of a movable MRI system that allows non-invasive scans of patients before, during and after surgery.

In 2006, the Government of Canada, in partnership with the University of Ottawa and the provinces of Quebec and Ontario, opened the NRC W.G. Schneider Building, which houses five spectrometers. Such spectrometers (e.g., Fig. 2) have helped scientists develop new battery composites, nano-materials for electronics, plastic polymers for vehicles, glasses for more sensitive sensors and faster computer processors, new materials for hydrogen storage and health-enhancing antibiotics.

BIOPHYSICS MEETS CARBOHYDRATE CHEMISTRY

In the early 1970s, NRC chemist Harry Jennings devised a solution for successfully vaccinating children with meningococcal meningitis caused by three major strains of *Neisseria meningitidis*. At the time the vaccine – composed of purified sugars from the bacteria surface – was ineffective in children because the contents did not stimulate the immune system.

Jennings had heard about this problem from a chance encounter with a U.S. scientist working on meningitis who wanted to collaborate on NRC's NMR methods. As Jennings considered the problem, he realized it was possible to overcome the limitations of the existing vaccine by linking the polysaccharide to a protein to create a conjugate vaccine. Ian Smith was involved in the NMR work that laid the foundation for the meningitis vaccine.

While Jennings encountered a number of roadblocks in finding an industrial partner that would take the vaccine candidate forward, he persevered. However, it was not until 30 years after joining NRC that he found an industrial partner to commercialize it in 1996. The first major test of the vaccine against meningitis C was in 1999 against an outbreak among hundreds of British children.

This success led to a renaissance in vaccine research, opening up a number of possibilities for diseases that were not thought to be amenable to vaccines. Since the first conjugate vaccine patent for Meningitis C in 1982, the Institute for Biological Sciences has solidified a family of meningitis patents and continues to explore vaccines for a number of other diseases, including cancer.

PIONEERING STUDIES OF FREE RADICALS AND ANTIOXIDANTS

Studies of free radicals and antioxidants was an area of extensive work at NRC for almost 60 years in the Division of Chemistry, and then the Steacie Institute for Molecular Science. Chemist Keith Ingold, who joined NRC in 1955, is a pioneer in understanding the role of oxidation in the aging process and the role of Vitamin E in medicine and health as an antioxidant. When he began his research, the chemistry of intermediates such as free radicals was unknown.

Ingold's mandate was to examine the degradation of engine oils and learn how to prevent it. This launched his lifelong love affair with free radical chemistry (Fig. 3). Applying the chemistry of free radicals to living organisms – specifically the human body, which produces about 10 kilograms of superoxides every year – is the area for which his research is best known. He also demonstrated the role of antioxidants in preventing degradation of a wide range of materials and helped to redefine the petroleum and plastics industry.

In the early 1980s, Ingold turned his attention to the role of oxidation in aging and the development of cancer and atherosclerosis – two leading causes of mortality in industrialized society. His team's pioneering work proved that vitamin E behaves as an antioxidant in living animals. NRC's game-changing findings on vitamin E led to a variety of medical breakthroughs, including improved treatments for patients awaiting heart surgery and a greater understanding of certain diseases involving vitamin E deficiency. However, vitamin E can actually promote oxidation in some cases, so there is still much to learn, and the field remains active.

The benefits of antioxidants in food and various products have been widely publicized, analyzed and debated, yet the general public believes they prevent the harmful effects of free radicals. Antioxidants are supposed to keep us healthy, allow us not to feel guilty for having that glass of wine in the evening and keep us from looking our age. However, a definitive review of the area of oxidants, published by Ingold and Derek A. Pratt in 2014, reports that while antioxidants are probably preventative, they are unlikely to be therapeutic.

Ingold continues to investigate the relationship between oxidation and atherosclerosis and cancer, the two leading causes of mortality in North America and Europe. In 2016, he was

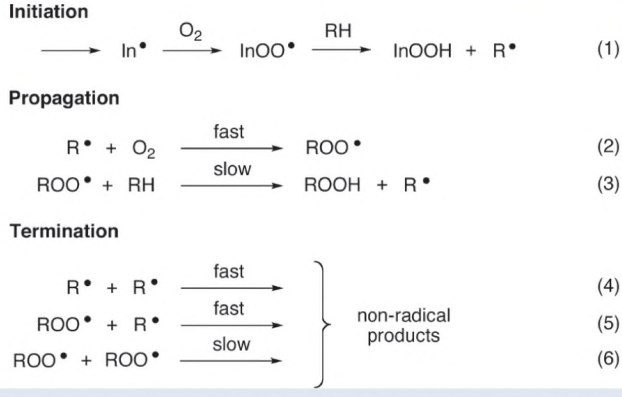

Fig. 3 Ingold was a leader in developing methods to study free radical reactions, among them quantitative measurement of reaction rates (ESR) [2].