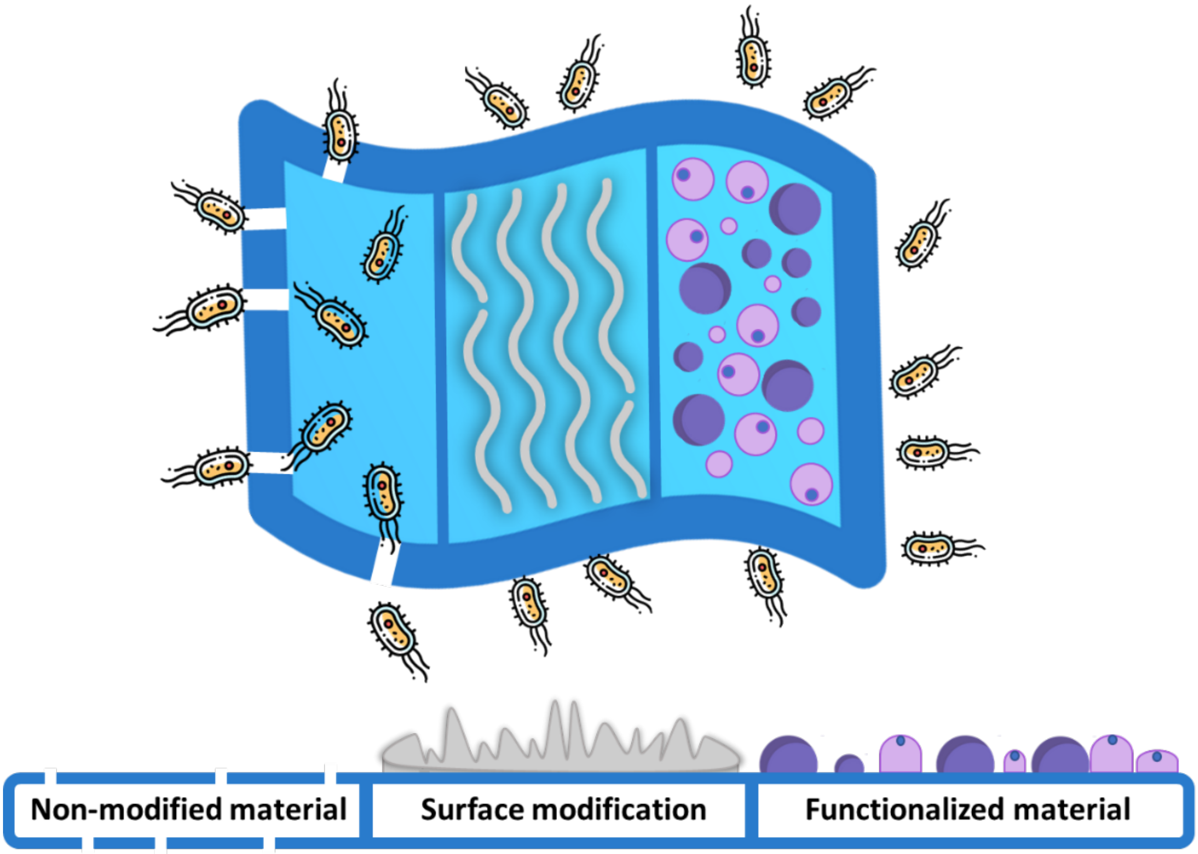
Antimicrobial Resistance Gallery

Design of new materials with antimicrobial properties

(Virginia Rivero-Buceta and Natalia Hernández-Herreros)



Scheme of different designs of antibacterial materials. Non-modified materials are vulnerable to bacterial colonization, whereas those subjected to surface modification or functionalization, involving the application of antibiotics or metals, exhibit bactericidal properties.

For centuries, we have relied on substances that fight microbes to keep us safe from dangerous infectious diseases. However, before the 20th century, illnesses caused by bacteria, viruses, and fungi were a leading cause of death. Today, thanks to medicines like antibiotics, antifungals, antivirals, and antiseptics, we live in a world where these threats are less prevalent in our lives. However, inappropriate use of these medicines, mostly by industry, but also by doctors and even normal people not disposing of them properly, has resulted in a massive increase in antimicrobial resistance. Unfortunately, we are not finding new medicines fast enough to keep up the emergence of resistant bacteria. So, it is really important to come up with new ways to fight them. Scientists are looking into different metals, salts, and new materials like insect peptides and carbon nanomaterials, which show promise in effectively killing lots of different microorganisms.

One major problem caused by microbes is their ability to stick to and proliferate on various surfaces within our bodies. These may be natural surfaces, like the surface of the lungs, or the surfaces of medical devices implanted in our bodies, such as plastic or metal tubes used to introduce or remove fluids, or to open up blocked vessels. When this happens, microbes form slimy coatings called biofilms – pathogenic biofilms – on these surfaces, which are difficult for our body defences to attack and remove, and are resistant to antibiotic treatment.

To deal with these problems, we need new materials that can block bacterial colonization and biofilm formation. Scientists are currently working on designing new antimicrobial materials to ensure safer use. Since the first step in forming pathogenic biofilms is the attachment of some microbes to the surface, a crucial strategy is to change these surfaces using special shape-changing materials to stop bacterial adhesion. In this sense, hydrogels (porous materials formed by polymers) are very popular in medicine because they are safe and can be created for different needs, including the production of microbe-inhibiting materials. They are very sensitive to moisture, retaining and releasing water dynamically, which prevents bacterial stabilisation. By the incorporation of specific compounds, like hyaluronic acid and polyethylene glycol, scientists modify their surfaces to increase the permeability and the roughness to stop biofilm formation. Moreover, these functionalized hydrogels are designed to catch and release antibiotics to heal infections, while others contain additional molecules to inhibit bacterial growth.

Another example of antimicrobial materials is the nanoparticles (NPs). These tiny particles (ranging from 1 and 100 nanometres in size) can both bind compounds with antimicrobial properties to their surface and retain and release them under controlled conditions. These microscopic materials have shown potential in combating infections, including those that resist traditional drugs. Metallic NPs based on metals like silver, nickel or gold exhibit inherent antimicrobial properties. Moreover, modifying parameters such as size, surface area, morphology, net charge, and physicochemical properties can improve their antimicrobial capability. NPs with antibacterial qualities can be incorporated into different materials. For instance, the combination of silver-NPs with polyethylene (which is the plastic used, for example, in packaging) improves both the antibacterial efficacy and the wear resistance of the polymer. Another example is a material that forms a methylcellulose hydrogel incorporating silver-NPs that has potential applications in wound care and medical environments.

In the future, through scientific research, the integration of these different approaches to material engineering, together with the discovery of new compounds with antibacterial properties, will allow the design of innovative antimicrobial materials to improve the control of everyday infections and reduce the current antibiotic resistance crisis.