by tape.

Attach a plastic carton cover to the second half-matrix. To the second half-matrix (which has 4 layers of cardboard, interspersed with 3 layers of 2-sided carpet tape) add another layer of 2-sided carpet tape. Then, trim the carpet tape to match the half-matrix and remove the protective plastic layer from the tape.

Then, attach this half-matrix to a plastic carton cover.



The above photograph shows a four-layer half-matrix pressed onto two pieces of 2-sided carpet tape. The far side of the carpet tape in this photograph is still covered by plastic sheet.



(Above) The half-matrix presented in the previous photograph but seen from the other side and with the 2-sided carpet tape trimmed to fit the half-matrix.



(Above) The previous photograph but seen from the side away from the carpet tape.



(Above) The previous photograph but seen from the side covered with 2-sided carpet tape, and with the plastic sheet covering removed. This half-matrix is ready to be attached to a plastic carton cover.



(Above) The half-matrix shown in the previous 4 photographs, attached to a plastic lid.

Punch holes in the plastic cover attached to the second half-matrix. Punch holes in the plastic carton cover using a hole punch (see photographs below). If it becomes necessary to bend the rim of the cover, bend it inwards, not outwards. If damage to the cover starts to appear, complete the hole creation using a soldering iron. The hole punch is preferable because it creates a perfectly flat hole, which the soldering iron does not. I explain the importance in a [later section of this PDF](#). If you cannot reach the central holes with the hole punch, you can leave them unpunched or you can melt the plastic with a soldering iron.

If you use a soldering iron, try not to widen the holes in the matrix. You want the filters to fit snugly into the holes with no space around the filter sides.



(Above) A plastic carton cover attached to a 4-layer half-matrix can be punched out with a hole punch. If it is necessary to bend the plastic rim of the cover, bend in inwards, rather than outwards.



(Above) If punching out the plastic holes with a hole punch is unsuccessful, you can melt the plastic with a soldering iron. This is a less desirable alternative, because it leaves raised rims around each hole. This importance of this is explained in a [later section of this PDF](#).



The above photograph shows the **soldering iron** used to create holes in the plastic cover that is attached to a 4-layer half-matrix. A soldering iron with a sharp tip is preferable. It is important not to widen or deform the holes in the cardboard half-matrix when using the soldering iron.

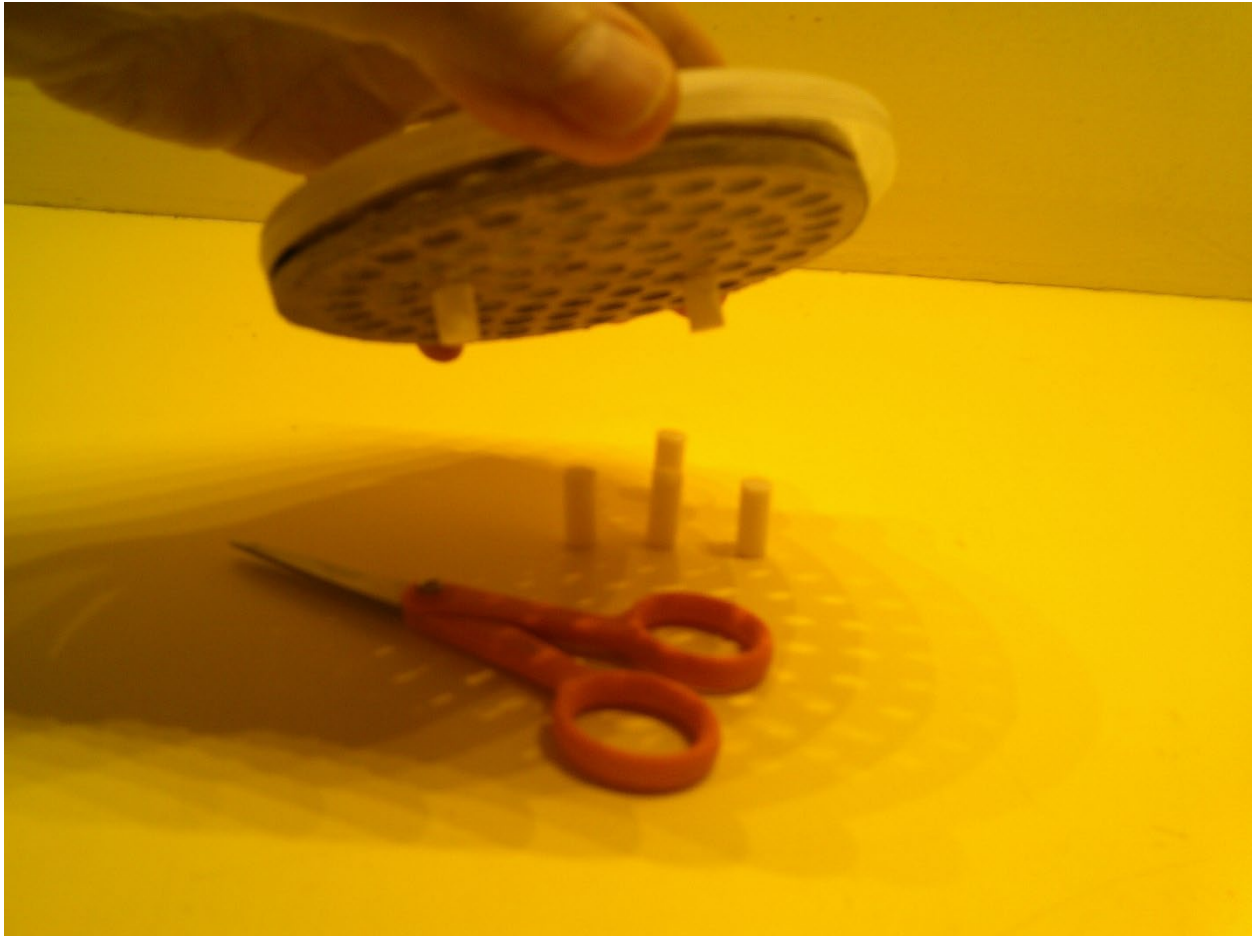
Use filters to join the two half-matrices together. Use filters to join the two half-matrices together. If the filters fit the holes snugly, it is not necessary to do anything else to join the two half-matrices. The filters are longer than the holes formed by the two half-matrices and the excess length should be removed by cutting. The filters can be cut with a shaving razor blade, an **industrial razor blade**, or an X-Acto knife. I prefer the shaving razor blade. Generally, one filter is long enough to fill two holes in the combined matrix.

If, for some reason, a hole seems too large for a filter, you can wrap tape around the filter. I have seen this to be necessary in only one case, where I accidentally widened a hole while using a soldering iron to melt holes in a plastic cover. Surgical tape is the best tape to wrap filters with.

As noted [below](#), although filters can hold the two half-matrices together and can plug the holes in the filter matrix, I recommend one additional step. This additional step is to coat the hole walls with either glue or rubber cement.



The above photograph shows two half-matrices (the 4-layer half-matrix which is attached to the plastic cover, plus the 5-layer half-matrix) held together by just two filters. If the filters fit the holes snugly, they will provide enough support to keep the two half-matrices together. In the finished mask, these filters will be cut so that they are flush with the cardboard surface. They will not protrude from the filter matrix.



The above photograph shows the arrangement seen in the previous photograph, but from a different angle. Just two filters are enough to keep the two half-matrices together. When the mask is complete, the half-matrices will be joined by 75 filters. As noted in the caption to the previous photograph, the filters will not protrude from the matrix when the mask is complete.

Coat the hole walls with Elmer's glue or rubber cement. Although filters fit the holes snugly and can hold the two half-matrices together, I recommend an additional step. This step is to coat the walls of each well with either an arts-and-crafts glue such as **Elmer's glue** or **rubber cement**. (Type 401 superglue, tile adhesive, construction adhesive, and melted beeswax are less suitable or unsuitable.) The purpose of this is to block any possible movement of respiratory droplets between the cigarette filters and the walls of the wells.



(Above) To decrease the chances that respiratory droplets will move between the cigarette filters and the cardboard of the matrix, dip a cotton swab in slow-drying glue and coat the walls of a matrix hole. Following this (see below), add a cigarette filter and then remove any glue that blocks the end of the filter.



(Above) After using a cotton swab to apply glue to the wall of a hole in the cardboard filter matrix (see previous photograph), insert a cigarette filter into the hole and remove any glue that blocks either end of the filter.



In the above photograph of the two half-matrices, some of the filters have been cut so that their surfaces are flush with the surface of the cardboard matrix. Other filters still protrude. When the facemask is complete, all of the filters will be cut so that their surfaces are flush with the surface of the cardboard matrix.



(Above) Filters can be cut with (counterclockwise from top) an **X-Acto knife**, an industrial razor blade, or a shaving razor blade. I prefer the shaving razor blade.



In the above photograph, a shaving razor blade is part way through the act of cutting a filter so that the filter's new surface is flush with the cardboard of the matrix.



In the above photograph, cutting of the filter by the razor blade is almost complete.



The above photograph shows the finished matrix. The two half-matrices have been joined together by 75 filters, all of which have been cut so that their surfaces are flush with the cardboard of the matrix. In practice, one commercial cigarette filter is long enough to occupy two holes, joining the half-matrices at each hole.



The above photograph shows the matrix seen in the previous photograph, but from what will be the front of the mask.

If, for some reason, filters do not fit snugly in the holes of the cardboard matrix, the filters can be wrapped with tape to widen them. In my experience, the best tape to use is surgical tape.



(Above) This roll of **surgical tape** can be used to wrap filters to increase their diameter, so that they will fit snugly into the mask matrix. However, in my experience, this has not been necessary unless a hole in the matrix has been accidentally widened by contact with a hot soldering iron (only one instance).

Creating a Matrix Using Glue Instead of 2-Sided Carpet Tape

Glue can hold cardboard layers together. Two-sided carpet tape may not be available to everyone who needs an anti-COVID facemask. Glue is less satisfactory than 2-sided carpet tape for laminating the cardboard layers of a matrix. However, at least 3 types of glue can be used for this purpose. These 3 types are traditional arts and crafts glue (represented by Elmer's glue), rubber cement, and superglue (represented by Brand 401 from China).



(Above) **A brand of superglue** (Brand 401) is shown on the left. A traditional arts and crafts glue (Elmer's glue) is shown in the middle. A brand of rubber cement (Elmer's Rubber Cement) is shown on the right. All three can be used to laminate cardboard layers to form a half matrix.

The superglue dries very quickly. It gets all over the user's hands or gloves. It binds irreversibly to a plastic knife used to spread it and releases irritating fumes. It also builds up in the wells of the cardboard template making it harder to punch holes in the second cardboard layer.

The traditional glue dries very slowly and tends to warp the cardboard. Two cardboard layers with traditional glue between them will tend to slip over each other and this must be prevented. Also, glue must be removed from the wells with a filter, a cotton swab, or some other means. A half-matrix to which a cardboard layer has just been added should be dried in an oven under low heat (in other words 200 °F or 93 °C) for at least 15 minutes while under a heavy, flat weight.

Rubber cement dries more quickly than does traditional glue, but more slowly than does superglue. It more difficult to remove rubber cement from the wells of a

growing half-matrix because the glue dries rapidly, but it is also less necessary. Nevertheless, buildup of rubber cement in wells of a growing half-matrix can make punching out of holes difficult. The rubber cement dries completely in about 30 minutes at room temperature, without heating.

Using traditional glue to laminate cardboard layers. To create a matrix with non-corrugated cardboard and traditional glue, start with a punched-out cardboard template and a square of cardboard. These are also the materials needed to create a matrix with non-corrugated cardboard and rubber cement.



(Above) The starting materials for creating a cardboard half-matrix using Elmer's glue are a cardboard template and a blank square of non-corrugated cardboard.

Add traditional glue to a cardboard square and spread the glue with a plastic knife. Then, press the template into the glue, anchor the template with tape, and remove the glue from the wells of the template using a cotton swab or a filter. This

is necessary to prevent glue from hardening in the wells and making it impossible to punch out new holes.

Rubber cement should be spread over the cardboard square using the applicator that is included in the jar of rubber cement. If this is impossible, instead use a plastic knife.



(Above) To begin construction of a cardboard half-matrix using a traditional arts and crafts glue such as Elmer's glue, spread the glue onto the surface of a square of cardboard. Notice that the moisture in the glue is already starting to warp the cardboard square.



(Above) Laminate a template cardboard layer and a cardboard square with Elmer's glue between them. Tape the template in place with masking tape. If rubber cement is used in place of Elmer's glue, it may not be necessary to tape the template layer in place because it is less likely to slip.



(Above) It will be necessary to remove glue from the wells of the growing half-matrix. One method is to use a cotton swab. If rubber cement is used in place of glue, this step will be harder to perform, because the cement dries quickly, but is less important.



(Above) Excess cigarette filters can also be used to remove glue from the wells of a growing half-matrix.

If Elmer's glue was used, dry the growing matrix at 200 °F (93 °C) under a heavy weight for at least 15 minutes. Longer times or temperatures as high as 250 °F (121 °C) are OK. When rubber cement was used, I typically dried a growing matrix for 30 minutes at room temperature, without a weight.



(Above) A growing half-matrix is dried under a heavy weight in a pan at 200 °F (93 °C).

The remaining steps in constructing a matrix with traditional glue or rubber cement. The remaining steps in building two cardboard half-matrices are like those where 2-sided carpet tape is used, except that when each layer of cardboard is added, the growing half-matrix must be dried in an oven for at least 15 minutes. The most efficient practice is to work on punching holes in the cardboard of one half-matrix while the other half-matrix is drying.

When rubber cement is used to hold the cardboard layers together, it is not necessary to heat the matrices to dry them. Instead, matrices with a new layer added should be dried at room temperature for 30 minutes.

When you join the 4-layer half-matrix to a plastic carton cover with traditional glue, dry the assembly for 1 hour at 170 °F (77 °C). The lower temperature is used to avoid melting the cover. When the joining is with rubber cement, allow the assembly to dry at room temperature for 45 minutes.

Finally, when the plastic carton cover is attached to half-matrices held together by either traditional glue or rubber cement, create holes in the plastic carton cover using a soldering iron. I recommend against using a hole punch to create holes in the cover because the matrix is less firmly bound to the cover than would be the case with 2-sided carpet tape, and if the matrix starts to peel away from the cover, it is much harder to reattach. The photograph below is of the final product (a matrix held together by traditional glue) seen from the inside of the mask.

More cardboard layers. When a matrix of non-corrugated cardboard is assembled using 2-sided carpet tape, one half-matrix has 5 layers of cardboard and the other half-matrix (which will be attached to a plastic carton cover) has 4 layers. Because arts-and-crafts glue and rubber cement have less volume than does 2-sided carpet tape, the half-matrices should contain 6 cardboard layers and 5 cardboard layers, respectively.



The above photograph shows a matrix (two half-matrices) constructed of cardboard layers and Elmer's glue.

What If Cardboard and a 2-inch Hole Punch Are Not Available?

Non-corrugated cardboard is probably the best material to construct filter matrices from. However, if the cardboard or the necessary 2-inch hole punch are unavailable, other materials and hole-making techniques can be used. Among the other materials that can be used are the soles of old tennis shoes (also known as “running shoes” or “sneakers”) and sheets of 1/8-inch silicone rubber. Among the other tools for creating holes in filter matrix material are cork borers and electric drills—although of these two, cork borers are generally better.

One material that seems not to be suitable for construction of a filter matrix is neoprene rubber. The problem is that it is too difficult to bore or drill clean, non-ragged holes in the neoprene.

Shoe sole material. Improvised Bugeye Facemasks are most suitable for countries where anti-COVID vaccination rates are low and high-quality medical facemasks are difficult to acquire. One type of material that may be plentiful in such countries is worn-out shoes.

Tennis shoes differ from each other in their construction, but the soles of many contain a soft rubber pad that is impermeable to air. The tennis shoes of a person with large feet will likely contain a pad whose area contains a circle of diameter 10.0 centimeters.

As discussed below, these soft pads can potentially be transformed into good filter matrices, provided that they are large enough. However, they have two drawbacks. First, they may contain preexisting holes which must be plugged with impermeable material. Second, they are frequently curved, which requires that special measures be taken to hold them firmly against the plastic carton cover that they will be attached to.

Use of a cork borer. The best way to create appropriate-sized holes in rubber sole material is with a **1/4-inch cork borer**. I used the 1/4-inch member of a “*Humboldt H-9662 Plated Brass Cork Borer Set with Handles, 0.1875" to 0.5" OD (Set of 6)*”, but other products may be equally suitable. Cork borers become dull quickly, so it is better to have access to a **cork borer sharpener**. The “HUMBOLDT H-9680 Cork Borer Sharpener” is the best choice that I know of,

albeit it is quite expensive. The “*Beyondsupply-Cork/Rubber Stopper Borer Sharpening Tool*” is also suitable and is less expensive.

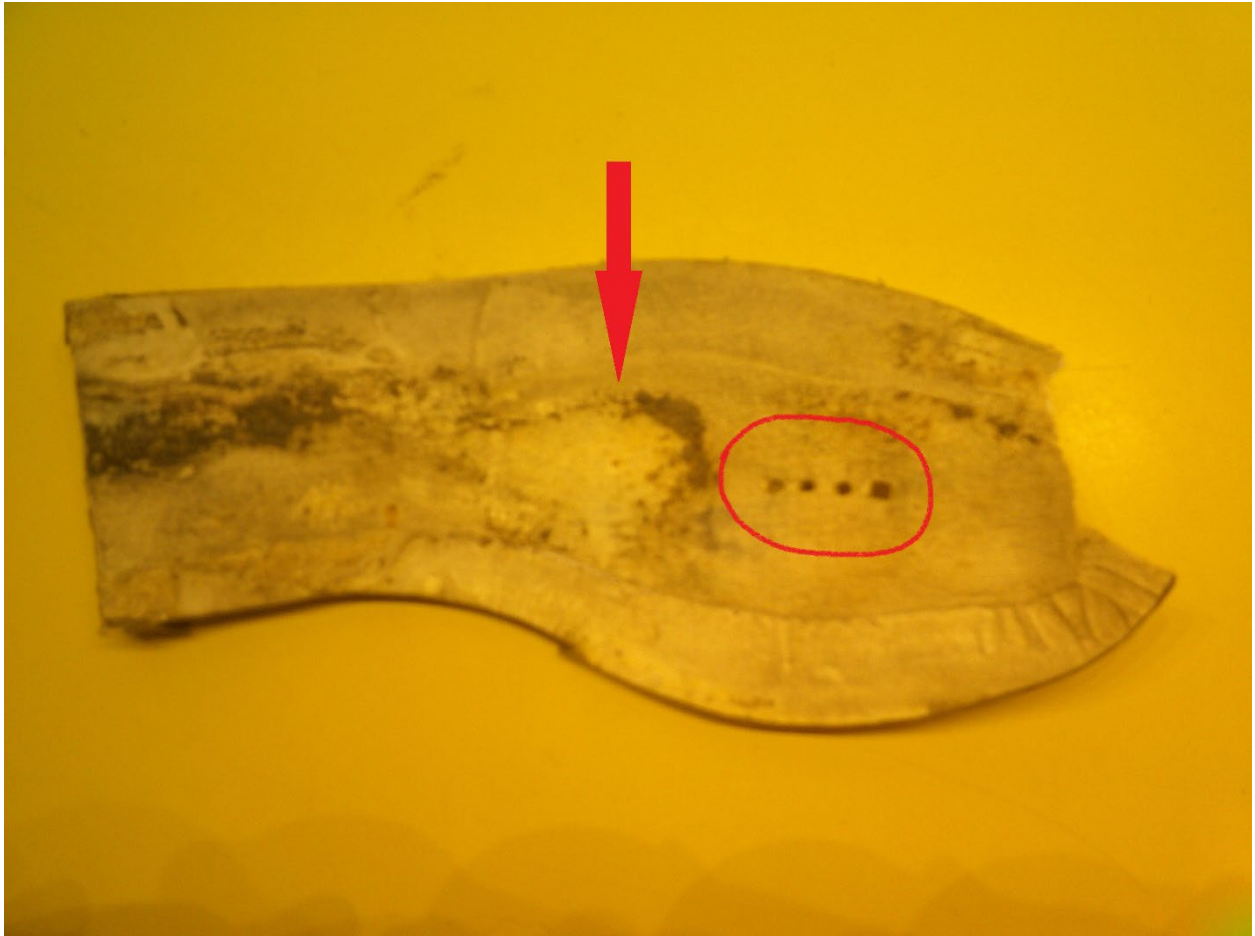
Use rubber cement to attach the paper template. Although 2-sided carpet tape can attach a paper template to a rubber pad very effectively, the carpet tape interferes with the boring of holes. Hence, it is better to attach the template to the rubber pad using rubber cement. The sequence of 9 photographs below shows the disassembly of a worn-out tennis shoe, retrieval of the soft rubber pad in **the shoe’s sole**, and transformation of this soft rubber pad into a filter matrix.



(Above) An old tennis shoe whose sole supplied material for a filter matrix. The shoe was about size 12 in American men’s sizes.



(Above) As a first step toward creating a filter matrix, the sole of the tennis shoe shown in the previous picture was separated from the remainder of the shoe.



(Above) The soft pad was separated from the remainder of the sole. Although the pad appears to be worn through in its central region (identified by red arrow), this is an illusion caused by a stain on the pad; the pad was solid. Note that the pad is not perfect material for a filter matrix: there is a row of four pre-existing holes (circled in red) that would have to be plugged with an impermeable material for the pad to serve as a filter matrix.



In the above photograph, a paper template has been attached with rubber cement onto the soft rubber pad from a tennis shoe sole.



(Above) A cork borer has been used to bore holes in the shoe pad shown in the previous picture.



(Above) The entire set of 75 holes has been drilled in the shoe pad in places specified by the paper template.



(Above) The set of 75 holes shown in the previous picture were filled with filters. The original filters were much longer than the holes in the above matrix, but the excess filter material was removed with a shaving razor blade. As noted in the caption of the picture that is 4 steps ahead of this picture, the filter matrix is not perfect because of small preexisting holes that were present in the rubber.



(Above) The set of 75 holes shown in the previous picture has been cut loose from the remainder of the shoe pad, and the result is a filter matrix. Three of the filters have been marked with black dots. These filters adjoin pre-existing holes in the filter matrix which would have to be plugged for the filter matrix to function properly.

Use of a 1/4-inch drill bit. The use of a 1/4-inch drill bit in an electric drill would seem to be a good choice for creating holes in matrix material, especially since drills and drill bits are likely to be common worldwide. However, in my experience, drilling with an electric drill was usually unsuitable for two reasons. First, the location of the holes was difficult to control and, second, the holes created were too ragged to be useful. The first problem might be solved with a drill press, but the second problem seems generally insoluble—with one exception. The only exception was that drilling in the soft rubber of some shoe pads created a clean, even hole that could serve to hold a filter in a filter matrix. An example is shown below. However, with most materials including non-corrugated cardboard,

drilling is not suitable for filter matrix construction. This subject is discussed in greater detail [below](#).



The above photograph shows a piece of soft rubber taken from the sole of a tennis shoe. A hole was drilled into the rubber with a 1/4-inch drill bit and a filter was inserted into the hole. The fit is snug. The inked writing near the filter reads “1/4 inch Drilled”.

Use of hard rubber from soles. In some cases, it may be impractical to separate the soft rubber insert from the hard rubber sole of a tennis shoe, either because they are fused together too firmly or because the soft rubber insert is too thin to be useful alone. Hence, it may be necessary to create a filter matrix from both the soft and hard rubber layers combined (see picture below).

It is much more difficult to bore through hard rubber than through soft rubber, which ensures that boring 75 separate holes will be arduous. Furthermore, the outermost layer of hard rubber tends to spring back after it has been bored with a

cork borer, creating a hole whose terminus is crimped. Fortunately, the crimped terminus can be widened with a hot soldering iron (see the picture that follows the picture immediately below)



The above picture shows a template glued onto the sole of a tennis shoe. The hard rubber of the sole (not facing the camera) has not been separated from the soft rubber. It is harder to bore through hard rubber than soft rubber.

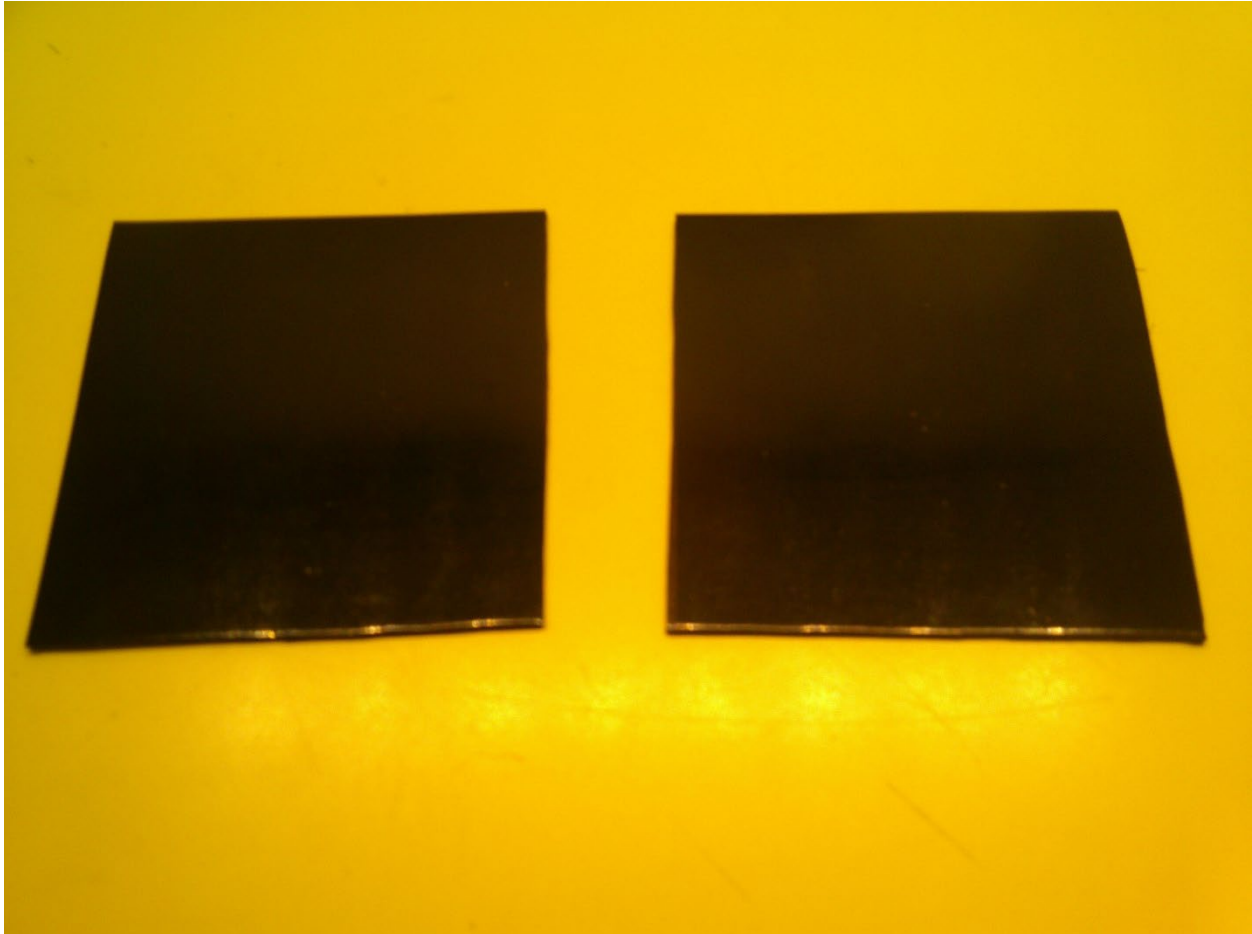


(Above) The outer part of the hard rubber layer tends to spring back after a hole is bored through it, crimping the end of the hole. A hot soldering iron can widen the end of the hole.

Use of silicone rubber sheets. **Silicone rubber sheets** of 1/8 inch thickness can also be used as a filter matrix, although silicone rubber presents some special problems. The silicon rubber sheet is likely to have a smooth surface and thus be difficult to attach a paper template to. Silicone rubber sheets also collect dust, which must be wiped away with a wet cloth before the sheets are used. Silicone rubber is heavier than other filter matrix materials discussed in this report and special measures must be used to join it firmly to the plastic carton cover that will attach it to the facemask frame. Moreover, if the silicon rubber is deep black, it may be difficult to mark with a ballpoint pen or a felt marking pen.

Drilling is useless. Drilling of silicone rubber sheets with a 1/4-inch drill bit and an electric drill fails. The problem is that the holes created are too ragged and thus will not form a tight seal with inserted cigarette filters.

Cut out two silicone rubber squares. As the first step toward creating a filter matrix from silicone rubber sheets, cut out two 12-centimeter X 12-centimeter squares of silicone rubber sheet. The exact dimensions are not important, but the sheets must comfortably accommodate a circle 10 centimeters in diameter. It is better to have extra material to work with.

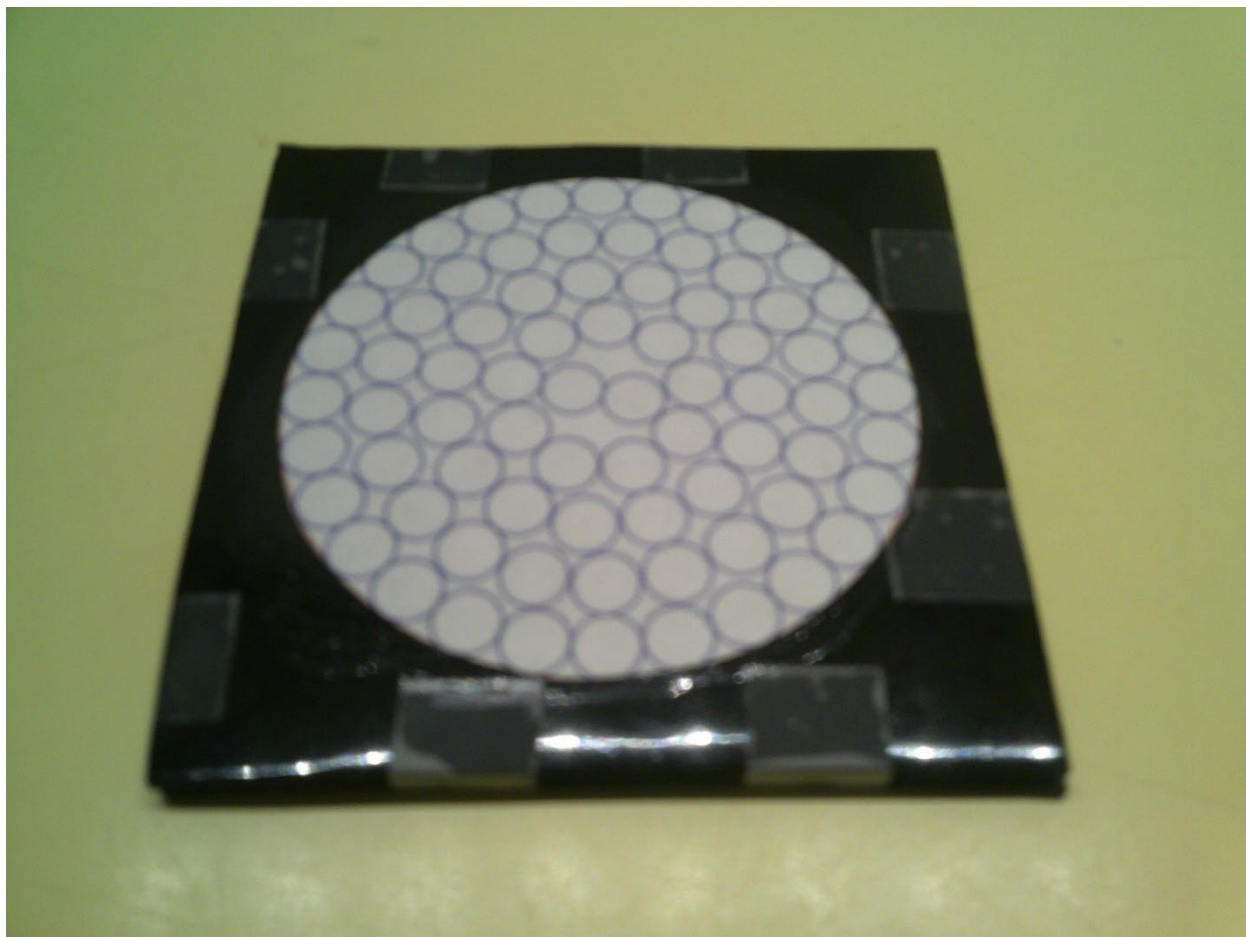


(Above) Two squares of black silicone rubber are shown. The two squares are approximately 12 x 12 centimeters in size.



(Above) The two silicone rubber squares shown in the previous photograph have been taped together to form a bilayer. The tape used to join the two squares should not encroach on the central circular area of 10 centimeters diameter.

Affix template to bilayer. Use rubber cement and translucent Scotch tape to glue a circular 75-hole template to the square bilayer of rubber created above.



(Above) Rubber cement and translucent tape were used to attach a paper template to the silicone rubber bilayer. The template was 10 centimeters in diameter and included 75 holes.

Bore holes in the template. Use a 1/4-inch cork borer to bore holes near the centers of the 75 circles in the template. Boring the holes shreds the template (see photo below). Hence, be careful and work through the template in a steady progression rather than skipping around.



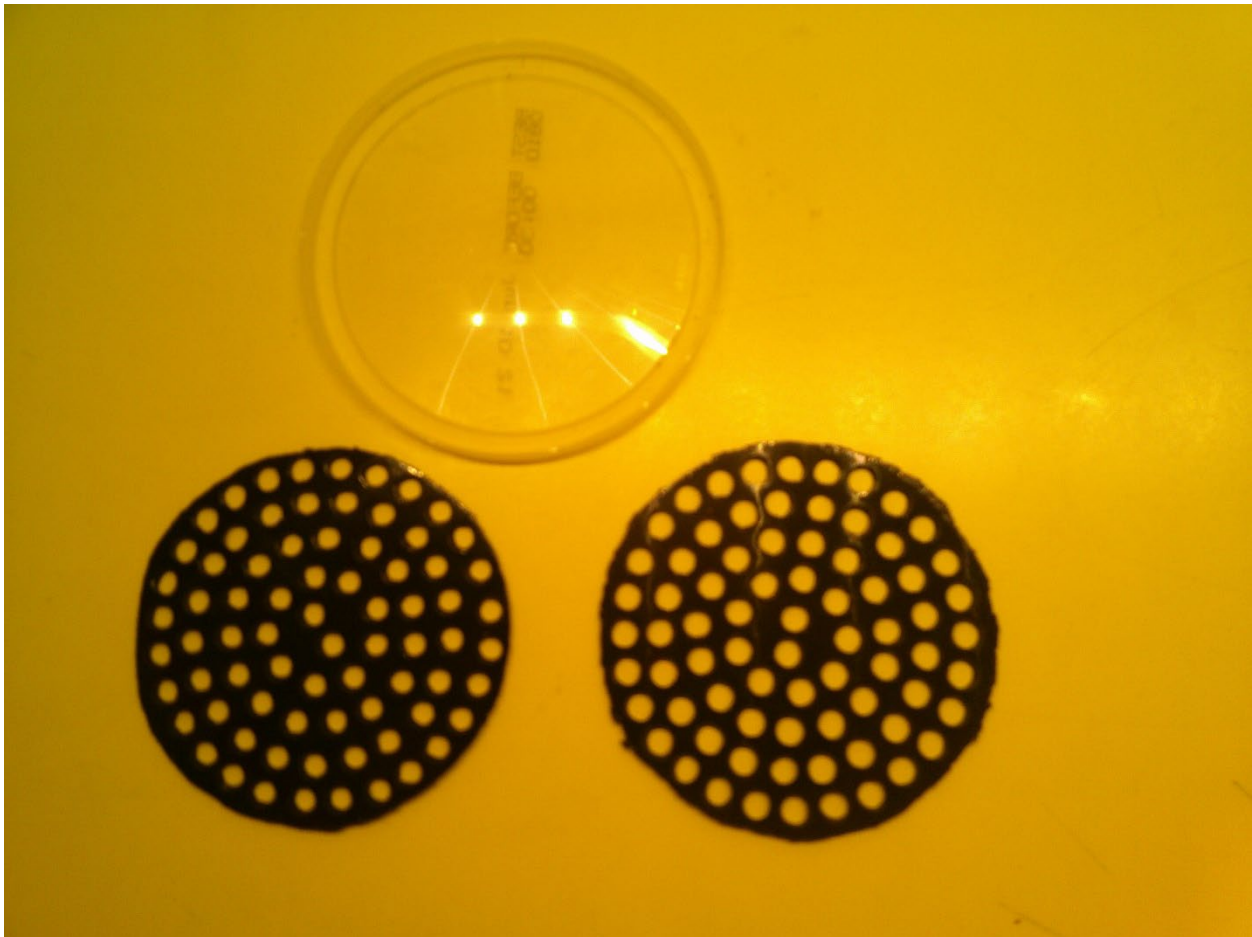
(Above) Boring holes through the 75-hole paper template destroys the template. Hence, it is better to start at one edge of the template and work progressively through the template.

Cut out a silicon rubber circle containing the holes. When all 75 holes have been bored, remove the remains of the template and any tape used to hold it in place. If there remains any rubber cement that had been used to attach the template to the bilayer, get rid of it by rolling it up with your fingers.

Use Scotch tape to firmly bind the two silicon rubber layers together. Then, using a cardboard circle as a guide, draw a circle around the holes that have been bored in the bilayer. Although my silicone rubber layers are a very deep black, a black ink circle on the surface of a layer was clearly visible.

The circles can be excised from the bilayer using either sharp scissors or an X-Acto knife. Accurate cutting with scissors is difficult, and it is very easy to remove too much rubber, so be careful.

The cutting can also be done with an X-Acto knife, using a backstop of Neoprene rubber. The Neoprene rubber greatly facilitates cutting by the X-Acto knife. Use the point of the X-Acto knife and saw out the 2-layered circle. I removed the upper circle first, and then the lower circle after more cutting.



(Above) Two identical silicone rubber circles, each with 75 holes, were excised from the silicone rubber bilayer discussed above. These two circles will be combined to form a filter matrix which will be attached to the plastic carton cover seen at the top of the photograph.

Add 2-sided tape to one circle. Add 2-sided carpet tape to one side of one disc of silicone rubber but do not remove the protective plastic of the tape. Trim the tape so that it exactly covers the disc. Then, remove the plastic sheet from the tape and press the disc against the inner surface of a plastic carton cover, so that the disc forms the first stage of a filter matrix.



(Above) A piece of 2-sided carpet tape has been added to a silicone rubber circle. The next step is that the part of the circle that remains visible will also be covered with 2-sided carpet tape. The protective plastic sheet is still present on the near side of the tape.

Bore holes through the plastic carton cover. Using the first silicone rubber 75-hole circle as a template, use the 1/4-inch cork borer to bore holes through the combination of carpet tape and plastic carton cover. Use neoprene rubber, or a similar substance that is both firm and soft, as a backstop. It will be necessary to remove tape adhesive from the cork borer from time to time. Be careful to hold the silicon rubber disk and the two-sided carpet tape together so that they do not separate. If they do separate, press them together again.

Add the second disc and insert filters. Then, fit the second 75-hole silicone rubber disk over the first so that the holes of the two discs are perfectly aligned. Insert filters into a few holes to keep the discs in place and add filters to the remaining holes. Swab each hole with rubber cement, using cotton swabs, before adding the filter. The rubber material tends to snap back after being bored, leaving

a hole that is slightly too small, and it will be necessary to twist the filters to push them through the holes.

Use an entire filter to plug each hole. Because the silicone rubber is heavy, it needs additional support. Insert the filters so that they protrude from both the front and the back of the filter matrix. Remove any rubber cement that has adhered to the outer (front) end of any filter.



The above photograph shows the inner side of a filter matrix manufactured with 2 layers of silicone rubber, a plastic carton cover, and full-length (not shortened) cigarette filters.



The above photograph shows the outer (front) side of the filter matrix shown in the previous photo. The filters protrude from both the outer and inner surfaces.

Testing for air flow. The above instructions for constructing a filter matrix incorporate an unusual feature: the filters are full-length, rather than being less than half-length, as are the filters in other types of matrix. Because of this, the filters transmit less air for a given amount of effort than do filters in other matrix types. In addition to this, the filters are pushed through holes that have been swabbed with rubber cement—which may cover the outer (front) end of the filter with rubber cement.

It is therefore a good idea to test silicone rubber filter matrices before using them. To do this, attach the filter matrix to the test device shown in the picture below ([and described here](#)). Seal the junction between the matrix and the device and test how difficult it will be to inhale adequate air.

If rubber cement blocks the outer (front) ends of the filters, the filters can be shortened with scissors or a razor blade—but this should ordinarily be unnecessary.



The above photograph shows a test device joined with an airtight seal (green vinyl tape) to a silicone rubber filter matrix that was constructed as described in the text. Only air that enters through the filter matrix is inhalable through the green inhalation valve at the far left of the device.



The above photograph shows the same test device and filter matrix as does the previous picture, but from a different angle.



To confirm that air can enter the test device only through the filter matrix, cover the filter matrix with **clear plastic wrap** and attempt to inhale through the inhalation valve.

The Rare Usefulness of Electric Drills

With most materials that can be used to construct filter matrices, drilling with an electric drill is useless. The problems, as mentioned above, are that it is difficult to place the holes accurately and that the holes drilled are too ragged to form an airtight junction with a cigarette filter.

Nevertheless, drilling can produce useful holes in the soft rubber insert that is present in some tennis shoes. The three photographs below illustrate one example of this.



(Above) A drill bit of 1/4-inch diameter was used to drill smooth holes in tennis shoe sole insert material. As can be seen, the drill bit has the same diameter as the cigarette filters used.



The above photograph shows an insert from an old tennis shoe. A hole has been drilled through the insert and a filter inserted part way into the hole. The sequence of five small holes near the midline of the sole were created during the manufacture of the shoe.

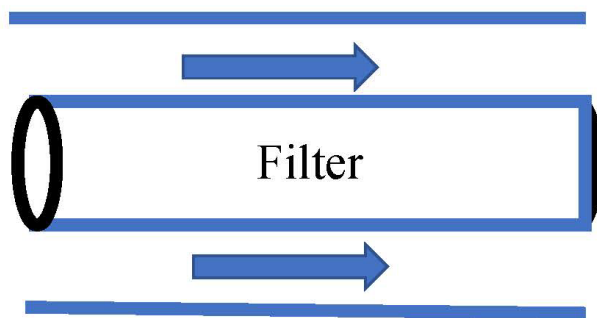


The above photograph shows the tennis shoe insert of the previous photograph but seen from a different angle.

Adding Extra Protection to the Filter Matrix

Could droplets move in the junction between filters and cardboard? One weakness of the Bugeye Facemask design is that respiratory droplets might move between the cigarette filters and the cardboard of the filter matrix. Tests with aerosolized food color and filter matrices held together by 2-sided carpet tape gave varying results, although there was NO case in which droplets migrated the entire distance along the filters and into the breathing space of the mask wearer. However, I did not test a filter matrix held together by an arts & crafts glue such as Elmer's glue.

Cardboard of Matrix



Cardboard of Matrix

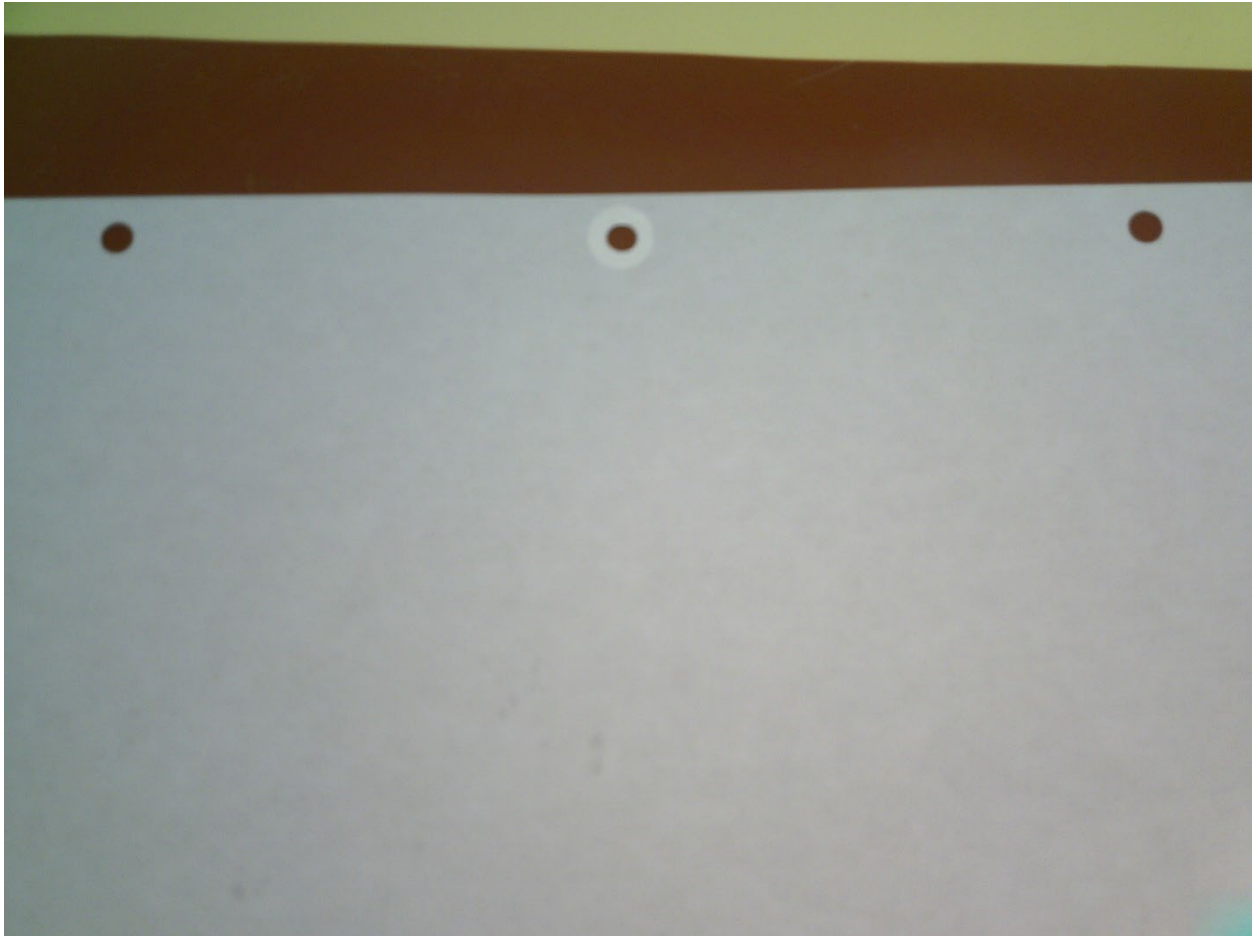
The blue arrows represent droplets of blue food color, or respiratory droplets, moving between the edge of the filter and the edge of the cardboard matrix.

The diagram above illustrates how respiratory droplets might move between cigarette filters and the cardboard of the filter matrix.

Because I do not want to increase the difficulty of creating this mask, I am not sure what to recommend. However, if you wish to decrease the likelihood of respiratory droplets moving between the cigarette filters and the cardboard of the filter matrix, there are 2 steps that you can take.

Protecting the filter-cardboard junction with reinforcing rings. One step is to cover the ends of the inserted filters with **reinforcing rings** of the kind that are used to prevent notebook paper from tearing when it is kept in a 3-ring binder. For this to be useful, the ends of the filters should be flush with either the plastic cover attached to the cardboard filter matrix or, at the other end of the filter, with the cardboard of the matrix. This may require that you trim the filters with a razor blade.

In addition, if the holes in the plastic cover have been made with a soldering iron, rather than with a hole punch, they will have raised rims that will make it more difficult to keep the reinforcing rings firmly attached to the plastic.



A reinforcing ring surrounds the middle hole in a blank sheet of notebook paper. Similar reinforcing rings are for sale in many countries and can might prevent aerosol droplets from moving along the junction between filters and the cardboard matrix.



(Above) Seven reinforcing rings block access to the junctions between filter and cardboard matrix.

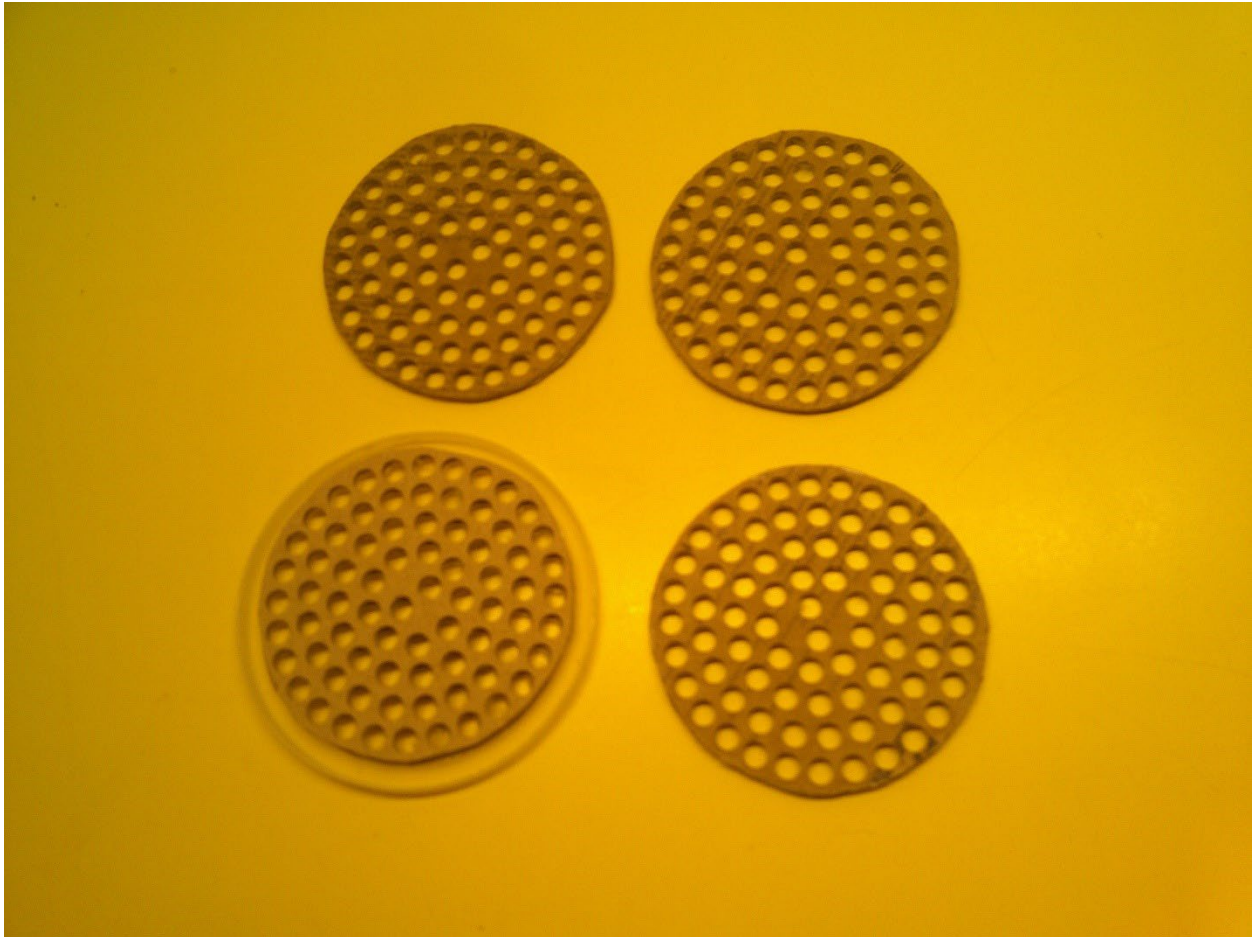


(Above) Reinforcing rings can also be added to the inner surface of a cardboard filter matrix

Increase the lengths of the filters and filter matrices. A second possible step is to increase the thickness of the cardboard matrix and the length of the inserted filters. In order to test this idea, I created a filter matrix with 19 cardboard layers attached to a plastic cover by creating three 5-layer partial matrices and a 4-layer partial matrix attached to the plastic cover. The cardboard layers were held together with 2-sided carpet tape. This cardboard matrix was the right thickness to exactly accommodate a single full-length cigarette filter.

It was more difficult to insert the filters all the way into the matrix holes without twisting and crinkling the filters than with 9-layer filter matrices. Furthermore, because the cardboard matrix was heavy and might tear away from the plastic cover, I inserted some of the filters so that they protruded a quarter-inch or so (about 6 millimeters) from the front of the plastic cover. Breathing through the 75 filters was more difficult than breathing through shorter filters was, but I

was still able to breath exclusively through the filter array while marching briskly for about 100 meters.



The above photograph shows three 5-layer cardboard matrices and one 4-layer matrix (bottom left) that were combined to make a 19-layer matrix.



This photo shows the 19-layer cardboard matrix with the plastic carton cover removed. In this photo, some of the filters protrude from the surface of the matrix. They were left this way to help anchor the cardboard matrix to the plastic cover. Use of such thick matrices may require additional methods to attach matrices to the cover or to the walls of air space.

Construction of the Mask Frame

Materials Needed

Scissors with sharp points and a razor blade of the kind used for shaving.

Scissors are needed to cut the plastic that will form the mask airspace, and a **shaving razor blade** is needed for cutting filters crosswise to fit the holes in the mask.



The photograph above shows scissors with sharp points and a razor blade of the type used for shaving.

A plastic carton for food. Creation of a facemask requires a disposable plastic carton that has been used to hold cottage cheese or some similar food marketed for public consumption. The best size for such a carton is one that hold 32 ounces (0.91 kilograms) of food. Smaller cartons are more difficult to work with ([see below](#)). The disposable plastic cover of this carton will be part of the mask. It is better if the plastic cover is translucent and not colored.

At least in the USA, food cartons of several different sizes all have plastic covers of the same size, about 4.5 inches (11.43 centimeters) in diameter. Hence, if the plastic cover of a 32-ounce carton is lost or damaged, it may be easy to replace.



(Above) A 32-ounce (0.91 kg) **carton used to hold** cottage cheese. Both the main body of the carton and the translucent plastic carton cover will be used in constructing the facemask. Large cartons such as the above are easier to work with than are smaller cartons (discussed in [the text](#)).

Creating the Mask Air Space

Choose an appropriate carton. To create the mask air space you will need a plastic carton of the type that is used to hold food. The cartons shown in this report were used to store cottage cheese, but other foods are stored in such cartons as well. A large (32 oz or 0.91 kg) carton is better than a medium-sized (24-oz or 0.68 kg) carton, which is better than a small (16-oz or 0.45 kg) carton. The reason for the difference is the conic angle. A shallow conic angle makes the mask easier to construct.



(Above) The largest (32-ounce, 0.910 kilogram) carton is better than the 24-ounce carton, which is better than the 16-ounce carton.

Remove the bottom of the carton. First, remove the bottom one-inch of the carton. One way to do this is to wrap tape that is one inch wide around the bottom one inch of the carton and then cut the carton along the edge of the tape using sharp scissors. One inch is 2.54 centimeters.

In the photograph below, the edge of the tape has been accentuated with a black magic marker so that it can be seen more easily.



(Above) Tape that is one inch wide has been wrapped around the bottom one inch of the food carton and a marking pen has been used to mark the boundary.



(Above) The bottom one inch of a 32-ounce (0.91 kilogram) food carton has been removed.

Construction of the Mask Nosepiece

Materials to create a nosepiece for the facemask. Several types of material can be used to shape the mask to accommodate the wearer's nose. These include small (2-inch) L-braces, empty round cans that hold about 5 ounces (142 grams) of food, sardine tins that hold 3.75 ounces (106 grams), or empty 12-ounce cans of a soft drink.



(Above) Small **L-braces** (left), empty **cans of tuna** (center), or **empty tins of sardines** (right) can be used to shape the plastic of a carton in order to accommodate the wearer's nose.



(Above) Empty **cans of a soft drink** can also provide material useful in shaping the plastic of a carton to accommodate a wearer's nose.

You can create the nosepiece with a flaming candle. After the bottom has been removed from the food carton, shape the remainder of the plastic carton to create the nosepiece. This can be done in one of three ways. The first is to soften the plastic with a **candle** so that it can be bent into the shape of a nose. I have not succeeded with this method, because the plastic melts too quickly and is damaged. However, another person, Paul Elkins, is able to do it. Here is a link to [his YouTube video](#) (see 2:56 to 3:32)



(Above) The plastic of a food carton can be softened with a candle and shaped to fit the wearer's nose.

You can shape a nosepiece using a small L-brace. The second method is to use an L-brace of the kind that is used to support shelves. My L-braces have arms that are 2 inches in length (that's 5.08 centimeters in length) and 5/8 inch in width (that's 1.59 centimeters in width).



(Above) An L-brace whose arms are 2 inches (5.08 centimeters) in length shown with a ruler that is 12 inches (30.5 centimeters) in length. Such an L-brace can shape the plastic of a food carton to accommodate a mask wearer's nose.

Below are photos of an L-brace narrowing the truncated end of a food carton that held 32-ounces (0.91 kilograms) of cottage cheese. If the L-brace does not narrow the plastic enough, the best remedy is to add material to the ends of the L-brace's arms and try again.



(Above) An L-brace is attached to a truncated 32-ounce (0.91 kilogram) food carton and shapes the end of the carton to accommodate the wearer's nose. However, a sharper bend in the plastic would be desirable.



The above photograph shows the previous photograph from a different angle.



The above photograph shows an L-brace with tape attached to the ends of the arms. The purpose is to sharpen the angle of the nosepiece.

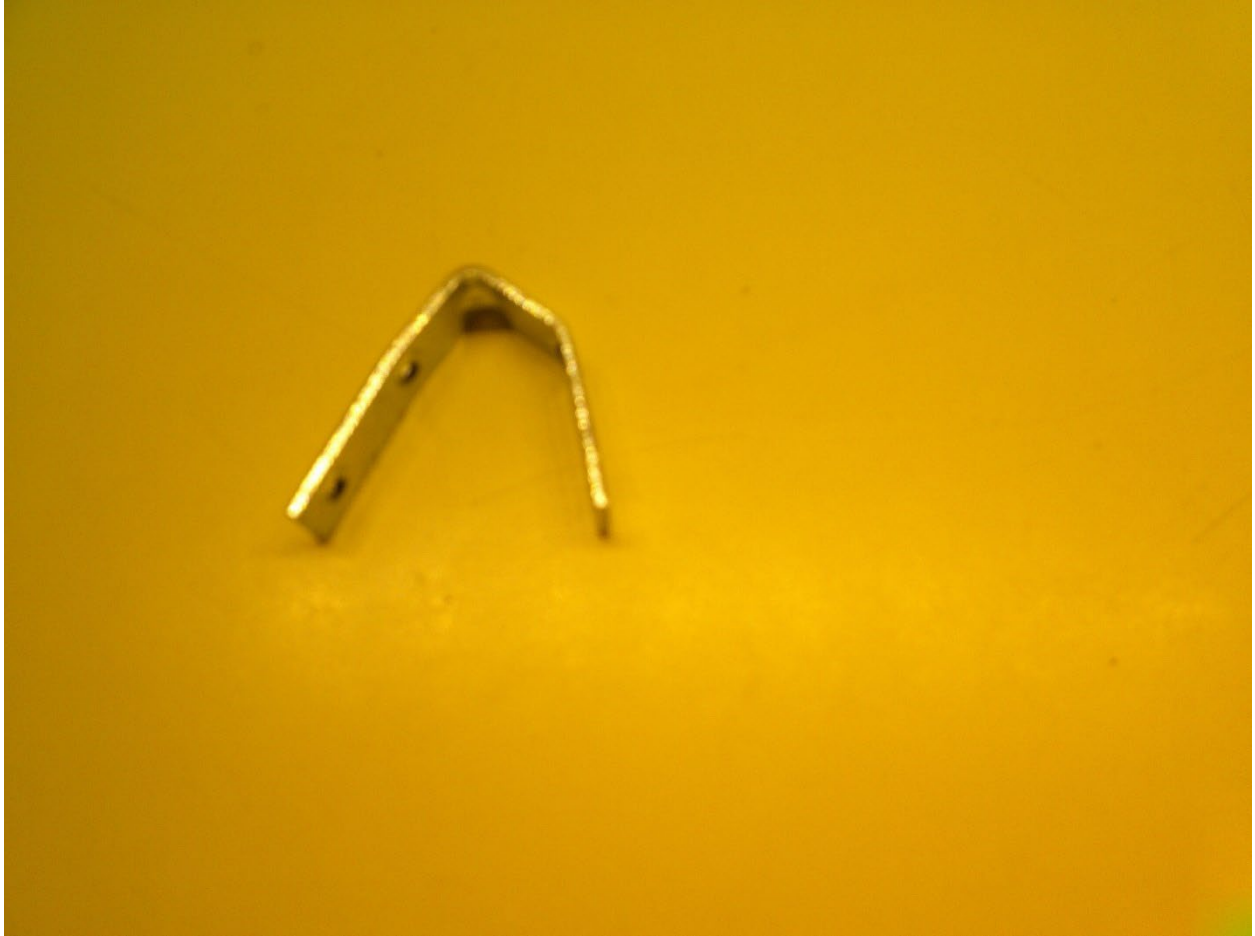


(Above) A plastic carton with a portion narrowed by a padded L-brace. More padding could be added to the L-brace if necessary.

It may be possible to narrow the angle of an L-brace by bending it. However, I had difficulty in bending the arms of an L-brace, and the L-brace that I was able to bend, bent unevenly. See the photographs below.



(Above) An L-brace before an attempt to bend it.



(Above) An L-brace after an attempt to bend it. Although one arm of the brace was bent, bending is difficult to control.

You can shape a nosepiece using metal from empty cans. The third method of shaping the plastic of a carton into a nosepiece is to make an artificial frame using cans that have been used to store food. Cut a 5-oz (142 gram) can of tuna fish or some other food into halves. In my experience, you will need **metal snips** to cut the cans. Neither wire cutters nor hacksaws are adequate. Be careful, the metal points and edges are sharp! Wear gloves and even a face shield or goggles.



(Above) Metal snips will be needed to cut the various kinds of cans needed for material that to create the facemask nosepiece.



(Above) An empty can that held 5 ounces (142 grams) of tuna fish. This is a source of metal that can shape the plastic of a food carton into a nosepiece.



(Above) Cut the can in half. Metal snips will probably be required.



(Above) Remove the bottoms of the two can halves shown above.



(Above) Here are the two halves of the can after the bottoms have been removed.



(Above) This photograph shows the two halves of cans from the previous photograph but bent in the shape of a nosepiece.

Most cans have a reinforcing seam around the top of the can. When assembling halves of cans, put these seams opposite each other.



(Above) Most food cans have a reinforcing seam around the top of the can. This seam is useful in shaping plastic into a nosepiece.



The above photograph shows the two halves with the seams at the extreme left and extreme right.



The above photograph shows the same two can halves, but with one resting atop the other. The seams are on opposite sides of the pair.



The above photograph shows the can halves taped together with vinyl electrical tape. The seams are on opposite sides of the arch. The can halves are from the previous photograph.



(Above) The frame from the previous photograph was used to create a nosepiece in the plastic of a 32-ounce food carton.

Empty sardine tins are also useful. In my experience, it takes all four corners of a sardine tin combined to make a sturdy frame.



(Above) An empty tin of sardines can supply material to shape a nosepiece.



(Above) Cut the sardine tin into quarters.



(Above) Use metal snips to remove the tops and bottoms of the cans, leaving only the bent metal of the corners.



(Above) Tape bent metal corner together as pairs.



(Above) Combine the two pairs of corners from the photograph above to form a four-layer mold that can bend the plastic of a food carton into a nosepiece.

It is possible to make a frame for a nosepiece from the tops of aluminum soft drink cans. The aluminum walls of the cans are thin enough to be cut with ordinary scissors, but metal snips are necessary for the remaining steps.

First, use scissors or metal snips to remove the top of the can. Then, cut the top in half with metal snips. From these two halves, remove all but the reinforcing ring metal. Tape the ring halves together with vinyl electrical tape. Use the taped rings as a frame to shape a nosepiece.



(Above) Empty soft drink cans can provide material to shape a nosepiece.



(Above) Cut the top of a can loose from the remainder of the can. Then, cut the top of the can in half.



(Above) From the two halves of the can top, remove all but the metal of the reinforcing top ring.



(Above) Tape the two metal pieces together.



(Above) Add more tape to the metal pieces shown in the previous photograph.

The picture below shows the final mask airspace but with some of the weather stripping removed to make the nosepiece easier to see. The walls of the cans are too flimsy to be useful. Even a combination of 16 strips of aluminum from the walls of two cans is not strong enough.



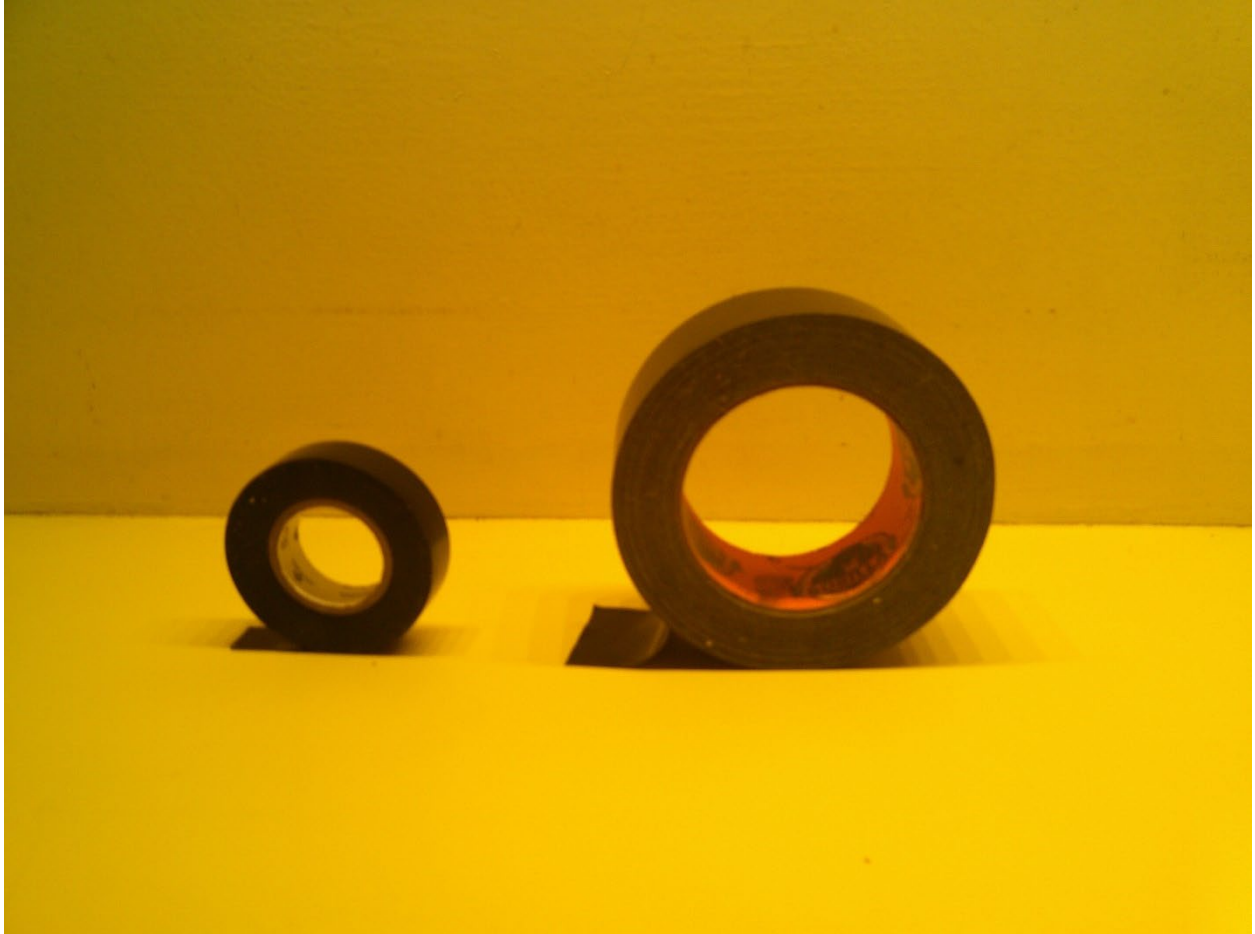
The photograph above shows a mask airspace with weather stripping and a nosepiece made of reinforcing rings from soft drink cans. In a serviceable mask, the weather stripping would extend to the nosepiece making an airtight contact.

Padding of the Facemask for Contact with Human Skin

Weather stripping or paper towels plus tape. Weather stripping can be used to pad the edges of a facemask, creating a tight junction between the mask and the wearer's skin. If weather stripping is unavailable, a rolled-up paper towel covered with duct tape or vinyl electrical tape can be used instead.



(Above) Weather stripping and a roll of paper towels. Both can be used to pad the edges of a facemask. Weather stripping is more comfortable and more effective at sealing the mask against unfiltered air.



The above photo shows **vinyl electrical tape** (left) and **duct tape**. Rolled-up paper towels, wrapped with these two types of tape, can protect and seal the edges of a facemask.

Pad the edges of the mask. Pad the edges of the mask with weather stripping. If the weather stripping binds tightly to things, you can add more than a single layer. If you do not have weather stripping, use a rolled-up paper towel that has been covered with vinyl electrical tape or with duct tape.

Over time, the weather stripping may peel away from the plastic. You can prevent this by using vinyl electrical tape to attach the weather stripping firmly to the plastic.



Weather stripping can pad the edges of a facemask. Weather stripping and the flesh of a person's face are both soft and pliable—which is very helpful in preventing unfiltered air from entering the mask.



If weather stripping is unavailable, a rolled-up paper towel covered with duct tape or vinyl electrical tape can substitute.



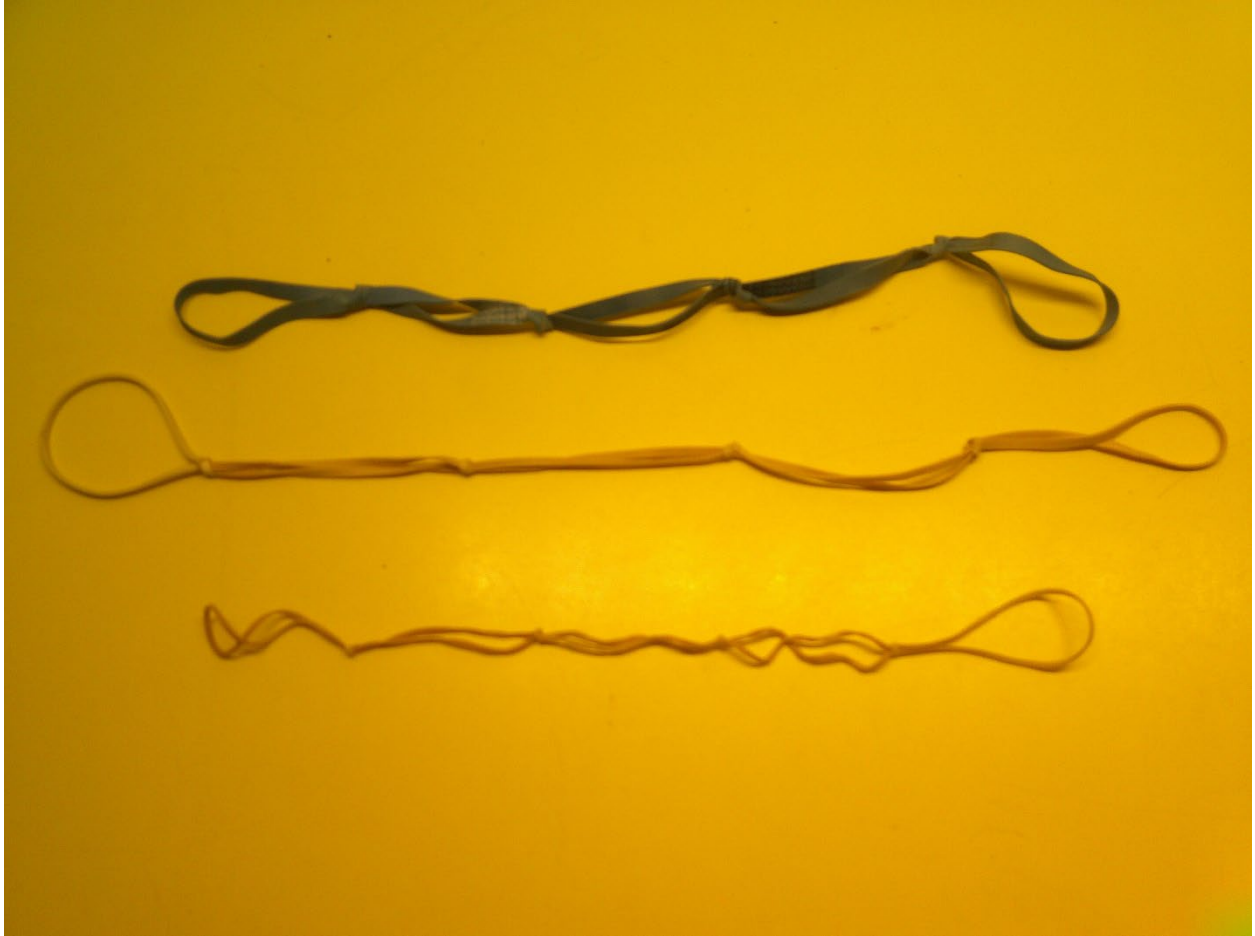
Although weather stripping is sticky on one side, its stickiness may need to be supplemented with vinyl electrical tape. The blue mark in the photograph above identifies a strip of vinyl electrical tape holding weather stripping in place in a facemask.

Adding of Rubber Band Straps

Chaining rubber bands together. In order to exclude unfiltered air, the mask must be pressed tightly against the mask wearer's face, which will require use of a **rubber band** strap. A rubber band strap can be made by chaining rubber bands together. It is important that the rubber bands be attached securely to the mask frame so that the mask does not fall off of the wearer's face.



(Above) Chained rubber bands can form a rubber band strap to keep the mask pressed against the wearer's face.



(Above) Several different sizes of rubber band can be chained to form a useful facemask strap.

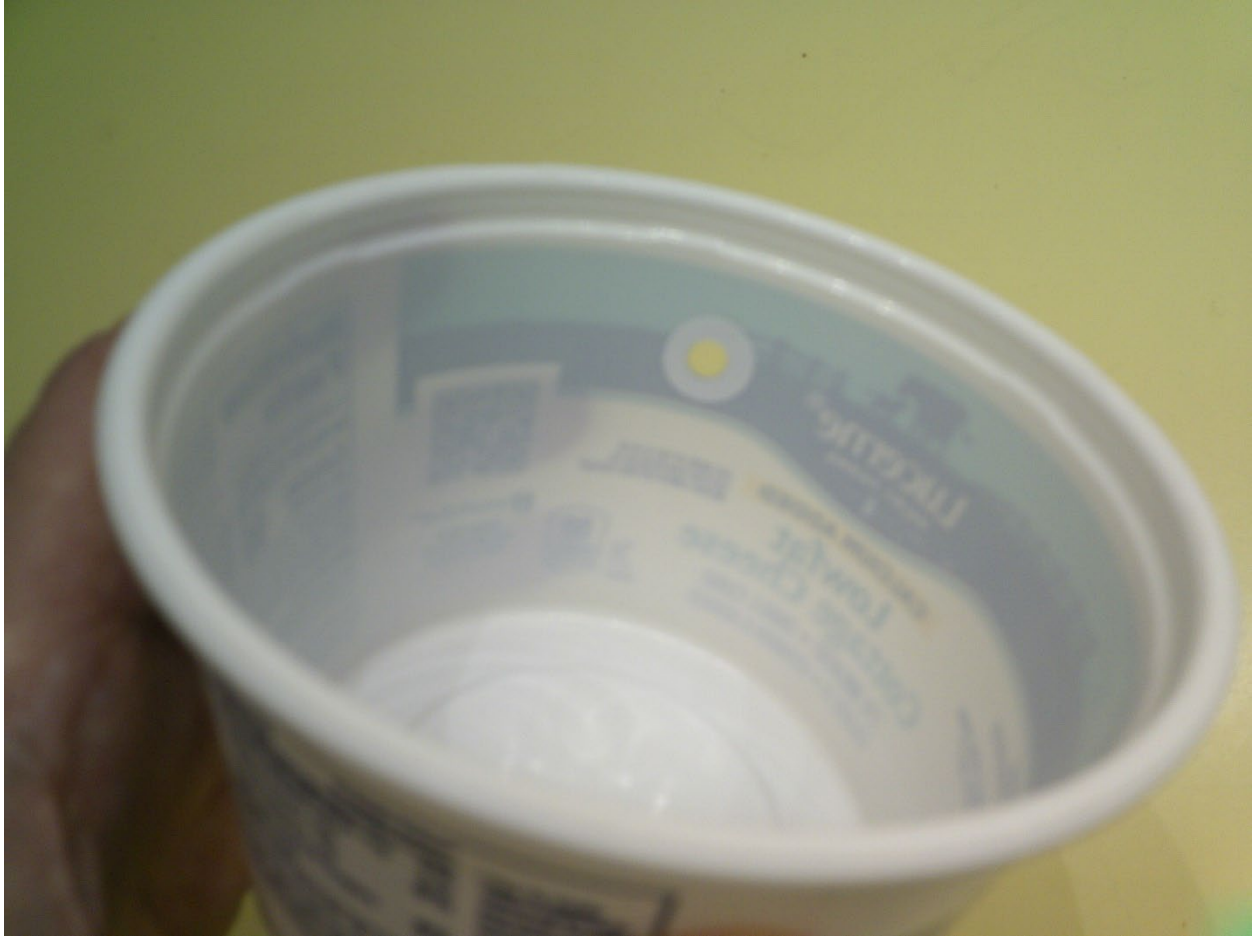
Anchoring the rubber band strap to the mask frame. One way to anchor the rubber band strap to the mask frame involves using a hole punch and a paper clip. The hole punch that I use for this purpose creates a hole of 1/4 inch (6.35 millimeters) diameter.



A hole punch can be used to make a 0.25-inch hole in the side of a plastic carton. The above photo is of a plastic carton that is smaller than I recommend for mask use, but it illustrates the point.



The above photo shows a punched hole in the side of a plastic carton.



(Above) The punched hole can be reinforced with a reinforcing ring intended for notebook paper.



(Above) It is better to reinforce the hole on both sides of the plastic wall.

The above four photos are of a plastic carton that is smaller than I recommend for mask use, but they illustrate the point. First, punch a hole where you want the rubber bands to go. Then, reinforce the edges of the hole on both sides of the carton wall with reinforcement rings if you have them. Further reinforce the edges of the hole with vinyl electrical tape.

Push a rubber band through the hole and attach a large paper clip to it. Alternatively, a squeeze fastener will also suffice.

Tape the paper clip or squeeze fastener to the wall of the carton.

After attaching the rubber band strap, use tape to tightly seal the hole to make it airtight.



(Above) A large paper clip can be used to anchor a rubber band strap to a mask.



(Above) A squeeze fastener can be used to anchor a rubber band strap to a plastic facemask.



(Above) Two **squeeze fasteners** shown with the squeezing pliers.

Anchoring multiple rubber band straps. When large **paper clips** are used, it is possible to attach more than one rubber band strap to each paper clip, and thus create a mask with two or more rubber band straps. A mask with two rubber band straps will fit the wearer's face more tightly and will not come off if one of the straps breaks for some reason. Notice that it is important to chain the rubber bands symmetrically so that both sides of each link are about equal in length. In one of the straps shown, I failed to do this with the rubber band closest to the mask.

Use vinyl electrical tape to tape the large paper clips securely to the walls of the mask (see the photo).



(Above) A facemask with 2 visible straps. Note that I neglected to chain symmetrically the rubber band closest to the mask. Avoid this and instead make sure that the rubber band connections are symmetric.



The above photograph shows the inside of a facemask. Notice that the anchoring paper clip is taped securely and airtightly to the inside wall of the mask.

Anchoring rubber band straps using an office stapler. It is also possible to attach the rubber bands using a **stapler**.



The photograph above shows a stapler with staples (left) and rubber bands (right). The rubber bands are chained together ([see text above](#)) to create a rubber band strap. The staples can be used to attach a rubber band strap to the facemask.

Protecting rubber bands from staples. It is very important not to penetrate a rubber band with a staple, because this will increase the chances that the rubber band will break. If a rubber band is flat, you can protect it from damage caused by the flat part of the staple by wrapping the rubber band with vinyl electrical tape (see photo below).

The photograph below shows a flat rubber band wrapped in two places with vinyl electrical tape.



(Above) A flat rubber band wrapped with vinyl electrical tape in two places and taped to a surface by a third piece of vinyl electrical tape. The tape wrapping can protect the rubber band from the flat part of a staple that attaches the rubber band to the plastic of a facemask.

Staples will usually penetrate the plastic wall of a carton, but not if the carton wall is covered with tape. The stapler can be used flat. However, if you do this, you will have to bend the staples on the inside of the carton, which can be difficult.

Below is a six-staple pattern that can securely attach a rubber band chain to a plastic carton. If you use staples, cover them with tape to hold them in place and to prevent air from entering the mask around the staples.

Positions of staples are indicated with black marks



The above photograph illustrates how staples can attach a flat rubber band to a plastic carton. The black marks indicate where the staples straddle the rubber band.





The above two photographs show the author wearing a mask attached to his head by a rubber band strap. The cover of the carton, with the filter matrix fastened to it, is attached to the carton in the photograph. How to attach the carton cover to the carton is explained immediately below.

Attachment of Filter Matrix to the Mask Frame and Finishing Touches

Seal the plastic cover to the mask frame. Before attaching the plastic carton cover to the mask frame, use a turkey baster, an eyedropper, or a syringe (without a needle) to add liquid rubber cement (or another liquid adhesive) to the groove that rings the lower surface of the carton cover. Then, attach the mask frame before the cement dries. It is better to have added the [nosepiece](#) to the mask frame before this is done.

The purpose is to prevent any respiratory droplets that have moved sideways under the plastic carton cover from escaping into the mask air space. The rubber cement may seal the crack between the plastic carton cover and the first cardboard layer.



(Above) After the filter matrix is attached to the plastic carton cover, but immediately before the filter matrix assembly is attached to the mask frame, add rubber cement or other adhesive to the groove between the filter matrix and the rim around the plastic carton cover. The red arrow in the above picture indicates the groove. The middle object is a syringe without an attached needle.

Attach the carton cover to the carton. Attach the cover of the carton, including the matrix with cigarette filters, to the carton. Then, use tape to make the seal airtight.



The above photo shows a facemask matrix seen from the inside. It is attached to a carton cover which will snap onto the front of the mask.



The above photograph shows a plastic food carton with the bottom one-inch removed. After the carton is modified to create a mask frame, the filter matrix/plastic carton cover shown in the previous photograph will snap onto the carton's top.



The above photo shows a plastic carton cover / filter matrix attached to the airspace of a facemask.



Use adhesive tape (**masking tape** is a good choice) to seal the plastic carton cover / filter matrix to the airspace of the mask. Make sure that the seal is airtight.

Obtain two green nylon scouring pads. At least in the USA, **nylon scouring pads** are typically colored green and have dimensions of 4 inches X 5.5 inches (10 cm X 14 cm). When clean and dry, they are very permeable to air. Two such pads will be needed to construct a facemask. The purpose of the first pad is explained in this section. The purpose of the second pad is explained [here](#) .



The above photograph shows two scouring pads made of green nylon.

Insert a green scouring pad into the air space. Cut a green scouring pad so that it is the same shape as, and slightly smaller than the front of the mask. Then, insert the cut green scouring pad into the mask air space. If you do not have a green scouring pad, an air purifier pre-filter or a stiff wire screen may be adequate.

The purpose of this is to prevent cigarette filters from choking mask wearers if the filters slip out of the filter matrix. In my experience, the filters are anchored securely, especially if 2-sided carpet tape is used to construct the filter matrix, but other people may have different experiences.



The above photograph shows an intact green nylon scouring pad (upper left), a green nylon scouring pad that has been trimmed to fit into a facemask (upper right), the scissors used to trim the scouring pad (lower left) and the plastic carton cover / filter matrix of the facemask (lower right) as a size reference.



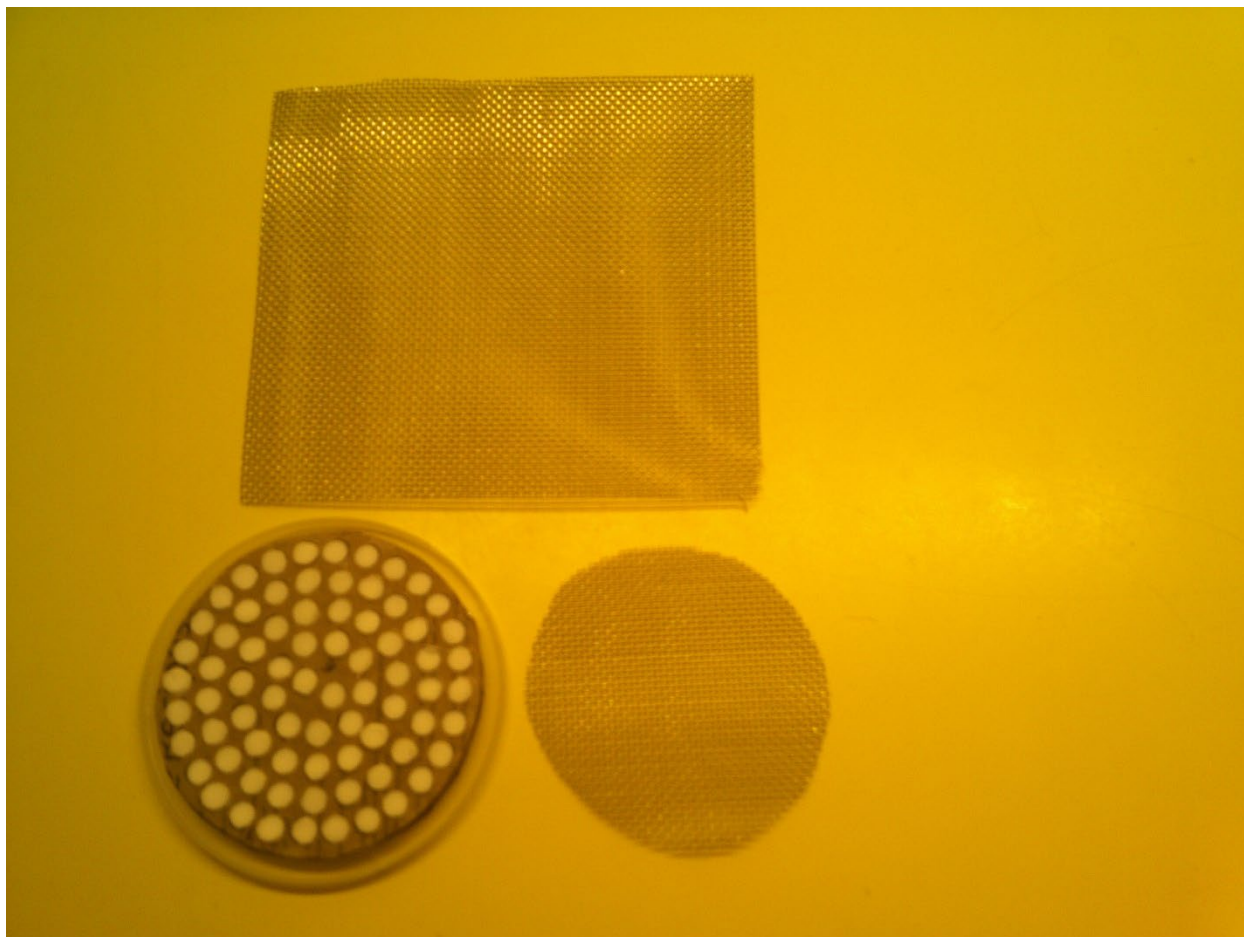
(Above) The trimmed green scouring pad should be inserted into the facemask.



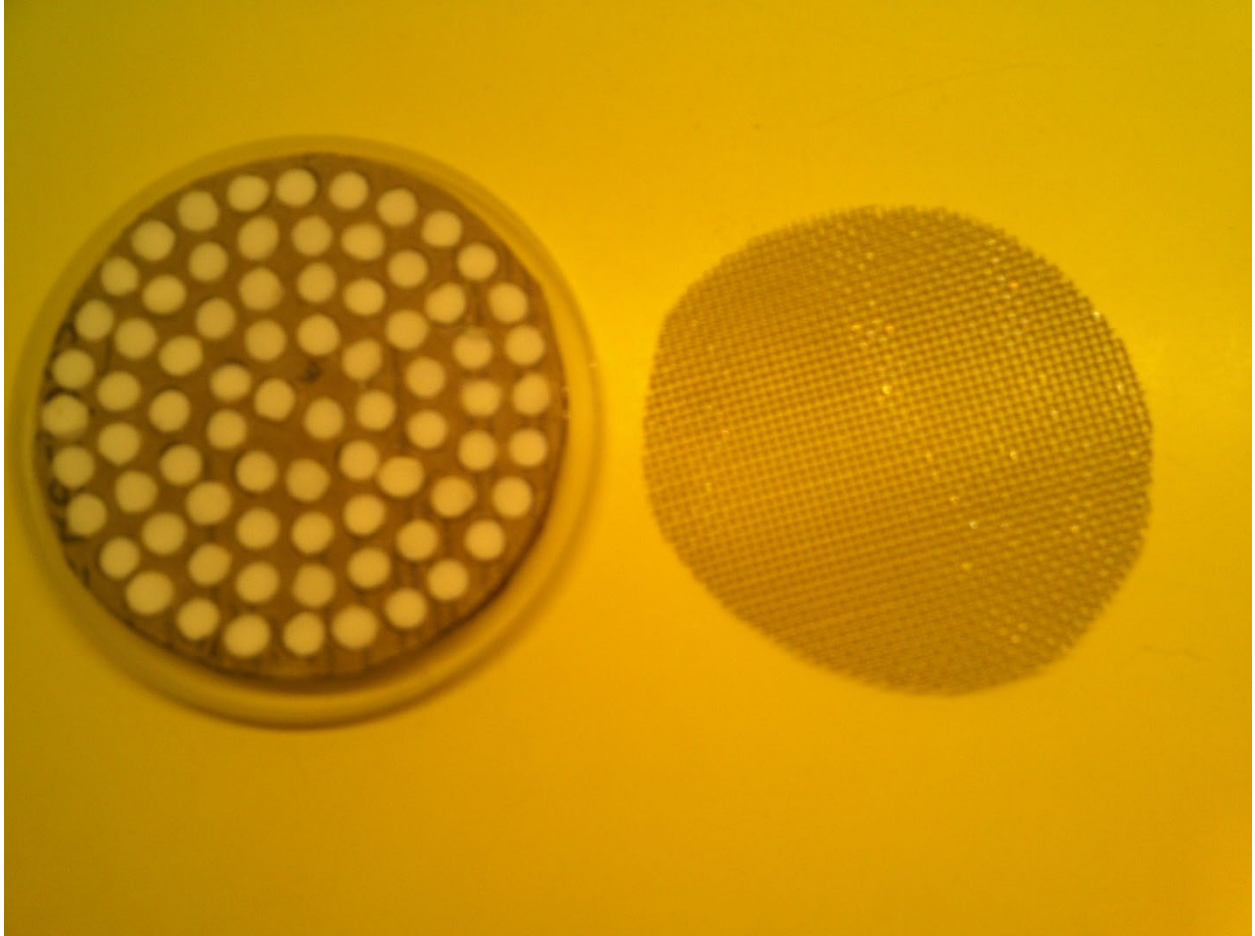
In the above photograph, I am shining a small flashlight into the facemask where the trimmed green nylon scouring pad is installed. The nylon pad is soft and permeable to air; it will prevent the mask wearer from choking on any filters that might come loose from the filter matrix—although, in my experience, filters have never come loose.



The above photograph shows a **folded pre-filter** for a furnace (above), a patch cut from that pre-filter (lower right), and a plastic carton cover / filter matrix of the facemask (lower left) as a size comparison.



The above photograph shows a **stiff wire screen** (top), a circle cut from that screen (lower right) and a plastic carton cover / filter matrix of the facemask (lower left) as a size comparison. Although less suitable than the trimmed green scouring pad or the trimmed furnace pre-filter, the stiff wire screen can be inserted into the facemask to prevent the mask wearer from choking on loose filters. As stated several times in this report, in my experience the filters are securely anchored and have never come loose.



The above photograph shows the stiff wire screen at a greater magnification.

Check the mask for airtightness. Following this, check the mask for airtightness. Use a piece of plastic wrap, or something else to cover the filter array and check the airtightness of the mask.



(Above) Wrapping the front of the facemask with plastic wrap allows one to check the facemask's airtightness.

Adding a Test for Mask Failure Caused by Wicking

The purpose of a layer of food color. The Bugeye Facemask will stop protecting against intruding fluids, including respiratory droplets, if enough moisture accumulates in a filter to allow capillary action (also known as “wicking”). However, a layer of porous material soaked in blue food color can alert a mask wearer that that wicking is occurring and that the mask is no longer reliable. If wicking occurs, the blue food color will be transported through one or more filters and will appear on the inside of the mask.



The photograph above shows blue food color. Blue food color can be used to detect loss of facemask integrity caused by capillary action (wicking).

How to create the layer of blue food color. To add this feature to a facemask, I use blue food color and a coffee filter, but a roll-type paper towel can replace the coffee filter. Kleenex tissue, Swiffer mop material and Handi-Wipe cloth are less satisfactory or unsatisfactory.

Add the food color to the paper coffee filter or paper towel using an eyedropper. The food color should spread quickly through the paper. It dries quickly at 200 °F (93 °C).



(Above) A layer of porous material soaked in blue food color, can alert a mask wearer that the mask is no longer screening out respiratory droplets. This happens if enough moisture accumulates in the mask to support capillary action (wicking) in the filters.



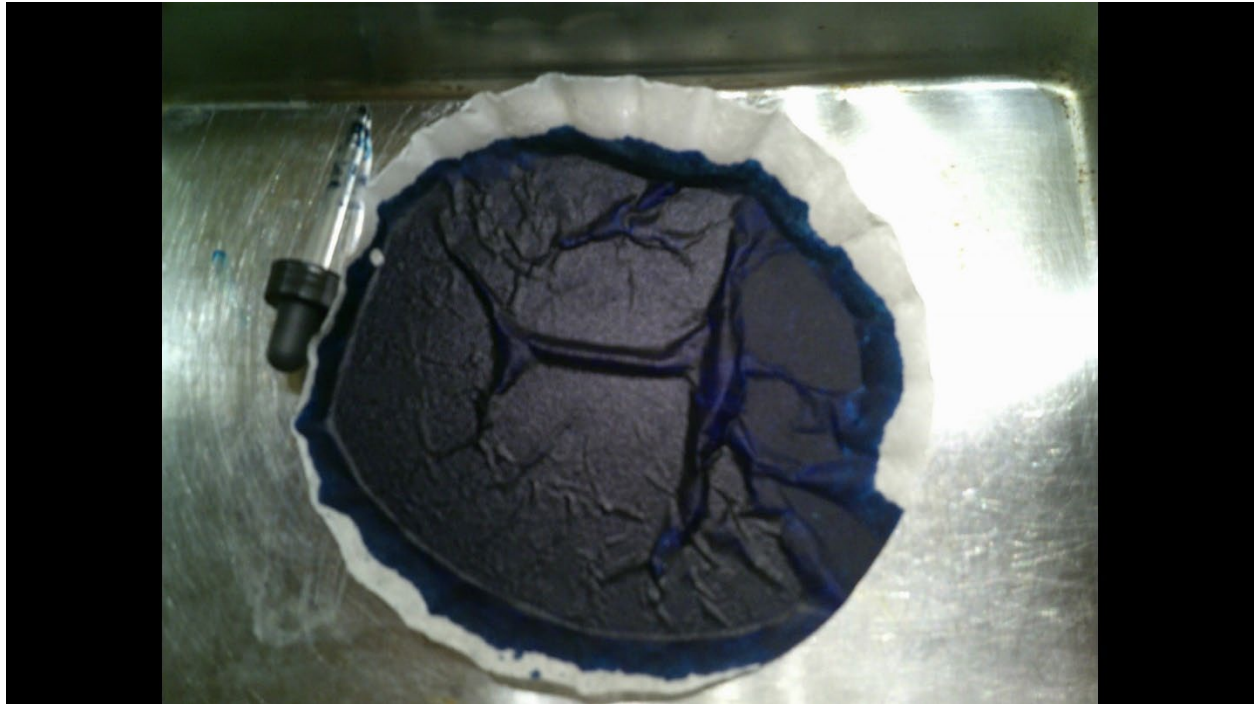
(Above) I create such a layer using commercial blue food color and a **coffee filter** as shown in the above photograph.



(Above) A paper towel from a roll of paper towels can be used in place of a coffee filter. (Compare with the previous photograph).



(Above) Add blue food color to the coffee filter using an eyedropper.



(Above) Saturate most or all of the coffee filter and then dry the filter briefly in an oven under low heat.

Attach the layer of blue food color to the front of the mask. The way that I attach the layer of blue food color to the front of the mask is as follows. Place the blue layer over the front of the mask. Then, add a green scouring pad that has been cut to the size of the mask. Then, add netting of some kind, such as flexible fiber replacement for window screens. Use one or more rubber bands to hold all of these components in place.



You will need four components: the facemask (upper left), the coffee filter (upper right), a green nylon scouring pad cut to a round shape (lower left), and **flexible netting** (lower right).



(Above) First, drape the coffee filter over the mask.



(Above) Second, add the circularized green scouring pad.



(Above) Finally, cover the front of the mask with flexible netting and fasten the arrangement in place with a rubber band. The flexible netting and the green scouring pad will push the blue-soaked coffee filter against the front of the filter matrix.

When to check for mask failure. If you have been exposed to rain or high humidity, be sure to remove the green scouring pad from the inside of the mask and check the insides of the filters for blue food color.

Further Development of the Bugeye Facemask

Confirm effectiveness against live virus. Although cellulose acetate filters immobilize food color carried by aerosol droplets, the filters have not been shown to immobilize SARS-CoV-2 and other viruses carried by similarly sized respiratory droplets. Hence, the next step should be to test the filters' effectiveness against live virus in authentic respiratory droplets, or at least against live virus in droplets of physiologic saline.

Masks from stamped plastic. If cellulose acetate filters are indeed effective in removing SARS-CoV-2 from inhaled air, it may make sense to construct better facemasks made of machine-stamped plastic. Such facemasks would be far less laborious to construct, could be much more reliably airtight, and could include many more filters to transmit inhaled air through.

Pads of cellulose acetate. If cellulose acetate can remove SARS-CoV-2 virus from inhaled air, then it makes sense to manufacture it in larger pads, so that filters and filter matrices are not involved. The ideal antiviral facemask might consist of a large pad of cellulose acetate encased in a flexible fabric that was impermeable except where air was intended to enter.

Cellulose acetate filter tow is manufactured in multiple varieties and sold in large quantities. Hence, obtaining samples for experimentation may be difficult, but should be pursued.

Waste cellulose acetate. It is also possible that waste cellulose acetate filters can be disaggregated and reconstituted and then used in masks. It is uncertain whether reconstituted cellulose acetate would trap respiratory particles while allowing air to pass because, although the chemical structure of the reconstituted cellulose acetate would remain the same, its larger physical structure would be changed.

Cellulose acetate litter in the form of used cigarette filters is a major problem in many countries, and there plenty of it available. I have [linked](#) to a video of two men in India who collect discarded cigarette filters, clean them, and use them in air

purifiers. In addition, here is a [link](#) to a second company that converts used cigarette filters into useful products.

Facemasks for all who need one. With is sustained effort, it might be possible to supply everyone on Earth who needs a facemask to prevent communicable respiratory disease. It is a goal worth striving for.

About the Author

I am a retired molecular biologist. I believe that US national policy on technology and manufacturing should change to enable individuals and small groups of people to become more self-sufficient and more resistant to widespread misfortune. The Bugeye Facemask described in this report may become an example of a widely useful technology that does not depend on massive corporations and armies of PhDs. However, I must emphasize that I have NO training in any medical or healthcare profession and no training in bioengineering or any other branch of engineering, and that the Bugeye Facemask has not been proven effective.

Addendum on January 23, 2023

The cellulose acetate of cigarette filters is not hygroscopic enough to become wet from moisture in the air, but it is highly wettable. If a cigarette filter is held vertically over a container of water and one end of the touched to the surface of the water, water will travel up the cigarette filter and soak the entire filter within a second or two. The same will happen if the water is replaced by commercial liquid blue food coloring. Hence, it seems likely that the filters will remove water from respiratory droplets that enter the filters. The remaining liquid in the droplets might bind both the solids in the droplets and the cellulose acetate of the filters, thus immobilizing the droplets.

Appendix – Printable Template

