Associate Professor in Biological Sciences at NC State

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Co-founder PhotoCideProtection, Inc.

PhotoCide
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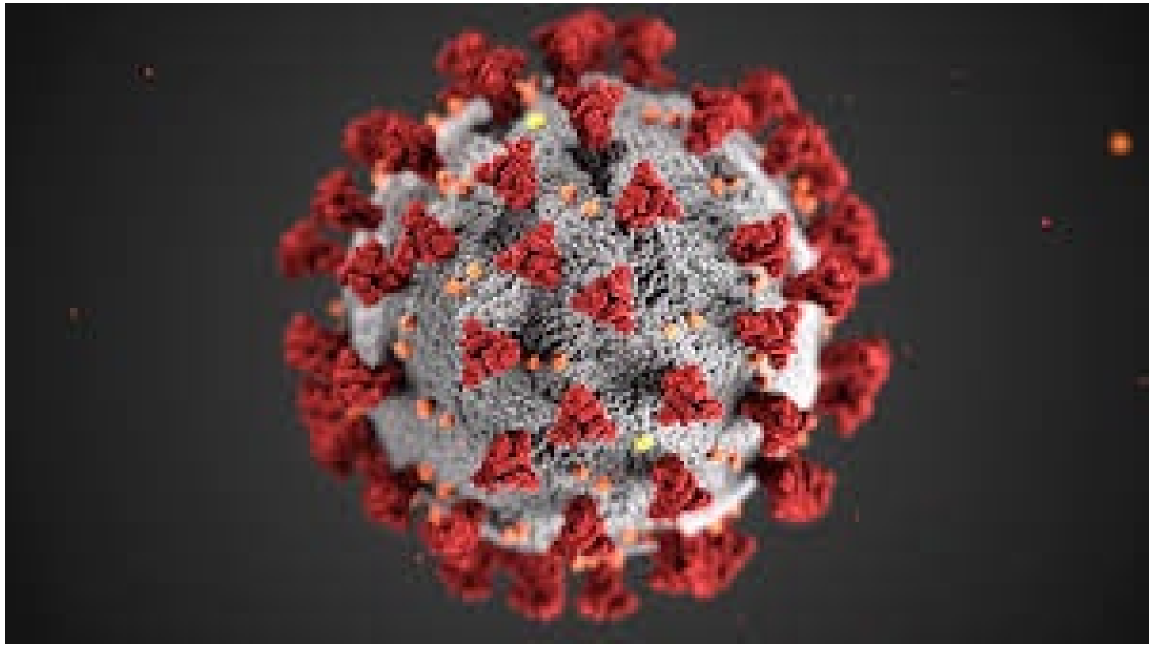
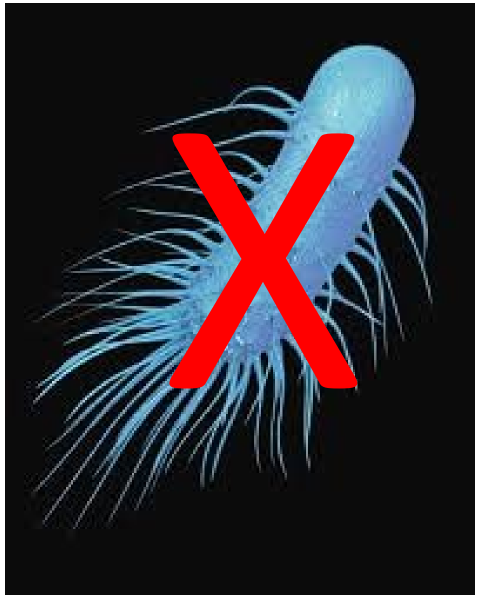
What are Viruses?



What are Viruses?

- Viruses are NOT small bacteria
- They are not organisms
- They are completely dependent on a host
- They need to infect the cells of the host to replicate
- Without a host a virus will die out



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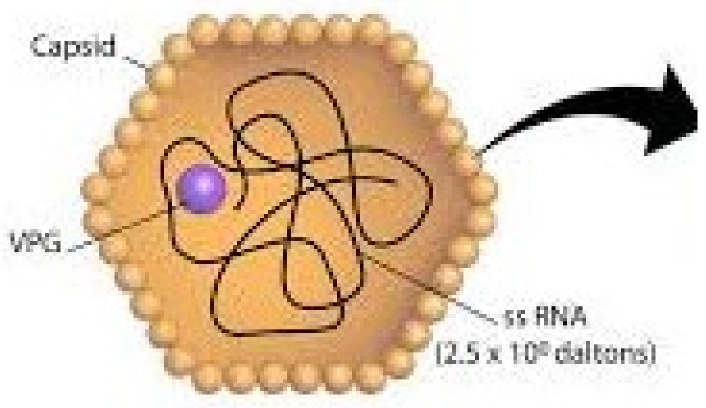
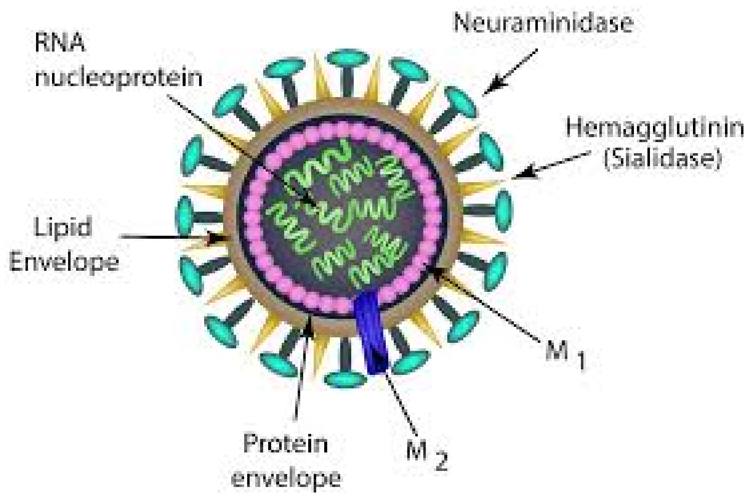
Rhinovirus: common cold



The simplest viruses consist of genetic material, their genome, covered in a protein shell. The protein shell is called the capsid.

Examples: Rhinoviruses, Hepatitis A, Norovirus

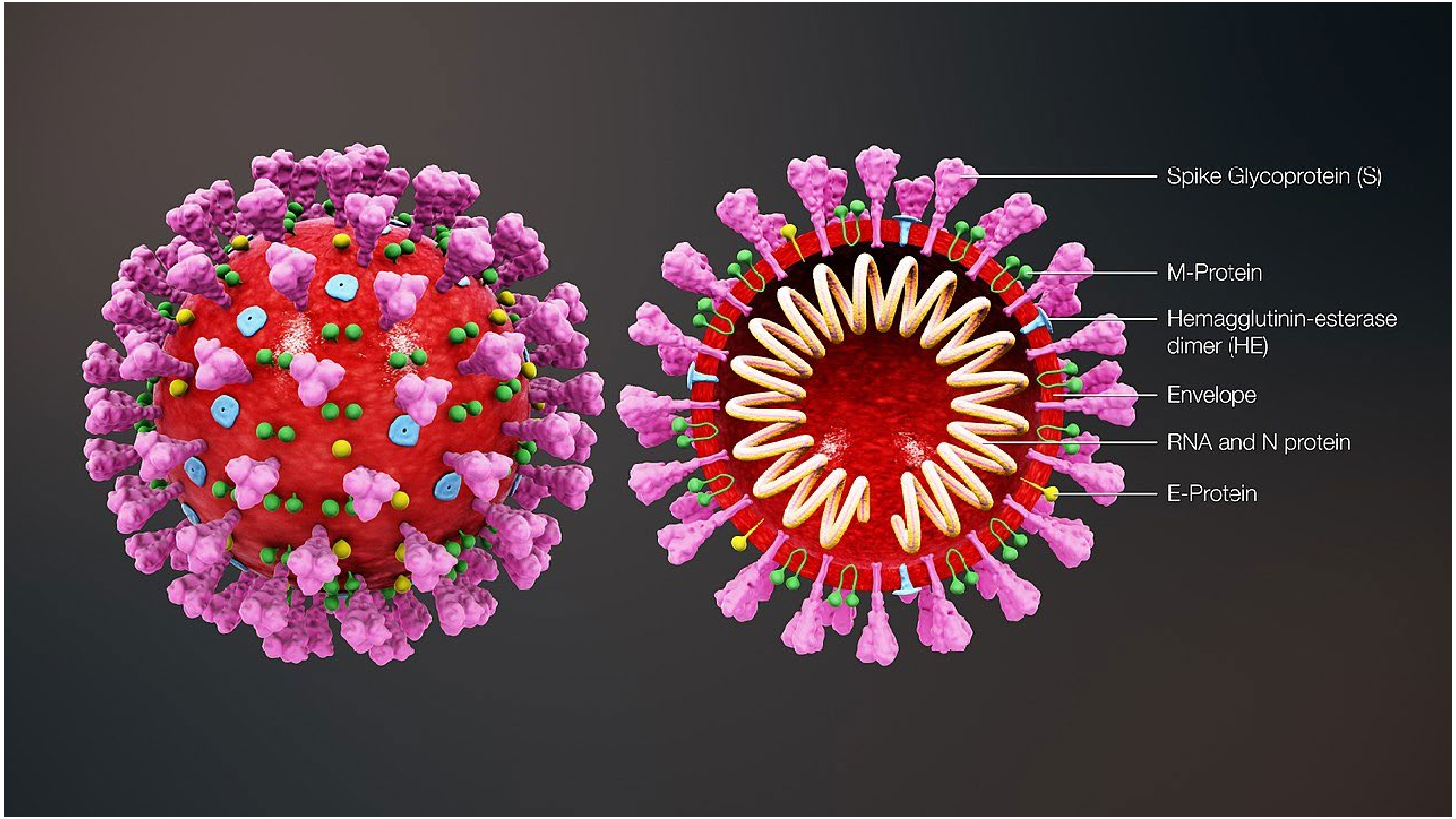


Influenza: flu

Other viruses are additionally covered in a fatty membrane, the envelope, that has virus proteins embedded in it. Capsids are inside the envelope.

Examples: Influenza, Coronaviruses

Coronavirus structure



What do virus genomes code for?

1. Structural proteins that make up the virus particle: capsid proteins, surface proteins and glycoproteins

2. Replication associated proteins to help amplify the virus genome during replication

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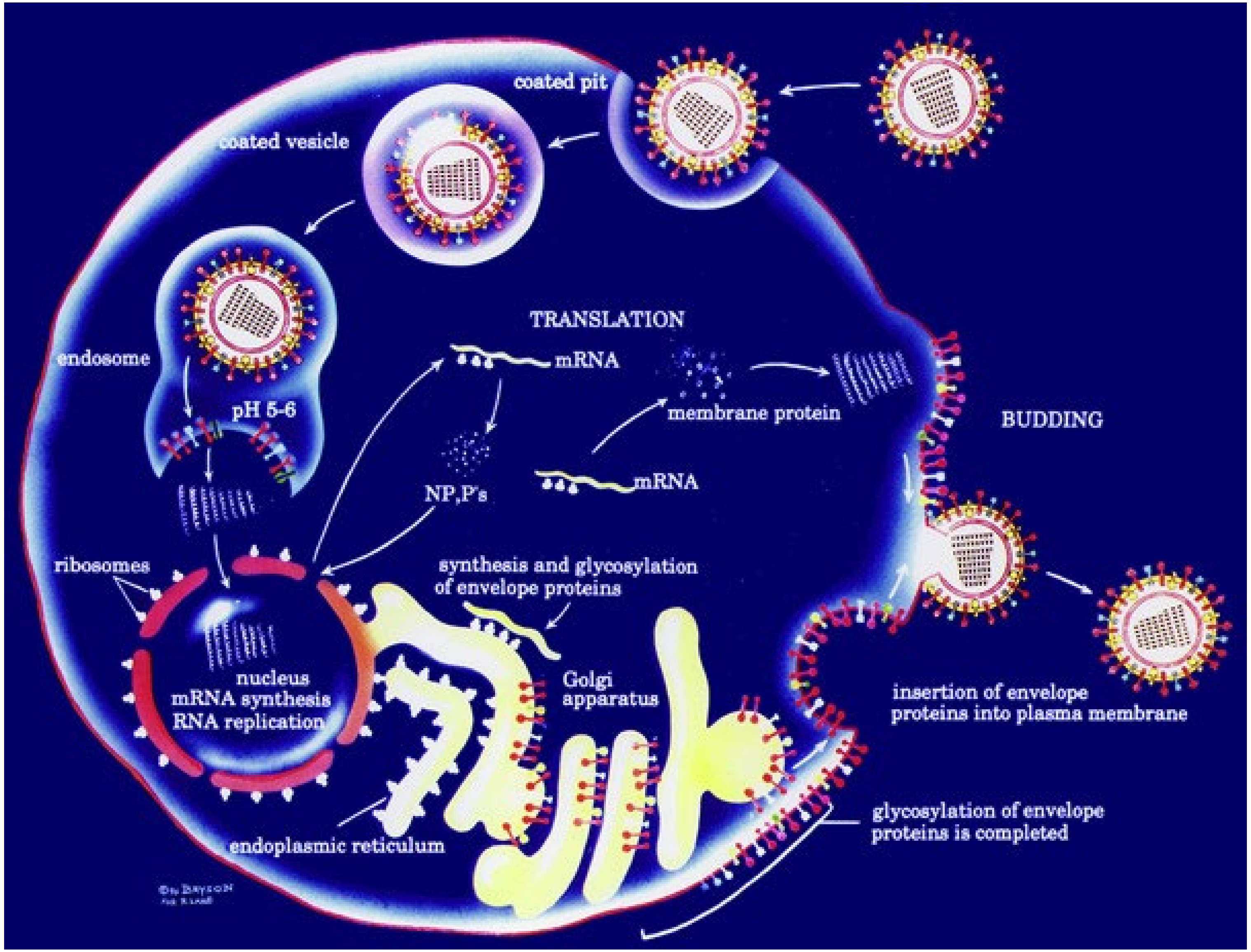
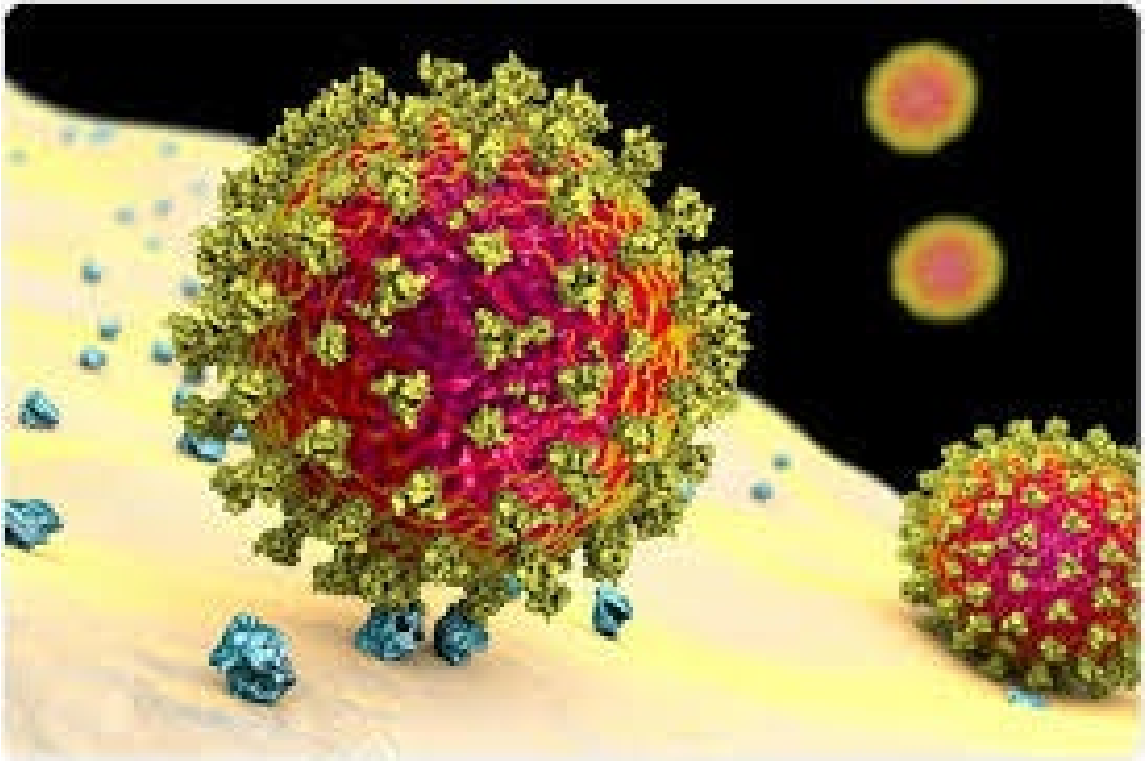


Virus infection cycle

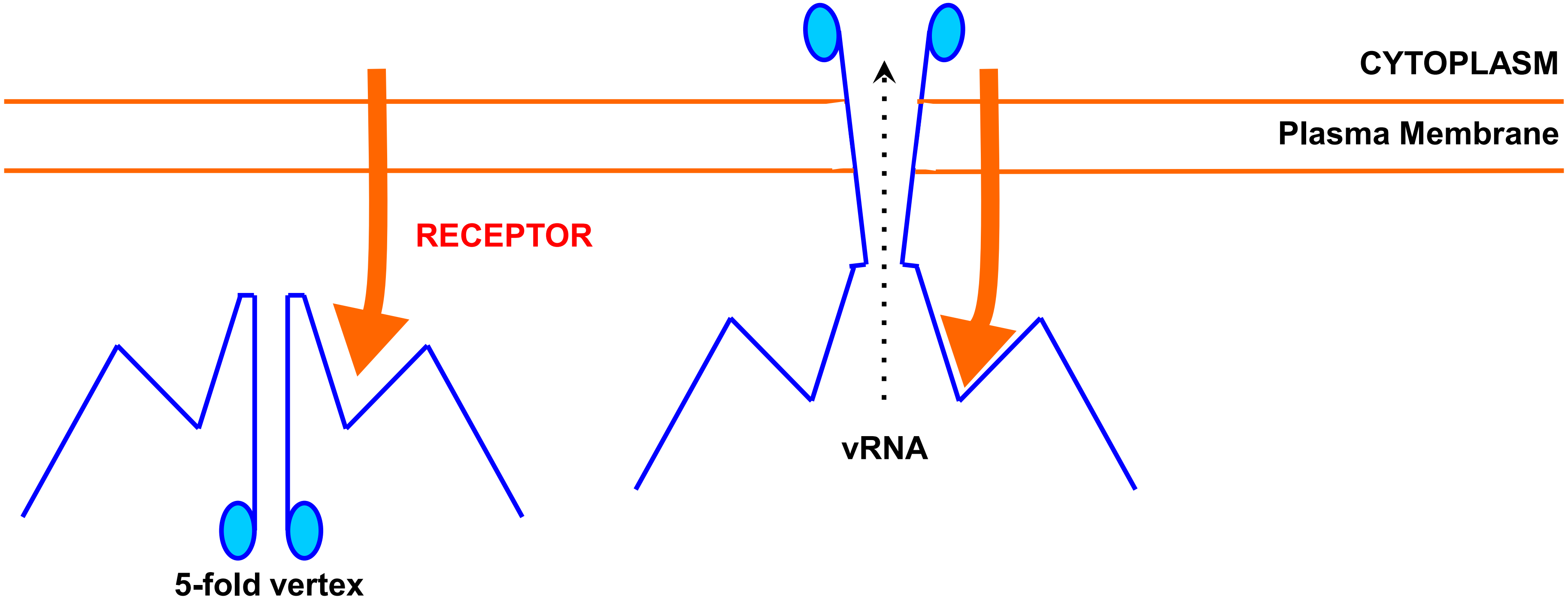
1. Attachment
2. Entry
3. Uncoating
4. Gene expression
5. Replication
6. Assembly and Release

ATTACHMENT

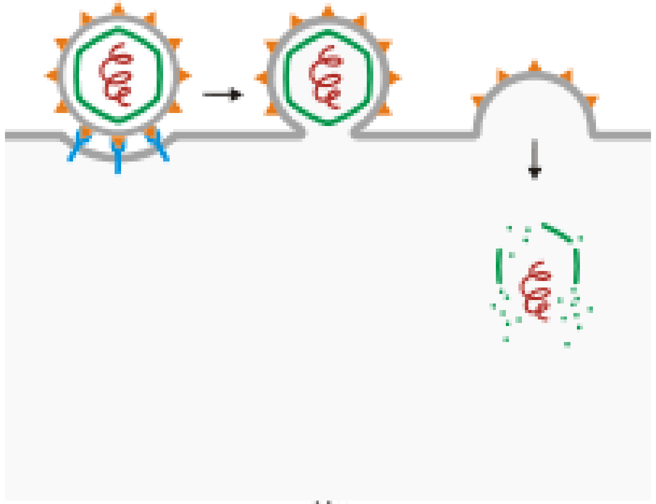


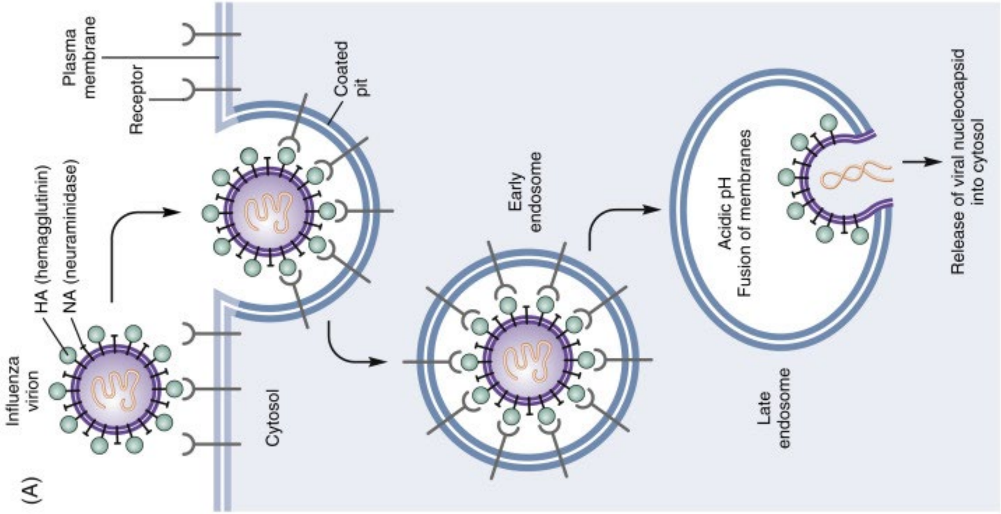
Specific interaction between a virus surface protein and host cell proteins on the cell surface

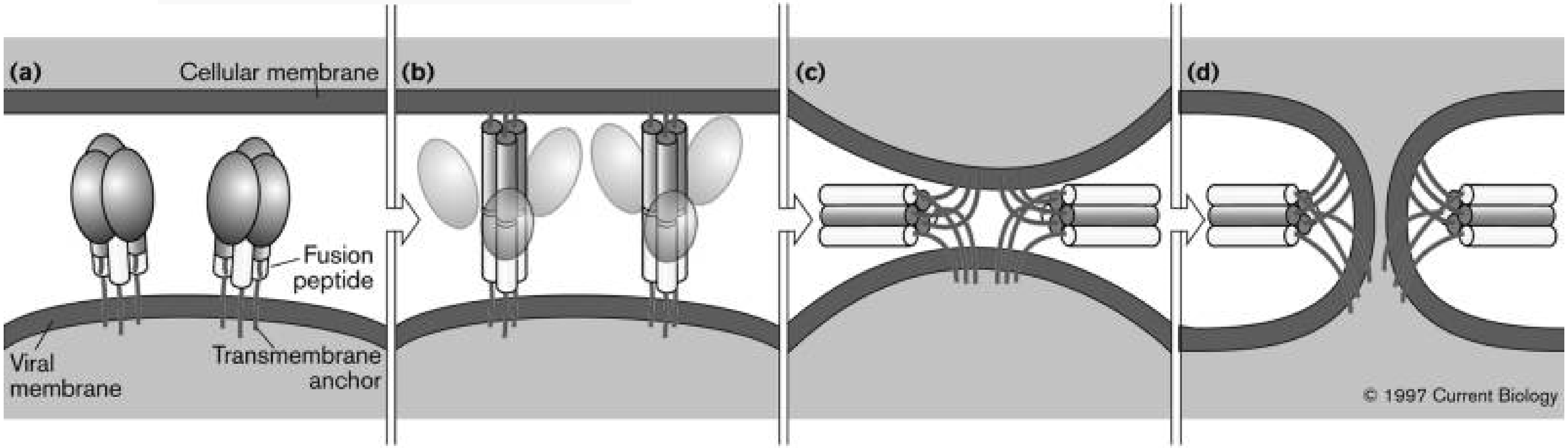
ENTRY: Non-enveloped Virus



ENTRY: Membrane Fusion of Enveloped Viruses







All remaining steps of the virus lifecycle are happening inside the host cell….that means we might be too late to interfere…..

Gene expression

Genome replication

Assembly

Egress

General considerations for PPE

Function	Pros	Cons
Barrier	Keeps wearer safe during exposure	Danger of exposure during doffing
Trapping ? (Filtration)	Keeps wearer safe during exposure (Trapping?)	Breathability? Effectiveness?
Inactivation	Keeps wearer safe during exposure. No danger of exposure during doffing.	Contact time?

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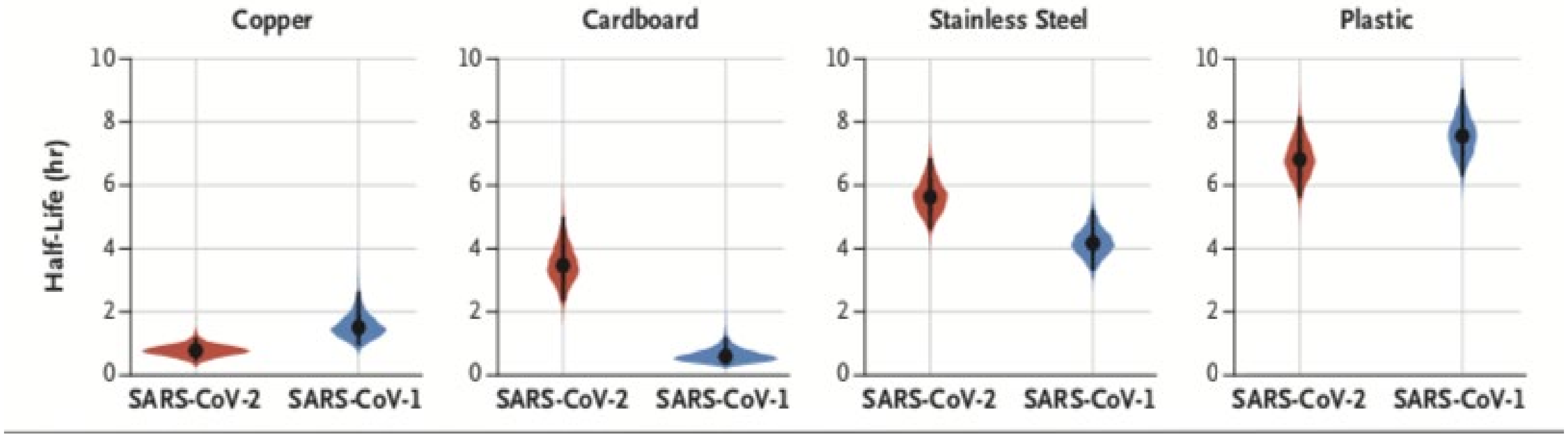
SARS CoV-2 Stability



van Doremalen N, Bushmaker T, Morris DH, et al. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. *N Engl J Med*. 2020;382(16):1564-1567. doi:10.1056/NEJMc2004973

Table II
Inactivation of coronaviruses by different types of biocidal agents in suspension tests

Biocidal agent	Concentration	Virus	Strain / isolate	Exposure time	Reduction of viral infectivity (log_{10})	Reference
Ethanol	95%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 5.5	[29]
	85%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 5.5	[29]
	80%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 4.3	[29]
	80%	MERS-CoV	Strain EMC	30 s	$>$ 4.0	[14]
	78%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 5.0	[28]
	70%	MHV	Strains MHV-2 and MHV-N	10 min	$>$ 3.9	[30]
	70%	CCV	Strain I-71	10 min	$>$ 3.3	[30]
2-Propanol	100%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 3.3	[28]
	75%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 4.0	[14]
	75%	MERS-CoV	Strain EMC	30 s	$\geq$ 4.0	[14]
	70%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 3.3	[28]
	50%	MHV	Strains MHV-2 and MHV-N	10 min	$>$ 3.7	[30]
	50%	CCV	Strain I-71	10 min	$>$ 3.7	[30]
2-Propanol and 1-propanol	45% and 30%	SARS-CoV	Isolate FFM-1	30 s	$\geq$ 4.3	[29]
		SARS-CoV	Isolate FFM-1	30 s	$\geq$ 2.8	[28]
Benzalkonium chloride	0.2%	HCoV	ATCC VR-759 (strain OC43)	10 min	0.0	[31]
	0.05%	MHV	Strains MHV-2 and MHV-N	10 min	$>$ 3.7	[30]
	0.05%	CCV	Strain I-71	10 min	$>$ 3.7	[30]
	0.00175%	CCV	Strain S378	3 d	3.0	[32]
Didecyldimethyl ammonium chloride	0.0025%	CCV	Strain S378	3 d	$>$ 4.0	[32]
Chlorhexidine digluconate	0.02%	MHV	Strains MHV-2 and MHV-N	10 min	0.7–0.8	[30]
	0.02%	CCV	Strain I-71	10 min	0.3	[30]
Sodium hypochlorite	0.21%	MHV	Strain MHV-1	30 s	$\geq$ 4.0	[33]
	0.01%	MHV	Strains MHV-2 and MHV-N	10 min	2.3–2.8	[30]
	0.01%	CCV	Strain I-71	10 min	1.1	[30]
	0.001%	MHV	Strains MHV-2 and MHV-N	10 min	0.3–0.6	[30]
	0.001%	CCV	Strain I-71	10 min	0.9	[30]

Virus Inactivation

Temperature

Humidity

pH

Detergents

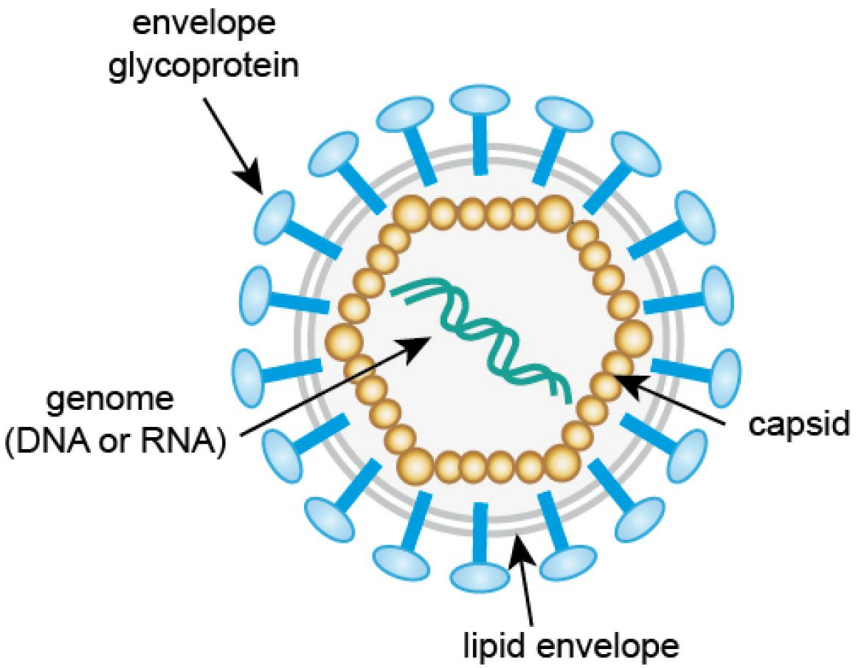
Oxidation

Metal ions

Radiation

Damage to particle

Damage to genome



Modes of inactivation

Detergents:	Effective against enveloped viruses, dissolves the lipid bilayer
Metal Ions:	Affect structure of glycoproteins, might cause genetic damage, produce reactive oxygen species (see below)
pH:	Many viruses are pH sensitive, especially non GI-viruses, hydrolysis of peptide bonds etc.
Oxidation:	Non-specific damage to lipids, carbohydrates, proteins, Nucleic acid if exposed

Antimicrobial groups by action mechanism

Inhibit Cell Wall Synthesis
- β-Lactams
  - Carbapenems
  - Cephalosporins
  - Monobactams
  - Penicillins
- Glycopeptides

Lipopeptides?

Depolarize Cell Membrane
- Lipopenpides

Inhibit Nucleic Acid Synthesis
- Quinolones
  - Flroroquinolones

Inhibit Protein Synthesis
- Bind to 30S Ribosomal Subunit
  - Aminoglycesides
  - Tetracyclines
- Bind to 50S Ribosomal Subunit
- Chloramphenicol
  - Lincosamides
  - Macrolides
  - Oxazolidnones
  - Streptogramins

Inhibit Metabolic Pathways
- Sulfonamides
- Trimethoprim

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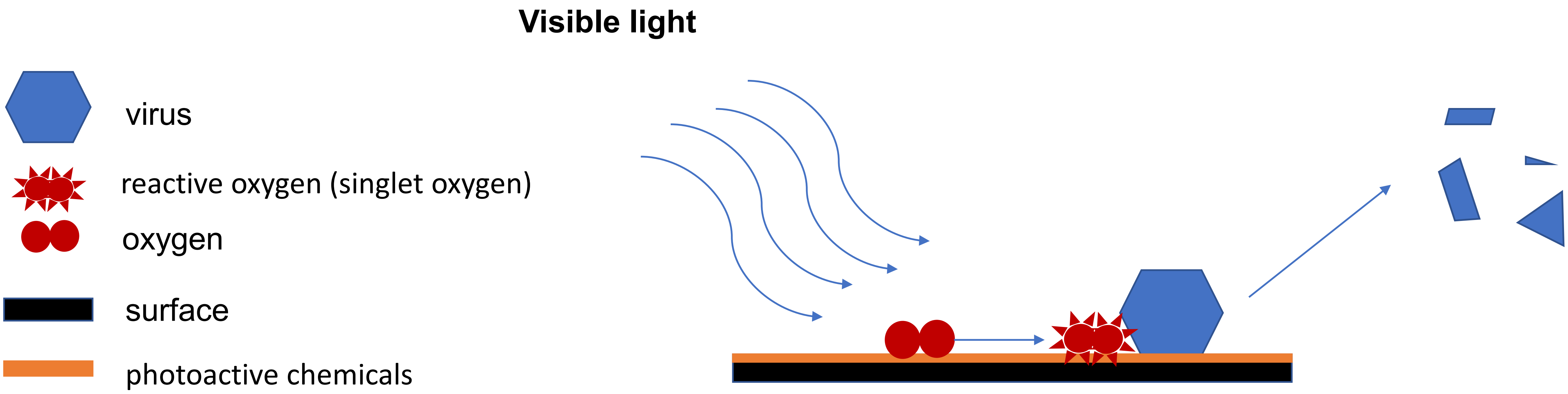
Photoactive compounds



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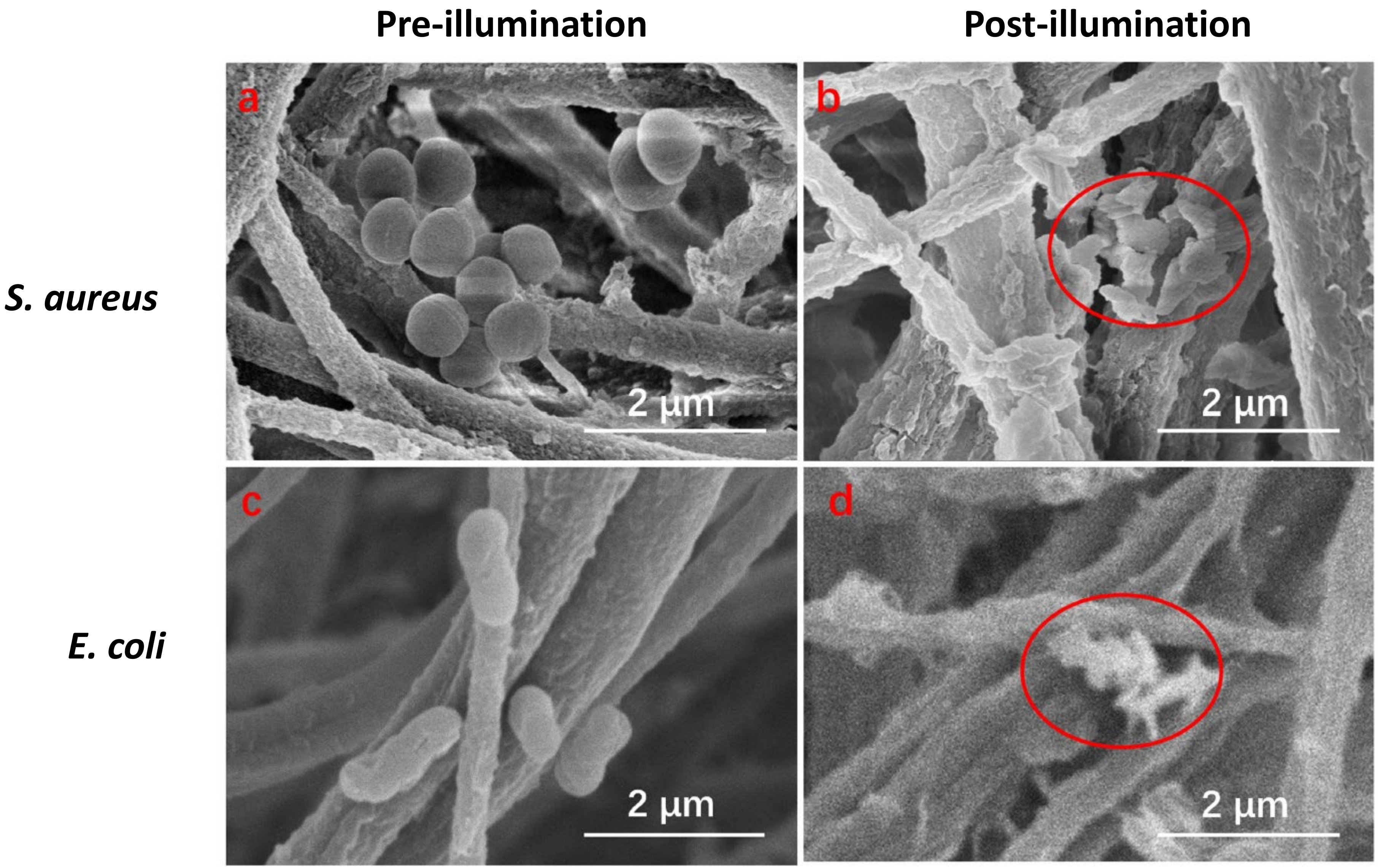
Oxidative Damage to Bacteria



Nanotechnology **2018**, *29*, e265601

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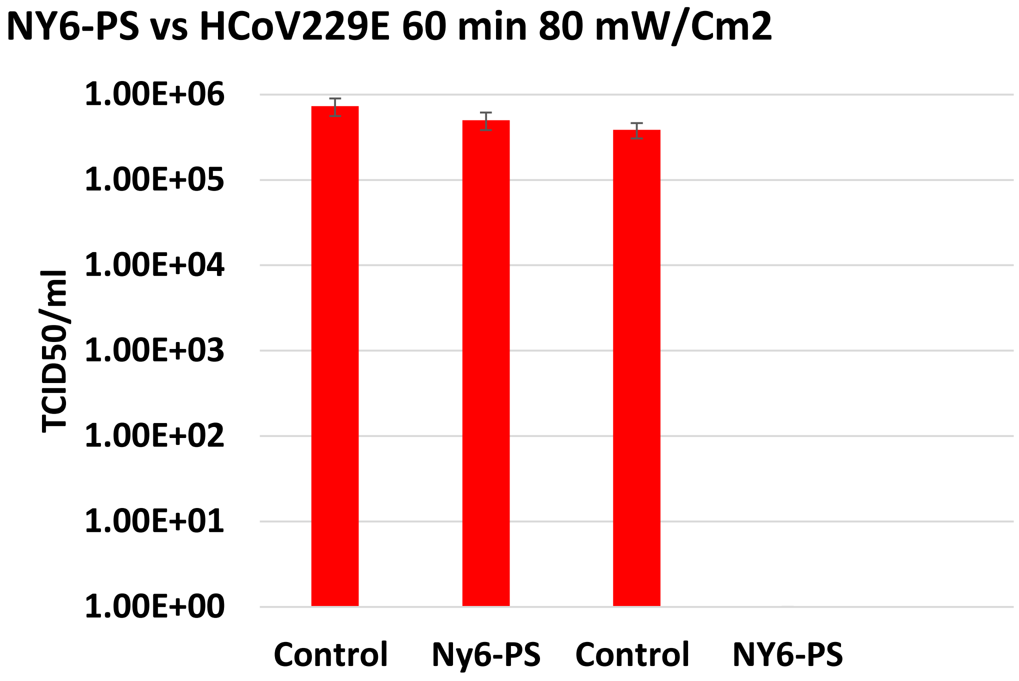
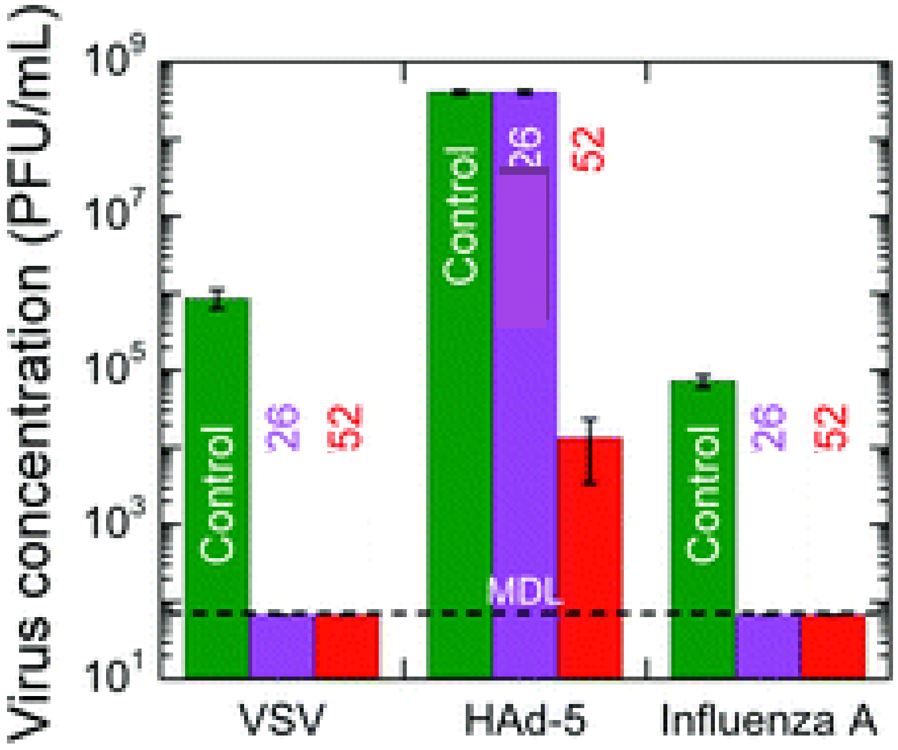
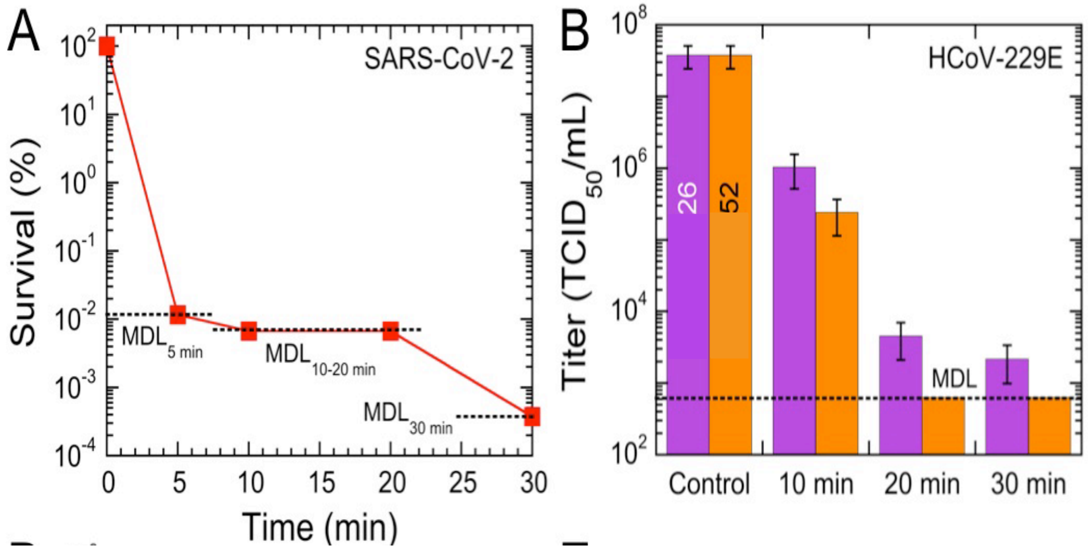
Inactivation of a common cold Coronavirus by a sprayable photoactive coating



Anionic polymers

Mode of action: decrease pH of aqueous solution to < 1





HeiQ Viroblock

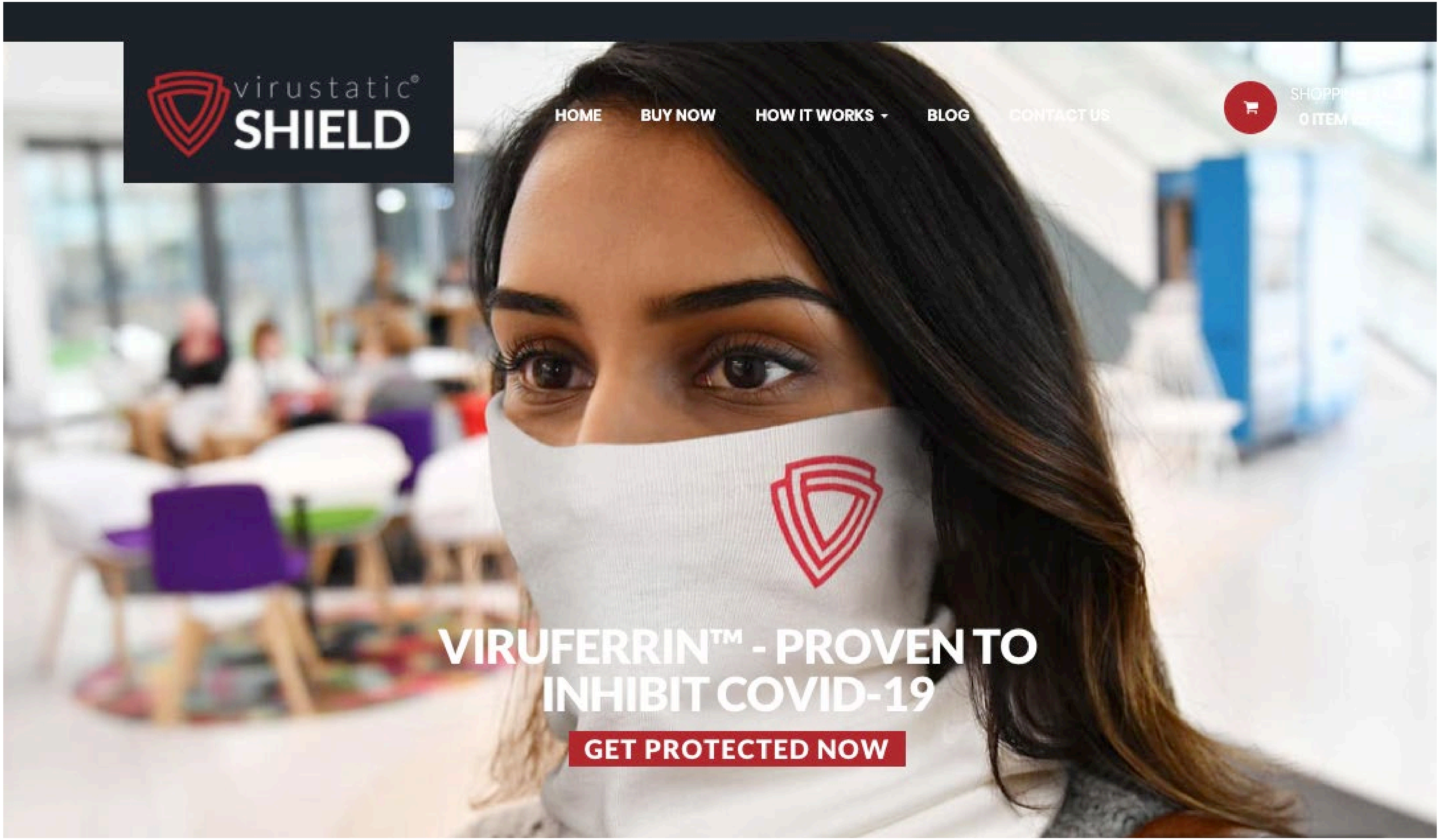
In Switzerland, in the last month, HeiQ launched HeiQ Viroblock NPJ03, an antiviral and antibacterial textile chemical compound that is added to the fabric during the final stage of the textile manufacturing process. This patent pending formulation claims to have strong antimicrobial effects against bacteria and enveloped viruses.

It is also suitable for washable fabrics, because the treatment remains effective for up to 30 gentle washes. It has been tested to ISO 20743 for rapid antiviral effect.

Sonovia Non-Contact Coating

In Israel, the Sonovia Group, has developed patents both for chemicals and finishing processes. Last June, it received patents for its non-contact process that uses a sustainable and safe ultrasonic antibacterial coating method, which can treat any type of fabric.

The technique uses a binderless formulation in a unique application process called "cavitation," which imparts a greatly improved performance to the fabric, which is now able to withstand up to 100 hard washes before the coating deteriorates.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Wearwell Virustatic® Shield

In England, the British workwear manufacturer Wearwell in association with researchers at Manchester University, using a patented antiviral fabric supplied by Pincroft, have started production of antiviral PPE for the National Health Service. The fabric uses a unique germ-trapping technology which is proven to offer 96% protection against viruses, including COVID-19.

Comprehensively tested by UK laboratories, the fabric will also protect against other viruses such as influenza, because the protein layer embedded within the fabric actively attacks the source of the infection.

Hong Kong University of Science and Technology-MAP 1 Coating

Researchers at a Hong Kong University have developed an antiviral coating which could provide 90 days of "significant" protection against bacteria and viruses such as the one causing COVID-19. The coating, called MAP-1, took 10 years to develop and can be sprayed on surfaces that are frequently used by the public, such as elevator buttons and handrails. The treatment is boosted by heat-sensitive polymers that, upon human contact, encapsulate and release disinfectants from the nano capsules that contain the antiviral chemicals. The coating is claimed to be non-toxic and safe for human use.

Promethean Particles Nano-Copper

In the UK, the trailblazing Promethean Particles company is cooperating with textile companies to explore the antiviral effect of its copper nanoparticles technology. Promethean Particles participated with UK and Mexican textile companies to develop durable antimicrobial textiles for the healthcare sector. They found that by embedding nano-copper in the fiber extrusion process, the fabrics formed lasted much longer than surface-coated products which lost their effect after multiple washes.

With this research, the way is now open for non-woven fabrics to be formed using the nano-copper technology, giving a much higher degree of virus resistance to face masks and other PPE equipment.

IIT Guhwati Spray Coating for PPE

In India, the IIT at Guhwati have filed for a patent for their metal-based chemical spray which they say is cheap and effective. Silver and copper nanoparticles are combined in an antiviral cocktail to limit viral penetration and reduce the risk of secondary transmission and infection. The compound can be sprayed or dip-coated onto textiles and provides a dynamic and consistent protection against coronavirus transmission.

Resources

SARS CoV-2 testing:	UTMB Galveston Southern Research (CRO) Creative Biolabs (CRO) Duke Regional Biocontainment Lab ?
Surrogate testing:	NCSU: CVM **CAVE** initiative: HCoV-229E, soon MHV and OC-43
Novel Materials:	NCSU **HAMMER** Manufacturing Hub (Highly Adaptive Materials Manufacturing for Emergency Response)