Some Examples of Accomplishments Under the Basic Energy Sciences Program During 1980

These selections do not necessarily reflect the full range of the basic research carried out through more than 1000 projects supported by Basic Energy Sciences.

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1. Fission Product Iodine Release in Nuclear Accidents

The release of fission product iodine as the result of a reactor core meltdown is currently considered one of nuclear power's most serious threats to public health. Fission product iodine is highly radioactive, it is concentrated by humans in the thyroid, and it has been assumed in the past that virtually all of it would be released to the atmosphere if fuel element meltdown occurred.

Continuing thermodynamic studies under the BES program predicted that fission product iodine in light water nuclear reactor fuel rods should be chemically bound as an iodide, probably cesium iodide, and not as molecular iodine as previously assumed. Stimulated by these studies, tests of irradiated commercial fuel rods were carried out under Nuclear Regulatory Commission sponsorship and the prediction based on the thermodynamics studies was verified.

The prediction, now bolstered by direct experiment, is in accord with the behavior of the reactor at Three Mile Island, where the observed release of iodine was only about one millionth of that expected. This work substantially improves our capability to predict the consequences of reactor accidents and could have a major impact on nuclear plant siting criteria and accident response procedures.

(Oak Ridge National Laboratory, T. B. Lindemer, E. C. Beahm and T. M. Besmann)

2. Dual-Phase Steels for Energy Efficient Cars

Reduction in the weight of new automobiles is providing a major contribution towards reduced fuel consumption per mile driven. Safety considerations however call for maintaining adequate strength and fracture resistance in the automobile structure. The strength and fracture resistance of steels depend on the structure and distribution of the phases of iron present -- in this case, ferrite and martensite. The composition of these phases in steel was studied using advanced electron microscopy capabilities uniquely available at LBL, making it possible to optimize the structure of steel for strength and fracture resistance. As a result, a new class of steel alloys which has greater strength and fracture resistance per unit weight than steels currently in use, has been designed. These steel alloys, called "dual-phase," can be fabricated using current commercial methods.

The annual energy savings possible through weight reduction by using these dual-phase steels in cars, trucks and trains may approach 10% of the 20 quads currently consumed by the transportation sector.

(Lawrence Berkeley Laboratory, G. Thomas)

3. Titanium Diboride Coating for Erosion Resistance

An extremely hard, wear-resistant titanium diboride coating for use on materials that must survive extremely erosive environments has been developed under a project to study the basic mechanisms of fracture and erosion in various chemical and thermal environments and to determine techniques to minimize failure.

Titanium diboride may have many applications where wear-resistant materials are needed. It is difficult to fabricate in bulk form, but coatings of the material can be readily deposited on surfaces by means of chemical vapor deposition techniques. The coatings exhibit excellent erosion resistance.

Initial laboratory tests of titanium diboride applications have focused on its use as a coating for coal liquefaction reactor letdown valves. Erosion of these valves has long been a limiting factor in the life of coal liquefaction processing systems. A new composite valve with the tip coated with approximately a 50 micron thickness of titanium diboride has been undergoing tests.

Two prototype valves, used as the primary and secondary letdown valve pair in a continuous flow reactor, have been opened and shut 1300 times with little degradation. Untreated stainless steel valves used in the same way eroded and failed after 30 opening and closing operations. The new valves are scheduled for tests at a pilot coal liquefaction plant. The uses of titanium diboride coatings for fusion reactor applications and as coatings on cathodes used in the electrolytic reduction of aluminum ore are also being studied.

(Sandia National Laboratory, E. Randich)

4. Layered Ultra-Thin Coherent Structures to Produce New Properties

Superconducting materials have been created in which as many as one-half of the atoms were normally non-superconducting copper. These materials are composed of layers only a few atoms thick, of different atoms which normally do not combine in a coherent fashion. Research on the synthesis of layered materials has shown that as the layer thicknesses are reduced and approach single atom thickness, the properties of the composite change dramatically. For example, an assembly of alternate layers of niobium with copper behaved as a homogeneous superconductor although half of the layers were of normally non-superconducting copper. This technique for synthesizing ultra-thin coherent structures offers the possibility of creating entirely new materials with predetermined properties.

(Argonne National Laboratory, I. Schuller, C. Falco)

5. Non-Destructive Evaluation of Oil-Bearing Shales

Small angle neutron and x-ray scattering techniques have been applied in a non-destructive way to determine the size, shape and amount of oil bearing pores in oil shale. Using neutrons from the High Flux Isotope Reactor, information on the total pore distribution was obtained by small angle scattering of the neutrons. X-ray small angle scattering was used on the same sample to determine the pore distribution for empty pores. The difference between the two sets of data provides information on oil bearing pores. This technique demonstrates the capability to obtain highly complex information on a material accurately and quickly. In the case of oil shale, the information obtained is important in determining not only the oil content but the choice of initial and secondary recovery methods.

(Oak Ridge National Laboratory, G. Wignall, H. R. Child)

6. Superconducting Device Used to Search for Geothermal Fields

A device known as the SQUID (Superconducting Quantum Interference Device), capable of detecting very small changes in the earth's magnetic field has been built in a portable form. The changes in the earth's magnetic field that are detectable are in a range that may be due to the presence of water or oil and the SQUID is being used in field studies. Recent measurements in Mexico in a known geothermal field have revealed a likely potential for extensive new geothermal sources along a fault line. Mexico plans to drill in this area for confirmation. The application of this device to search for geothermal fields resulted from research dealing with quantum theory and experiments related to it. The extreme resolution of the SQUID apparatus permits measurements at the limit of current theory and may lead to further refinement or verification of quantum theory as it is understood today.

(Lawrence Berkeley Laboratory, J. Clarke)

7. Kinetics of Hydrogen Permeation in Metals

The properties of many materials are strongly affected by hydrogen on their surfaces or diffusing into them. Recent experiments have led to a quantitative understanding of the rate at which hydrogen is dissolved in metals. It has been demonstrated that thin layers of palladium on niobium metal dramatically increased hydrogen adsorption, with the significant result that every hydrogen molecule impinging on the surface splits into separate hydrogen atoms. The experimental results correspond to the surface reaction steps of adsorption and dissociation being two hundred times greater on a palladium coated niobium surface than on clean uncoated niobium, and a similar enhancement of the permeation of the hydrogen atoms through the niobium. This work is expected to provide guidance for new catalyst development where an increase of one or two hundred in hydrogenation catalyst reactivity would constitute a breakthrough. In addition, this research will impact on hydrogen storage technologies, in which rapid hydrogen permeation into and out of materials is desirable, yet limited by surface reactions.

(Brookhaven National Laboratory, J. Davenport, G. Dienes, M. Pick, M. Strongin)

8. Increased Photovoltaic Efficiency of Silicon Hydrides

A method has been developed to control the di- and tri-hydride content in amorphous silicon hydride for increased photovoltaic efficiency. The defect structure of silicon and the nature of the alloyed hydrogen determine the alloy's optical and electrical behavior which in turn governs its photovoltaic efficiency. It has been found that initial introduction of hydrogen into the amorphous silicon matrix forms a silicon monohydride which has a good photovoltaic response.

As more hydrogen is added, however, di- and tri-hydrides form which degrade the photovoltaic properties. Recent results have shown that the additional implantation of other elements (e.g. helium) can displace the hydrogen from the dihydride configuration to the monohydride defect, thus opening the possibility of tailoring alloys for optimum properties.

(Pacific Northwest Laboratory, Pawlewicz; Sandia National Laboratory, H. J. Stein)

9. New Class of Cryogenic Steels

Research aimed at understanding brittle fracture paths in steels and at developing alloying and heat treatments to avoid these paths has led to a new and promising class of cryogenic alloys. These have been found to have sufficient strength, fracture resistance, and formability for applications such as for pressure vessels to contain liquid natural gas, or for support structures for superconducting magnets. The alloys are ferritic steels containing manganese, but no nickel. This result may also have wide-ranging implications for the control of intergranular failure in other steels damaged by improper heat treatments.

(Lawrence Berkeley Laboratory, J. Morris)

10. Cyclic Irradiation Enhanced Deformation

Radiation damage to structural materials in both fission and fusion environments continues to be an important research area. The ability to predict such damage and its effects after long periods of service is critical. The development of techniques to stimulate this damage in a controlled way to better understand the mechanisms involved is a goal of the research program. The phenomenon of "creep", deformation of the fuel rod cladding, observed with reactor structural materials exposed simultaneously to radiation and stress at high temperature, is being examined with ion simulation techniques. It was found that the creep phenomenon is greater per unit of radiation received under cycling conditions -- bursts of radiation interspersed with low exposure periods -- than under steady conditions. A mechanism has been postulated to explain this phenomenon and is being tested. This insight is expected to find early use in both nuclear and fusion reactor design and development activities.

(Pacific Northwest Laboratory, E. P. Simonen)

11. Plutonium Specific Complexing Agent Synthesized

A new class of chelating (from Greek for "claw") agents has been synthesized, one of which has been found to remove plutonium selectively from animal tissues. This class of chemical compounds has been designed on a molecular scale to satisfy two criteria crucial to precise selectivity: geometric configuration to fit that of the plutonium species to be removed, and a chemical bonding match to a plutonium ion bearing a plus four charge. The immediate interest has been in the application of the newly synthesized LICAM-C (linear catechoylamide carboxylate) to living systems where it was shown that, with minimal side effects, one dose of LICAM-C removed, through the kidneys, 70% of the plutonium injected into mice. This work has attracted attention in the public press, and LICAM-C has received publicity as a potential decontaminating agent in the case of accidents involving uptake of plutonium by people. Less dramatic, but of perhaps greater significance, is the possibility of tailoring chemical extractants to treat both nuclear and chemical wastes for removal of noxious species and recovery of valuable materials from dilute sources.

(Lawrence Berkeley Laboratory, K. Raymond, F. Weitl)

12. Water Photolysis Process Yielding Hydrogen and a Stable Oxygen Species

A photolytic process yielding gaseous hydrogen and trapping the active oxygen simultaneously produced in a stable form of probable interest for industrial application has been discovered. Photolytic reactions induced by sunlight in water normally yield atomic hydrogen and oxygen-containing species such as the hydroxyl radical. The hydrogen atoms produced combine to form gaseous molecular hydrogen, but if the oxygen-containing species is not readily removed from the system, or if it does not readily react to produce gaseous oxygen, the production of hydrogen will soon terminate. In water splitting as in many other chemical reactions, the inability to remove a product from a reacting system often results in the buildup of species that initiate undesirable reverse or side reactions in the system. What has been discovered is a reacting system that overcomes this difficulty -- i.e., the oxygen-containing species is not a problem but a desirable product -- and should permit the development of a continuous photolytic process yielding hydrogen and usefully combined oxygen.

(Lawrence Berkeley Laboratory, M. Calvin)

13. Catalyst Regeneration for Coal Gasification

Research has provided new insight into the poisoning by sulfur of the metal catalysts used for the methanation step of coal gasification. With this new insight also has come the demonstration that poisoned catalysts can be regenerated far more completely than current practice achieves. This may significantly improve economics of these catalyst systems for coal processing by extending the useful life of the catalysts and increasing the plant operating factor.

The usual regeneration practice for removal of the chemisorbed sulfur has been to heat the catalyst in air in order to oxidize the sulfur to gaseous sulfur dioxide. Since the catalyst surface also becomes oxidized and catalytically inactivated, normal practice has been to follow up with a hydrogen treatment which removes the oxygen. With the air treatment, however, an undesired oxidation of the metal surface proceeds faster than the desired oxidation of sulfur, which results in "buried" sulfur under the newly formed layers of metal oxide. The competing oxidation rates can be manipulated to favor oxidation of sulfur over that of metal, by drastically lowering the oxygen concentration to 1-10 parts per million and by carefully controlling the temperature. The catalyst, regenerated in this way, regains nearly 100 per cent of its original activity. The concept may be applicable to other catalytic systems which are poisoned by sulfur.

(University of Delaware, J. Katzer)

14. Catalyst Using Synthesis Gas as a Reducing Agent

Molecular hydrogen is required in many chemical processes involving reactions carried out through catalysis. However, the production of large quantities of chemically pure hydrogen is energy-consuming and expensive. A homogeneous rhodium carbonyl catalyst system which allows direct utilization of synthesis gas (mixture of CO and H_2) as a reducing reagent in place of molecular hydrogen for a specific class of reactions has been discovered. Synthesis gas is the principal product of the gasification of coal or char; it is a mixture of carbon monoxide and hydrogen of widely varying composition depending on the conditions used. Current practice requires further processing and separations to obtain hydrogen for use as a reducing agent. The catalytic reduction discovered proceeds by consuming both the CO and H_2 in proportion to their initial concentrations, thus allowing for the direct utilization of any composition of synthesis gas. The catalytic reduction reactions found are applicable in a number of industrial processes including production of plastics and some of the manmade fibers.

(University of Texas, R. Pettit)

15. Production of Highly Charged Ions for Fusion-Related Research

The study of highly charged ions -- atoms which have been stripped of most of their electrons -- is important to development of fusion energy because these ions may occur in fusion plasmas and dramatically reduce their energy. Until now obtaining such highly stripped ions for laboratory research on their properties was possible only in energy ranges far above those typical of fusion plasmas. A new method has been devised which overcomes this problem. It involves a beam of particles at millions of electron volts striking a gas target and stripping the gas molecules of most of their electrons. The resulting highly charged ions emerge from the target at relatively low energies, only a few tens of electron volts, an energy range heretofore not attainable for such highly charged ions. The ions are then accelerated to a few hundred electron volts for the fusion-related experiments. This technique is being adopted by several laboratories.

(Kansas State University, P. Richard, L. Cocke)

16. Sulfur Dioxide and Nitrogen Oxides Effect on Atmospheric Levels of Carbon Monoxide

Recent measurements of the isotopic (oxygen-18/oxygen-16) ratio in atmospheric carbon monoxide (CO) indicate a relatively large increase of technologically produced CO during this past 8 years. This increase, from 1971 to 1979, is by an amount greater than that attributable to the largest sources of technological CO, the internal combustion engine (ICE). Two possible explanations are: (1) a large increase from biomass burning which produces CO difficult to distinguish from ICE carbon monoxide or (2) a decrease in the atmospheric concentration of hydroxyl free radicals (OH) which are the principal scavengers of CO from the atmosphere. The first explanation does not seem very likely since patterns of biomass combustion have not changed dramatically during the past 10 years. The second possibility is disturbing, particularly if the reduction of OH radicals in the atmosphere were caused by an increase in the pollutant trace-gas scavengers for OH, such as sulfur dioxide and the nitrogen oxides.

(Argonne National Laboratory, C. Stevens)

17. Palladium from Nuclear Waste

A technology for recovery of stable palladium during the reprocessing of nuclear fuel elements has been devised. Its implementation could ease our current heavy dependence on Soviet and South African palladium for automobile exhaust cleanup catalysts, and possible future use as a coal conversion catalyst.

The crux of the process is a strongly radiation-resistant system which enables the processing of spent nuclear fuel after a minimum of cooling time. The object is to remove fission product ruthenium as soon as possible. This ruthenium has a relatively shoft half-life of about one year, decaying into 30-second rhodium which decays to stable palladium-106. The required radiation-resistant system involves a high temperature chemical partitioning between molten uranium and magnesium. In this system, the required initial separation of ruthenium from the also-present radioactive palladium, with a separation factor greater than ten thousand, has been demonstrated. The stable palladium-106 is ultimately recovered free of radioactivity.

The U.S. production of palladium has never exceeded 1,000 kg per year while the consumption has reached 46,000 kg/yr. It is estimated that an annual production of $\sim$ 1,000 kg is possible from reactors now operating or under construction.

(Oak Ridge National Laboratory, M. Duffie)

18. Energy Efficiency in Natural Systems Leads to New Thermodynamic Insight

Research on the mechanism of an important biochemical process has provided new thermodynamic insight into the possibility of attaining greater efficiency of energy utilization in complex chemical systems.

Living systems derive their energy supply from the conversion of ATP (adenosine triphosphate) to ADP (adenosine diphosphate). ADP is converted back to ATP during glycolysis, the process which converts sugars to oxidized chemicals via a multi-step (9 or more) reaction pathway. The concentrations of the intermediates in the glycolysis process are observed to oscillate, with frequencies on the order of 1 minute, with definite relationships among the different intermediates' concentrations and their frequencies.

A description of the thermodynamics of reactions in systems where intermediate species concentrations oscillate has been developed. It demonstrates that oscillations in the multi-step glycolysis sequence result in an increase of 10-15% in overall efficiency over that which would otherwise be observed. Essentially, this comes about because some of the energy which would be dissipated as heat is intercepted at peaks in the oscillations, and appears as useful chemical energy. Although developed to explain the biochemical phenomenon observed, the description has been recast to provide additional insight into the thermodynamics of a heat (Stirling) engine as an example of the generality of this concept.

(Stanford University, J. Ross)

19. Fluoroxysulfates: Powerful New Oxidants and Fluorinating Agents

A group of powerful oxidants and fluorinating agents which may prove to be uniquely useful synthetic and analytical tools for both inorganic and organic chemistry has been prepared, isolated and characterized. These are the first known ionic hypofluorites, or specifically, in this case, fluoroxysulfate (SO_4F^-) salts. The ionic character of these salts contribute to their relative stability. It is this stability and the ease of formation of these salts which make this new kind of reagent so potentially attractive. The fluoroxysulfate salt of rubidium or cesium separates out as a solid when fluorine gas is passed through a water solution of rubidium or cesium sulfate. Earlier, other chemists had noted that passing fluorine through aqueous sulfate solutions gave a powerful oxidant which decomposed in a few hours, but this observation had been largely ignored and even questioned before this recent work.

(Argonne National Laboratory, E. Appelman)

20. New Analytical Technique Using Fiber Optics Devised

A novel application for fiber optics may soon find many uses. A linear array has been assembled of 30 fibers (the number could be greater) with lengths varying from 1 to 59 meters, all leading into a single photomultiplier, a device which measures intensities of pulses of light. The 2 meter increment in length from one fiber to the next provides an incremental time delay of 10 nanoseconds (billionths of a second) between the pulses received by the photomultiplier from each fiber. A nanosecond pulse of light is spread by a diffraction grating into 30 different wavelength groups and each of these is focused on the receiving end of one of the 30 optical fibers. These all lead to the single photomultiplier, so that its output is a series of 30 electrical pulses, 10 nanoseconds apart, with intensity corresponding to the intensity of the light within the wavelength range of each fiber's placement.

The system can be tailor-made to monitor, as a function of time, the particular spectral range of interest in specific analytical applications. In practice it would compare a blank with a sample interposed between the light source and the diffraction grating, thus providing a fast, accurate analytical reading.

(Oak Ridge National Laboratory, H. Ross)

21. New Technique for Ohmic Contact Fabrication

During 1980, a project originally sponsored by Advanced Energy Projects (AEP), was found sufficiently promising to "graduate" from the program and receive favorable consideration for possible funding under DOE's Solar Technology Program. The project involved development of a technique called "arc plasma spraying," and also illustrates how the AEP program helps promote innovation: A small business firm -- four full-time and five part-time employees - received its first contract ever from AEP to develop a new method of fabricating ohmic contacts for solar cells. Assessment of the "arc plasma spraying" method shows it to be extremely well suited for mass production of large area solar cells.

(Solamat, Inc., J. Loferski, B. Roessler)

22. Powerful XUV Radiation Source Tunable at 83 nm Demonstrated

This project represents one of five different approaches to the development of new, bright and coherent X and XUV sources now under study. Such sources, when developed, will find applications in fusion plasma diagnostics, catalytic surface research, X-ray lithography, biology, medical diagnostics (X-ray holography) -- to name a few. This research has led to the development of the brightest laboratory radiation source ever observed in the soft X-ray region. The radiation, at 83 nm (nanometers, or 10^{-7} centimeters), is generated by using the third harmonic of tunable KrF* radiation in xenon. The radiation is coherent and tunable from 82.8 to 83.2 nm. At 83 nm, its spectral brightness is two orders of magnitude greater than that of the DORIS synchrotron, one of the brightest sources now operating.

There is now a reasonable possibility that in certain narrow wavelength regions, laser sources will compete with synchrtron light sources in brightness, at a small fraction of the cost.

(University of Illinois at Chicago Circle, C. Rhodes)

23. Novel Design for Solar Collectors

A new design for solar collectors allows increased separation between reflector and absorber surfaces. The novel approach for design of trough-like solar collector structures mitigates an important engineering limitation encountered in past design of such collectors, namely the requirement for very close spacing between the absorber and the reflector. In principle the effective absorbance of the structure as a whole drops sharply as the spacing increases. Yet some minimum spacing is required to allow a convection-reducing vacuum envelope to be placed around the absorber. The new design calls for corrugating a part of the surface of the reflector in a very specific but easily fabricable way. As a result, the optimum location of the absorber is shifted to a distance of up to one radius of the absorber which is ample for engineering purposes and does not degrade the collector performance.

(University of Chicago, R. Winston)

24. Fundamental Advances in Theory of Fluid Turbulence

The fine-scale motion of turbulent fluids plays a crucial role in many processes involving mass and energy transport. During 1980, scientists advanced a mathematical theory of fluid turbulence which enhances our ability to analyze the spatial, momentum and energy dynamics of rapidly moving fluids, such as may be found in heat exchangers, combustors and other devices important in energy transfer. The fine-scale motion of turbulent fluids (of the order of millimeters or less) is of concern also in practical design applications because of the vibrations and noise generated in turbulent flow. This theory, with its improved mathematical insights, is expected to find applications in design of more efficient, longer lasting components of energy systems.

(City University of New York, B. Levich)

25. Computational Method for Faster Energy System Modeling

Improving energy systems often depends on precise computation of system behavior. The same types of computation arise repeatedly throughout the energy field, and a major advance was made under our applied mathematical sciences program this year in handling one of the most important types -- called sparse least squares problems. More effective and realistic models will now be possible in analyzing, for example, structural integrity of fusion reactors and the efficiency of combustion processes. The advance came from new ideas on how to break down into simpler pieces the huge arrays of numbers that arise in these computations, and also on how to make optimum use of auxiliary computer storage, while avoiding the numerical instabilities that plague current methods. The new ideas have been incorporated into carefully constructed computer codes available to scientists and engineers throughout the nation.

(Oak Ridge National Laboratory, M. T. Heath; Stanford University, G. H. Golub)

26. Volcanic Gases Used to Fix Rock Histories

A mathematical code has been developed which effectively predicts the composition of gases from thermodynamics considerations in complex mixed systems at high temperatures. The code was developed to interpret volcanic gas compositions and tie them back to the energetics of the systems producing them and to provide information on the geologic history of these systems. Understanding the energy related aspects of volcanism is of particular importance in evaluating possible schemes for energy extraction from magma, and more generally, in gaining clearer insight into eruptive processes.

A valuable spin off of this work has been the use of this code to establish conditions required for controlled deposition from the gas phase of titanium boride, a process to provide a tough coating resistant to erosion prevalent in coal conversion applications.

(Sandia National Laboratory, A. T. Gerlach)

27. Mount St. Helens Yields Data on Particle Disperson, Magma Chambers

The eruptions of Mount St. Helens provided a unique opportunity for several DOE geoscience research programs. Preliminary results of experimenters concerned with volcanic gases at Sandia National Laboratory show that the volatile contents responsible for explosive eruptions may be relatively low. Volatile content has a large effect on magma viscosity and the recently acquired knowledge will be broadly useful in interpreting the geology of regions affected by recent or ancient volcanic activity. Other geosciences activities obtaining valuable information as a result of the Mount St. Helens eruptions include infrared photography and high altitude ash collection by Los Alamos Scientific Laboratory and analysis of data on atmospheric transparency changes on a continental scale by Pacific Northwest Laboratory. These activities are of value to the DOE long-range studies of climatic change.

28. Plant Polysaccharides as Hormones

Recently, it has been discovered that small polysaccharides (chains of sugars) act as regulators of plant growth and plant defense against attack by disease organisms. Plant-disease-causing fungi and bacteria produce specific small polysaccharides that act as hormones (messengers) causing the plant to produce new antibiotics, protective enzymes, and new growth blocking enemy attack. In addition, injury or trauma to plant cells causes release of specific enzymes that, in turn, release short polysaccharides from the plant's own cell wall. These cause specific changes in the plant depending on the type of "hormone" released. The data supports a novel hypothesis: The specificity of plant growth and response to disease relies upon a set of polysaccharide hormone-messengers. This new knowledge will add significantly to our ability to program plants for improved biomass production.

(University of Colorado, P. Albersheim)

29. Microbial Production of Hydrocarbons

Micro-organisms have been isolated that are capable of synthesizing, from simple carbon compounds, hydrocarbons with a chemical compositional pattern resembling that found in petroleum. Some of these micro-organisms can produce sizable amounts of hydrocarbons; however, these organisms are slow growing. The discovery of the existence of organisms with this capability suggests that others with similar properties, but with more advantageous growth rates, might also be found or genetically tailored.

(Colorado State University, T. Tornabene)

30. Anti-Flowering Compounds in Plants

Anti-flowering substances in plants have been discovered. Until now the prevailing concept has been that flowering occurs when a flowering hormone acts to initiate the process. More recently the presence of anti-flowering substances which can be transmitted through grafts has been shown. This advance sheds light on the chemical control over flowering and bears on biomass productivity since flowering can significantly reduce biomass production.

(Michigan State University, A. Lang)