

# Periodic Graphics

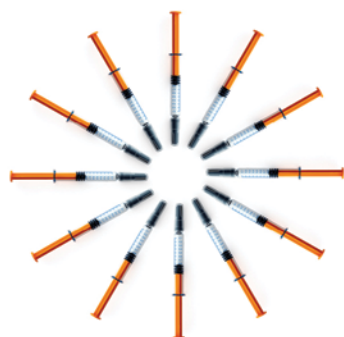
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A collaboration between C&EN and  
Andy Brunning, author of the popular  
graphics blog *Compound Interest*

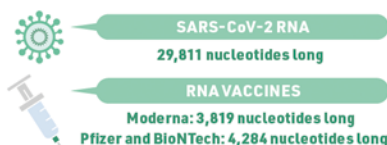
## HOW ARE RNA VACCINES MADE?

RNA vaccines produced by Pfizer and BioNTech and Moderna have become the first COVID-19 vaccines approved for emergency use in the US. How are these vaccines made?

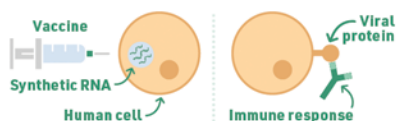


### WHAT ARE RNA VACCINES?

SARS-CoV-2, the virus that causes COVID-19, uses RNA as its genetic material. Just like DNA, RNA is made up of nucleotides.

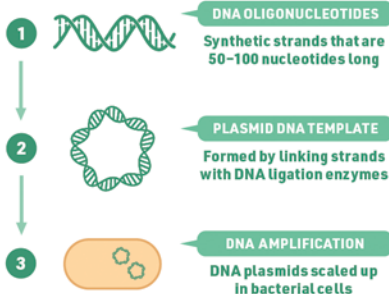


RNA vaccines deliver synthetic RNA that codes for a viral protein. Our cells take up the RNA and synthesize the protein, which then generates an immune response.

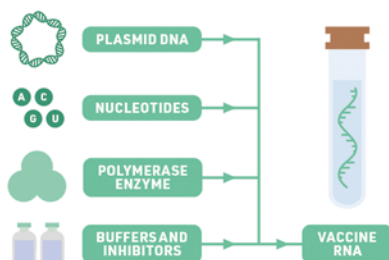


### RNA PRODUCTION

Manufacturers first make a plasmid DNA template to produce the synthetic RNA. They use bacterial cells to churn out large amounts of the template.



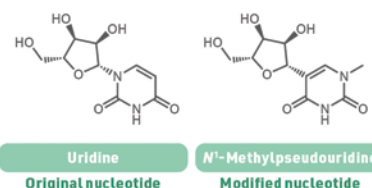
A transcription reaction that is run with enzymes and RNA nucleotides produces the RNA from the DNA template.



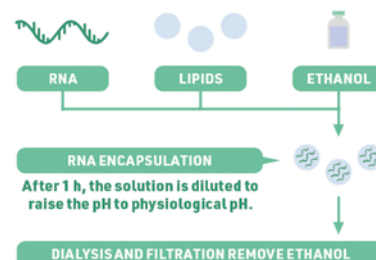
Finally, manufacturers purify the RNA for use in the vaccine.

### FROM RNA TO VACCINE

A key part of the RNA synthesis is the use of modified nucleotides. These modified nucleotides enhance RNA stability and prevent our immune system from breaking down the nucleic acids.



If the vaccine contained the RNA alone, enzymes would quickly destroy the nucleic acids before they could enter our cells. Encapsulating the RNA in lipid nanoparticles helps protect the RNA.



Several different lipids make up the nanoparticles. Some lipids help the particles form; others aid the structure or stability of the nanoparticle wall.