# Periodic Graphics

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

## More online

To see more of Brunning's work, go to compoundchem.com. To see all of C&EN's Periodic Graphics, visit cenm.ag/periodicgraphics.

## Making molecular sandwiches

PERIODIC GRAPHICS

The discovery of ferrocene revolutionized the field of organometallic chemistry. Here we look at the molecule's origins, the other sandwich compounds that followed, and their applications.

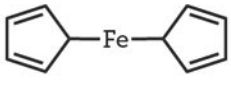
### The history of ferrocene

**1940s — First known synthesis**

Researchers at a US chemical company pass cyclopentadiene vapor through an iron pipe, making yellow sludge. Analysis years later shows that the sludge is ferrocene.

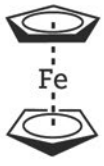
**1951 — Discovery**

Two groups of scientists independently discover ferrocene by accident while trying to synthesize other compounds. One group suggests a linear structure.




Initial, incorrect structure

**1952 — Determination of structure**




Several scientists propose a new structure for ferrocene in which the iron ion is sandwiched between two cyclopentadienyl anions. X-ray crystallography data confirm this structure.

**1973 — Nobel Prize in Chemistry**

The 1973 Nobel Prize in Chemistry is awarded to Geoffrey Wilkinson and Ernst Otto Fischer for their determination of ferrocene's structure and subsequent research on sandwich compounds.

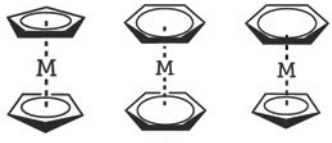
### Other sandwich compounds

**Metallocenes and arene sandwiches**

Ferrocene is a metallocene: a metal ion sandwiched between two cyclopentadienyl anions. Researchers have synthesized metallocenes with different metals. They have also made sandwich compounds with different arenes.

First-row transition metals for which metallocenes are known

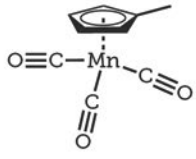
V Cr Mn Fe Co Ni




Sandwich compounds (M = metal)

**Other sandwich compounds**

Other types of sandwich compounds include half-sandwich compounds, such as methylcyclopentadienyl manganese tricarbonyl (MMT), and multidecker sandwich compounds.

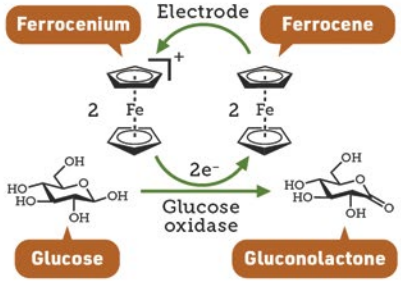



MMT

### Sandwich compound uses

**Glucose sensors**

Electronic devices that measure blood sugar levels use glucose oxidase to oxidize glucose molecules. Electrons from glucose oxidase then reduce ferrocenium cations to ferrocene. Electrodes regenerate the ferrocenium cations, and the device measures the current to determine a blood glucose reading.




**Antiknock agents in gasoline**

Canada and Australia use MMT as an antiknock agent in gasoline. Antiknock agents prevent uneven combustion by raising the temperature at which fuel ignites.

**Other uses**

Some ferrocene derivatives catalyze hydrogenation reactions. In medicine, the ferrocene derivative ferroquine underwent trials as an antimalarial drug.