Synchrotron-light for Experimental Science and Applications in the Middle-East

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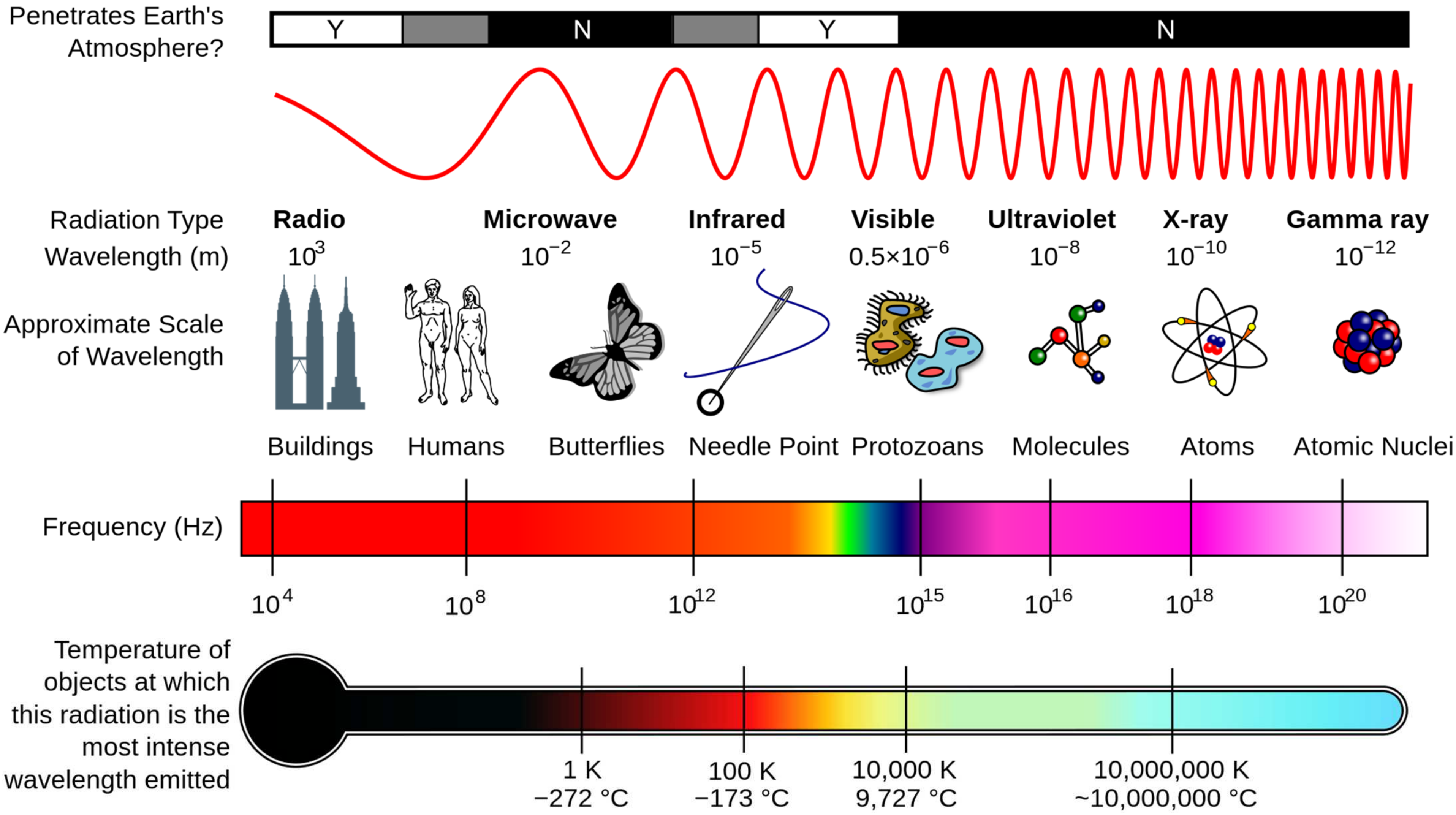
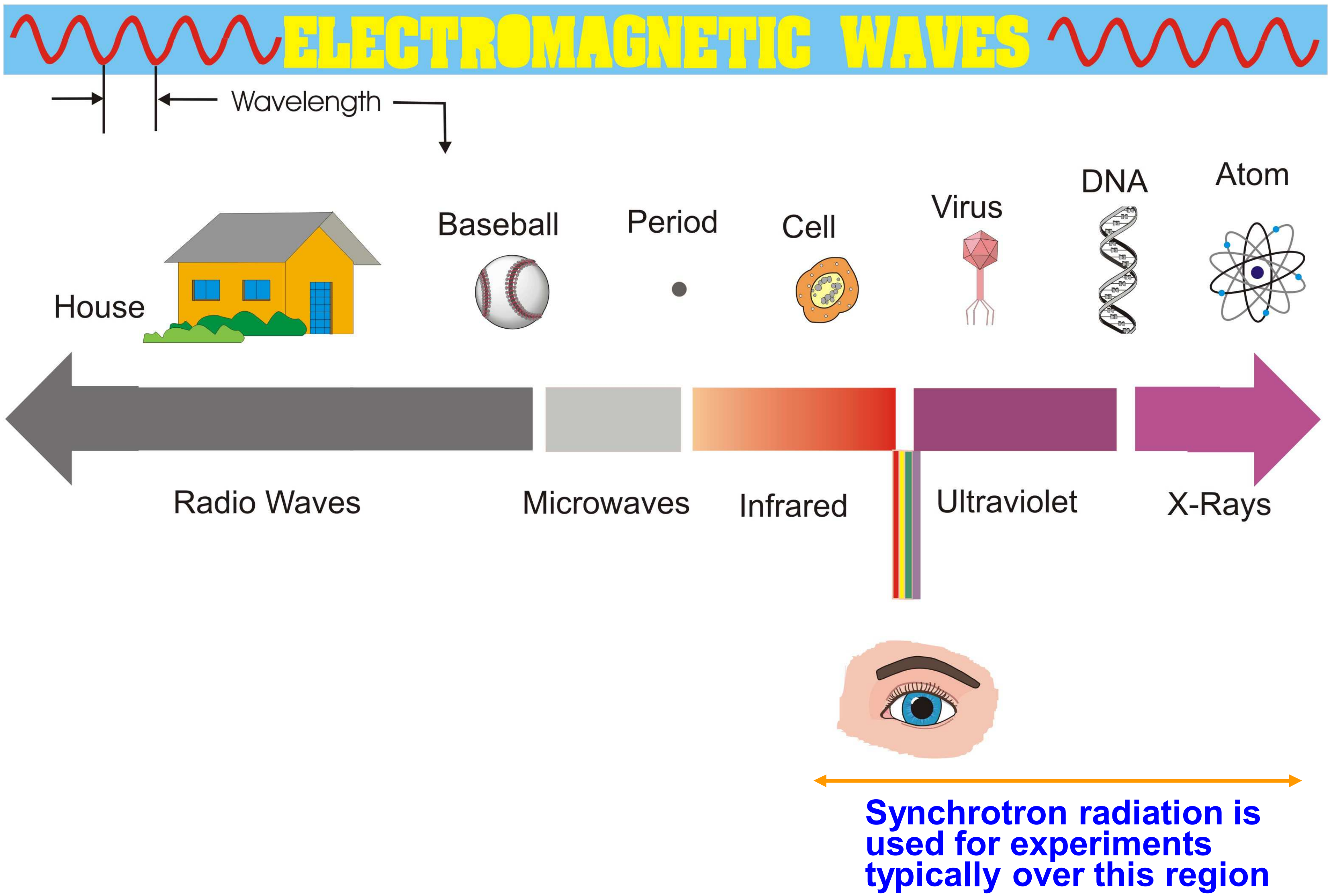
http://www.sesame.org.jo

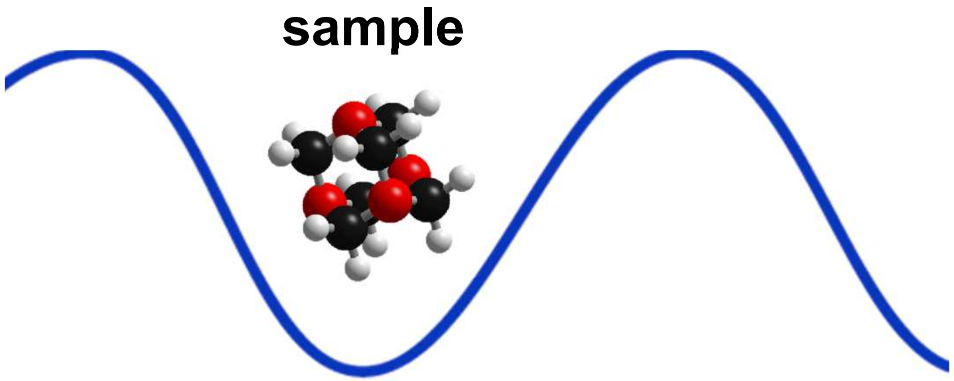
Electromagnetic Radiation - How It Relates to the World We Know



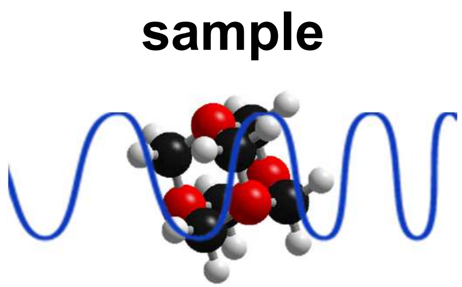
Electromagnetic Radiation - How It Relates to the World We Know



Why is wavelength important?



Visible light



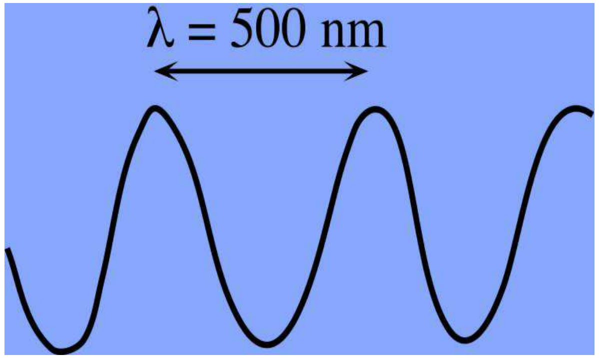
X-rays

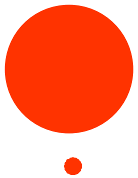
To study and penetrate a sample, one needs a wavelength of similar, or smaller magnitude.

Why can't we use a microscope?

Normally, to look at small objects we use microscopes...

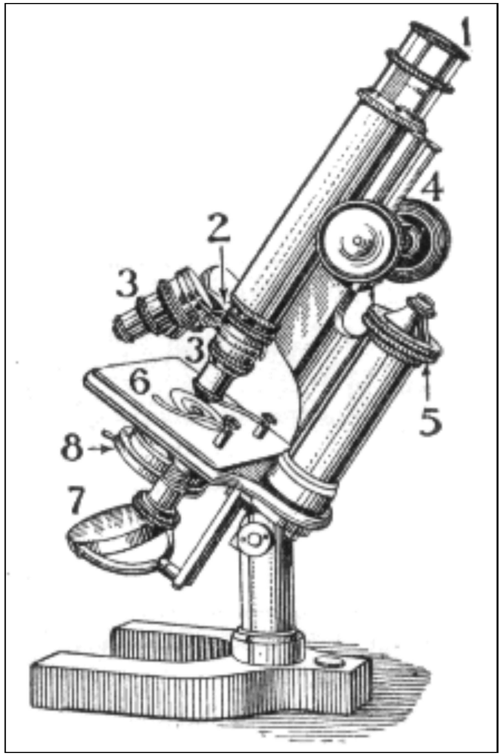
...but they can only provide images of things larger than the wavelength of light



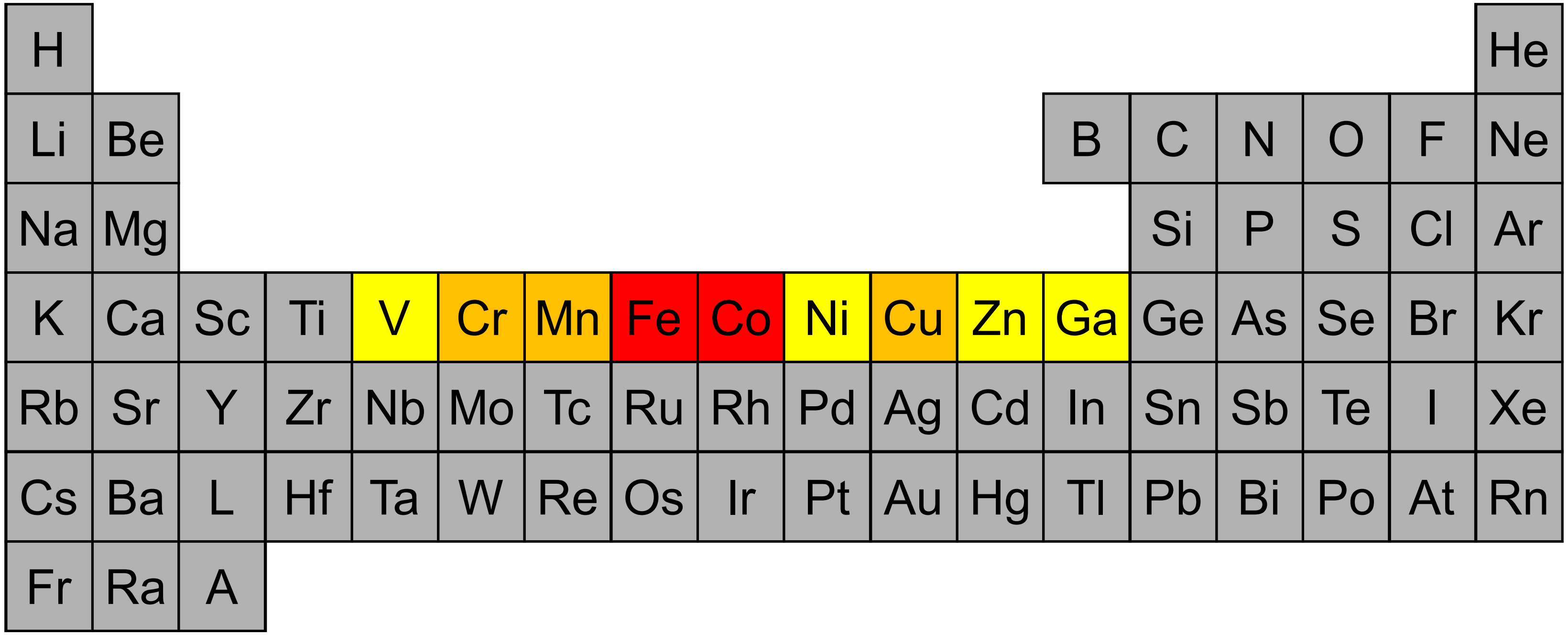


Protein (10 nm)

Atom (0.1 nm=1Å)



In theory, we could use **X-rays** (light of λ=0.1 nm, the **right size** for looking at atoms)...



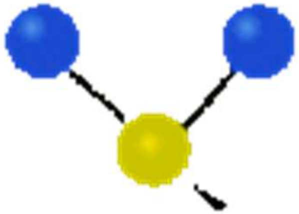
Synchrotron Radiation (SR) are produced by bending the beam of electrons in a storage ring.

Electromagnetic waves called photons at SR are produced covering range **from IR to hard X-rays**.

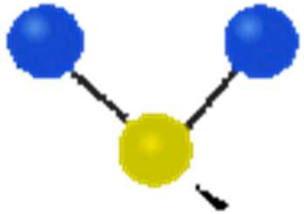
A synchrotron acts like a giant microscope – help us to see fine structure of a given sample and study their properties.

STUDY OF MOLECULES

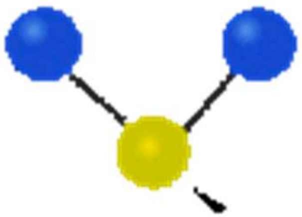
Symmetric Stretching



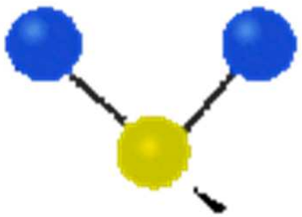
Antisymmetric Stretching



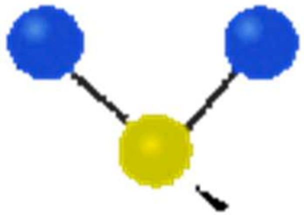
Scissoring



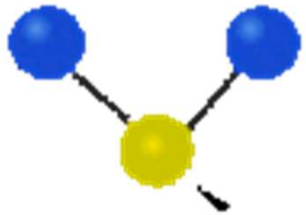
Rocking



Wagging

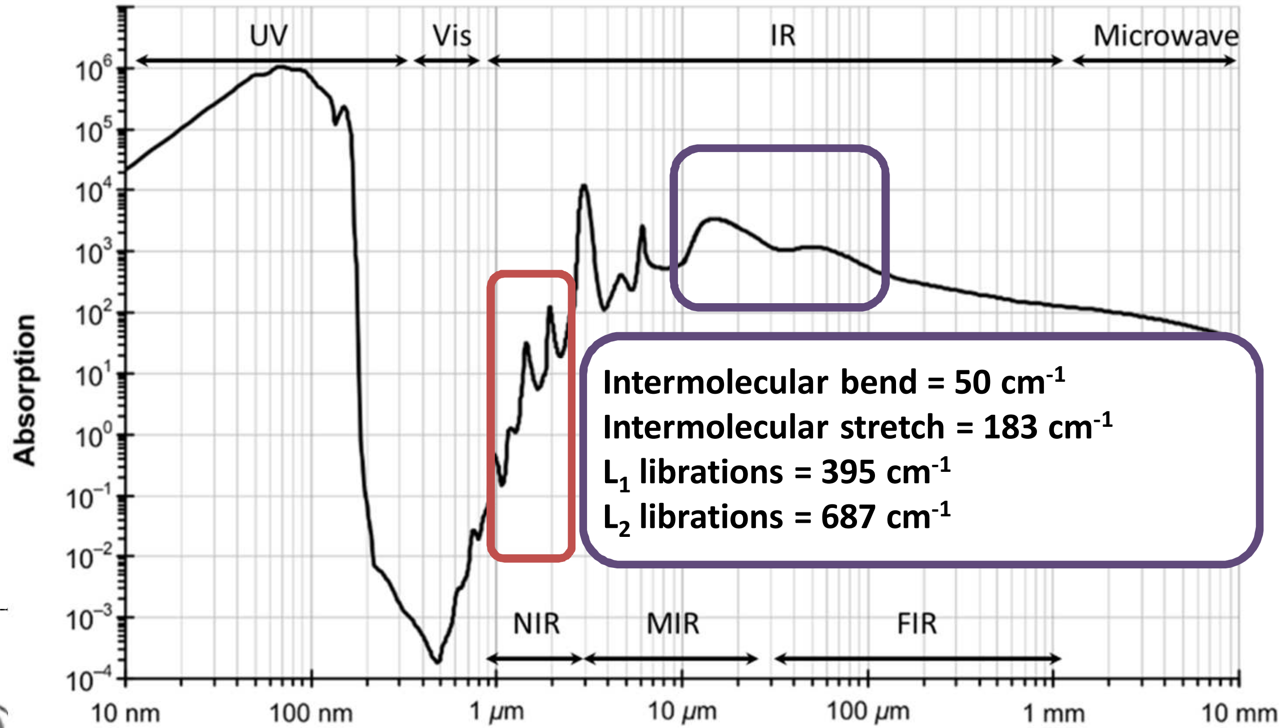


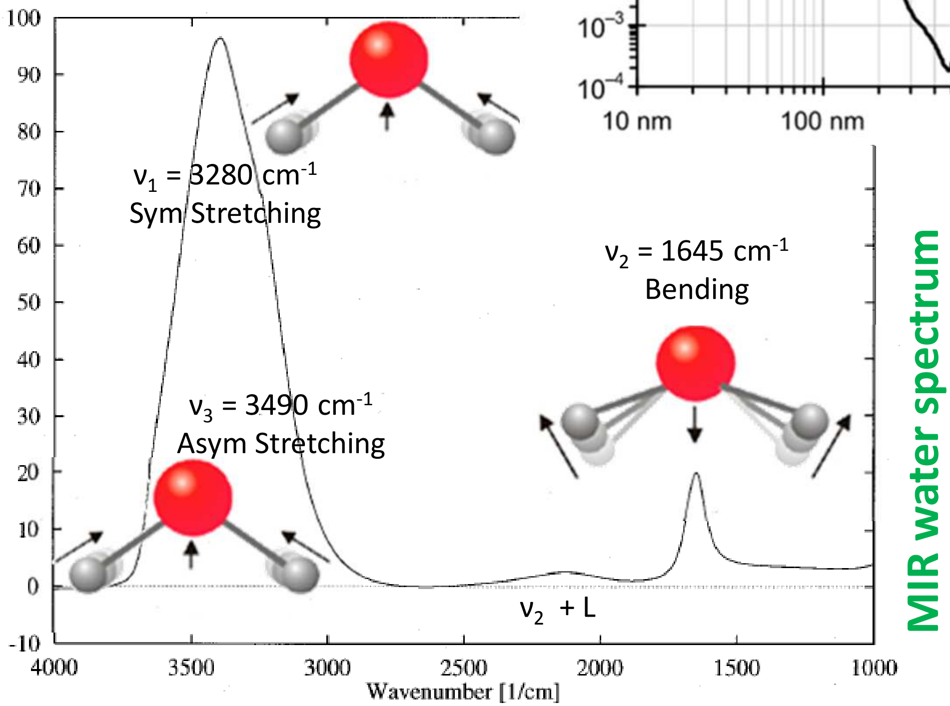
Twisting

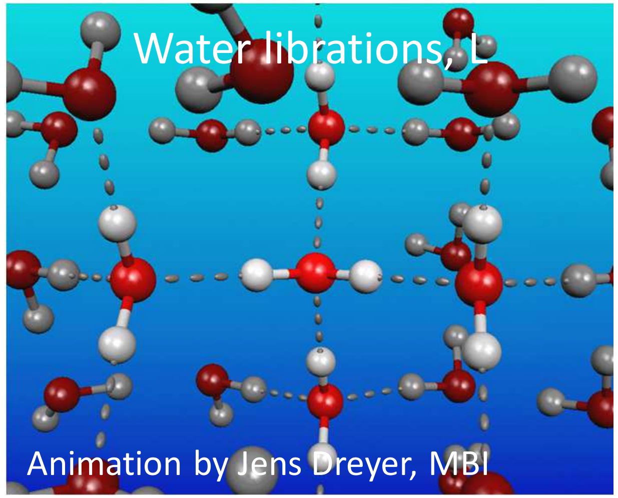


STUDYING LIQUID WATER

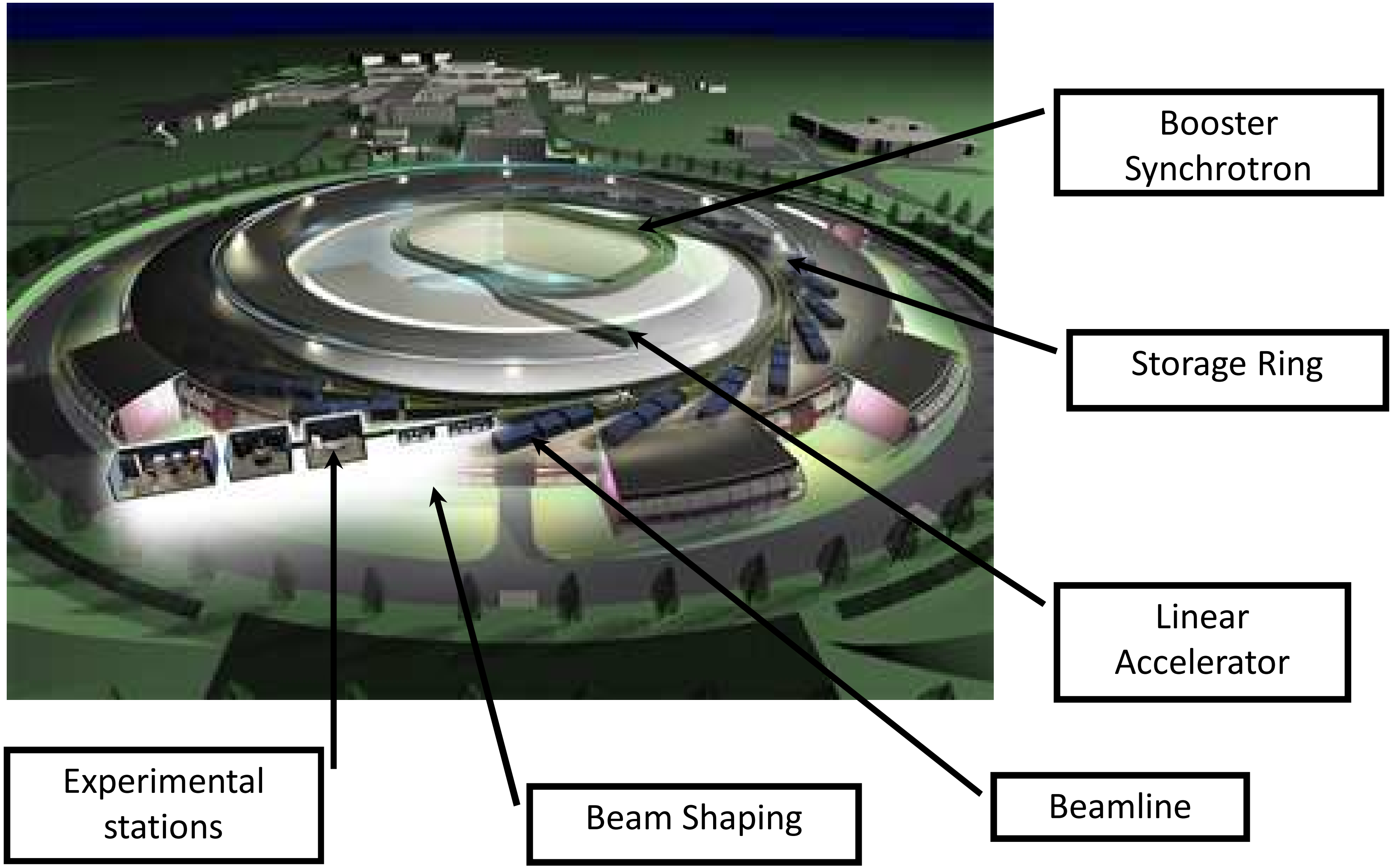
Overtones and combination bands







Synchrotron Facility Overview



Synchrotron around the World

- **Today 70 synchrotrons facilities are built or planned as funded projects throughout the world**
  - 12 in North America, among which 1 in Canada
  - 1 in Brazil
  - 20 in Europe
  - 22 in Asia
  - 1 in Australia
- **One synchrotron facility features between 7 and 65 lines**
  - Which corresponds to an estimated number of 1900 beamlines
  - One Synchrotron facility harbors about 1,000 or more users – **Total SR Users ~ 100,000**

Main Synchrotron Facilities

Facility	Organization	Location	Agenda	Lines
ESRF	European Synchrotron Radiation Facility	Grenoble, France	1988-1998	56 lines
Elettra	Sincrotrone Trieste S.C.P.A.	Trieste, Italy	1991- 2005	26 lines
SSRL	Stanford University	Stanford, USA	1973-1973	32 lines
NSLS	Brookhaven National Laboratory	New York, USA	1978-1986	65 lines
ALS	Berkeley Laboratory	San Francisco, USA	1987-1993	48 lines
Advanced Photon Source (APS)	Argonne National Laboratory (ANL)	Chicago, USA	1996-2006	68 lines
BESSY	Bessy GmbH	Berlin, Germany	1982-1999	50 lines
Spring-8	JASRI	Hyogo, Japan	1991-1997	62 lines
Max-Lab I-II-III	Lund University	Lund, Sweden	1976-2005	20 lines
NSRRC	National Synchrotron Radiation Research Center	Taïwan	1993-2004	32 lines
BSRF	Beijing Synchrotron Radiation Laboratory	Beijing, China	1985-2005	7 lines

Main Synchrotron Facilities

Facility	Organization	Location	Dates	Lines
Soleil	Société Synchrotron Soleil	Saclay, France	2002-2009	40 lines
Diamond	Diamond Light Source Ltd	Chilton, UK	2003-2013	40 lines
MPV	Australian Synchrotron	Melbourne, Australia	2002-2012?	30 lines
Alba	Cells	Barcelone, Spain	2006-2010	7 lines
Petra III	DESY	Hamburg, Germany	2006-2009	14 lines
Sesame	**IGO**	**Allan, Jordan**	**2005-15**	**7 lines**
CLS	Canadian Light Source Inc.	Saskatoon, Canada	1999-2007	30 lines
SLS	Paul Scherrer Institute	Villigen, Switzerland	2001-2010	17 lines
Max-Lab IV	Lund University	Lund, Sweden	2009-?	20 lines
SSRF	Shangaï Synchrotron Radiation Facility	Shangaï, China	2004-2010	20 lines
SAGA-LS	Synchrotron Light Application Center	Tosu, Japan	2001-2011	12 lines

Applications of SR

Materials Research

Basic understanding of semiconductors, metals, superconductors, alloys, elementary excitations, electronic structure, phase equilibrium, . . .

Surface Science

Structure of clean surfaces, ultra-thin films, interfacial junctions, dynamic and kinetic properties of surfaces, growth modes of thin films, . . .

Polymers

Structure-property relationships

Atomic, Optical, Molecular Physics and Chemistry

Vibration/rotation spectroscopy, Infrared micro-spectroscopy, Chemical dynamics

Molecular Environmental Science

Study of environmental contaminants, molecular structure, composition, oxidation state, reaction mechanisms, stability, toxicity, mobility, bioavailability, SPECIATION

Applications of SR

Geosciences

Mineral interfaces, compositional variations, coordination chemistry of materials at high temperature and pressure in the earth's crust, amorphous geological materials, mineral phases and phase transitions at high temperature and pressure, . . .

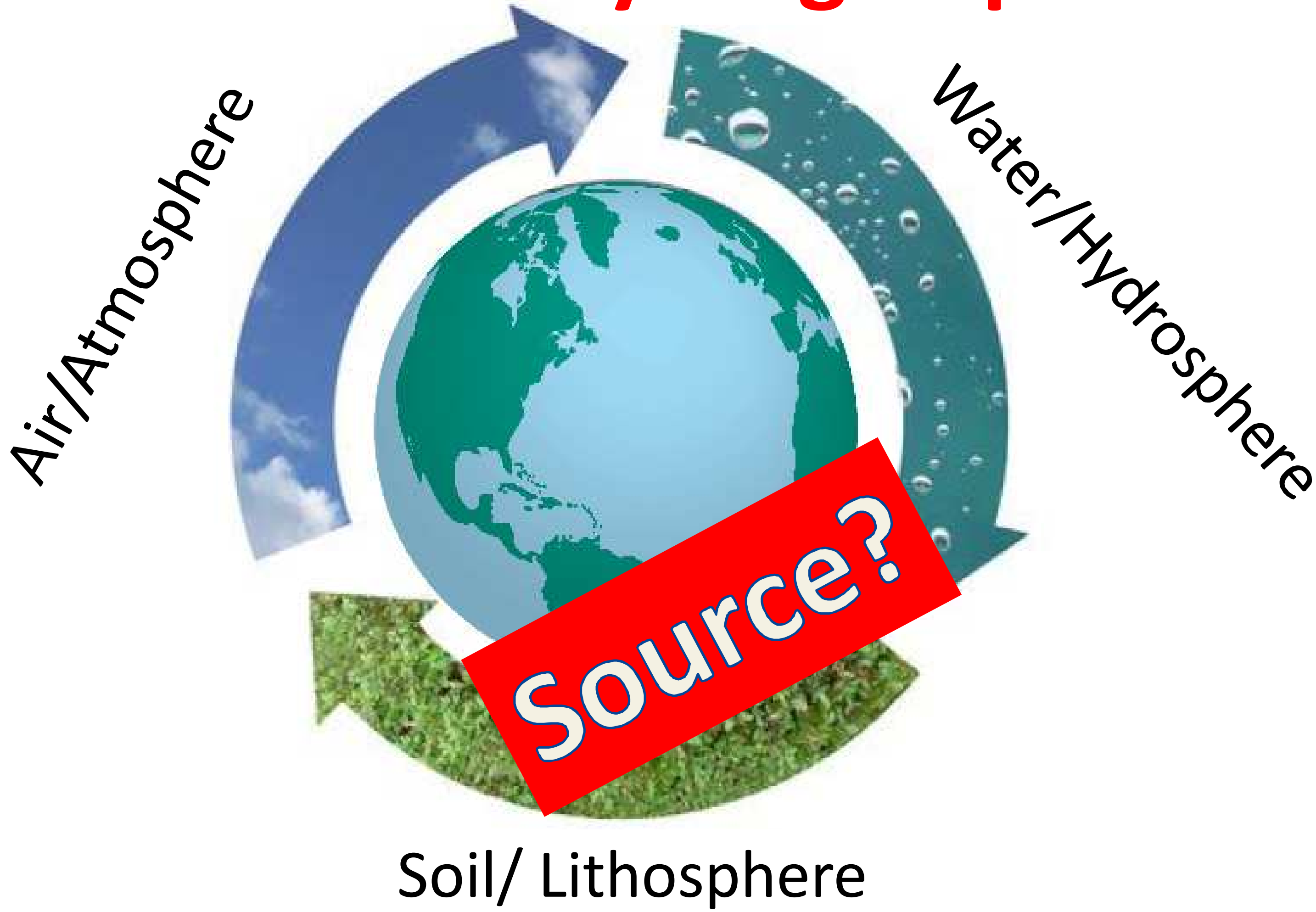
Structural Molecular Biology (Macromolecular crystallography)

- Determination of the 3-dimensional structure of proteins
- Elucidating biological pathways
- Drug design
- Sequencing of the human genome has led to the need to understand the structure and function of tens of thousands of proteins

Cultural Heritage

- Study of archeological objects such as: Dead Sea Scrolls
- Study of arts – painting, musical instruments
- Fossils

Environmental cycling of pollutants



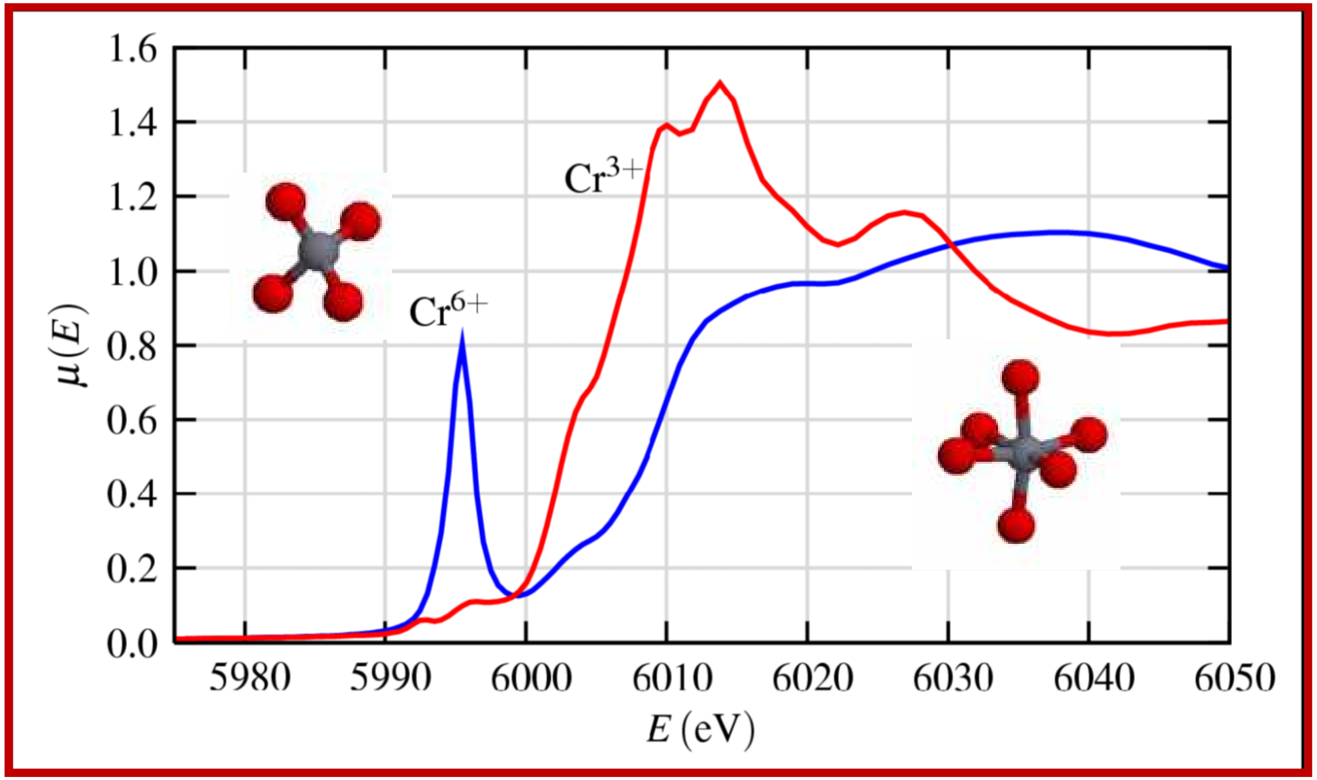
Source → **Transport and Fate of chemical species** → **Exposure**

Natural or Man made

Dilution, Alteration, Removal

The Speciation of Chromium

- Large quantities of Cr compounds are discharged in solid, liquid, and gaseous wastes into the environment
- Two common oxidation states of Cr present in the environment: Cr(III) and Cr(VI)
- Cr(III) is essential for life, Cr(VI) exerts toxic effect on biological systems leading to a large variety of clinical problems



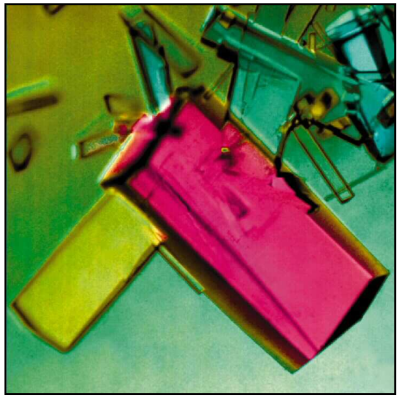

Mediterranean Sea
Qumran

The story goes that: In 1947, a Bedouin shepherd of the Ta'amirah tribe lost a goat and discovered the entire scroll of the prophet Isaiah in a cave near a ruin on a plateau on the western side of the Dead Sea.

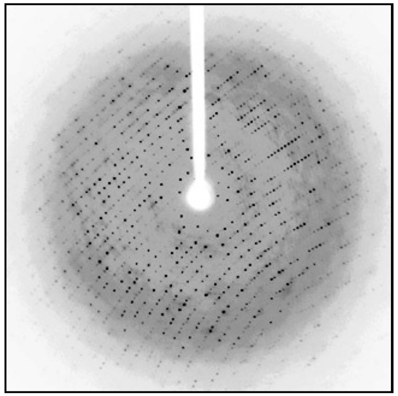
This find was the start of discovering an estimated 930 biblical and extra-biblical scrolls written in Hebrew, Aramaic and Greek, during 1947-1956

Two disintegrated pages of one of the 930 Qumran scrolls

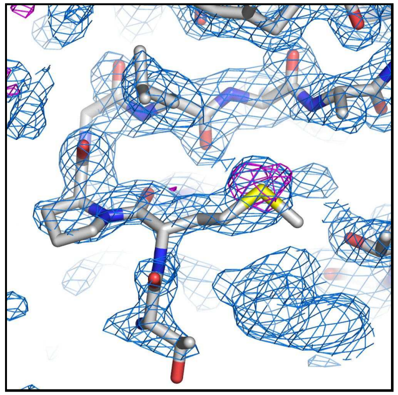
The technique



Crystal



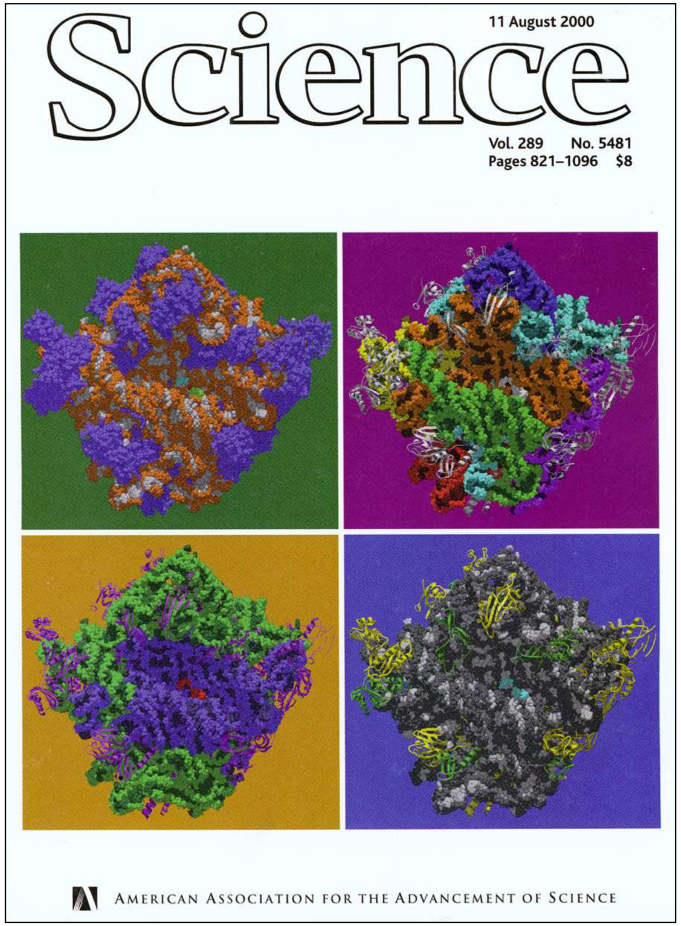
X-ray Diffraction pattern

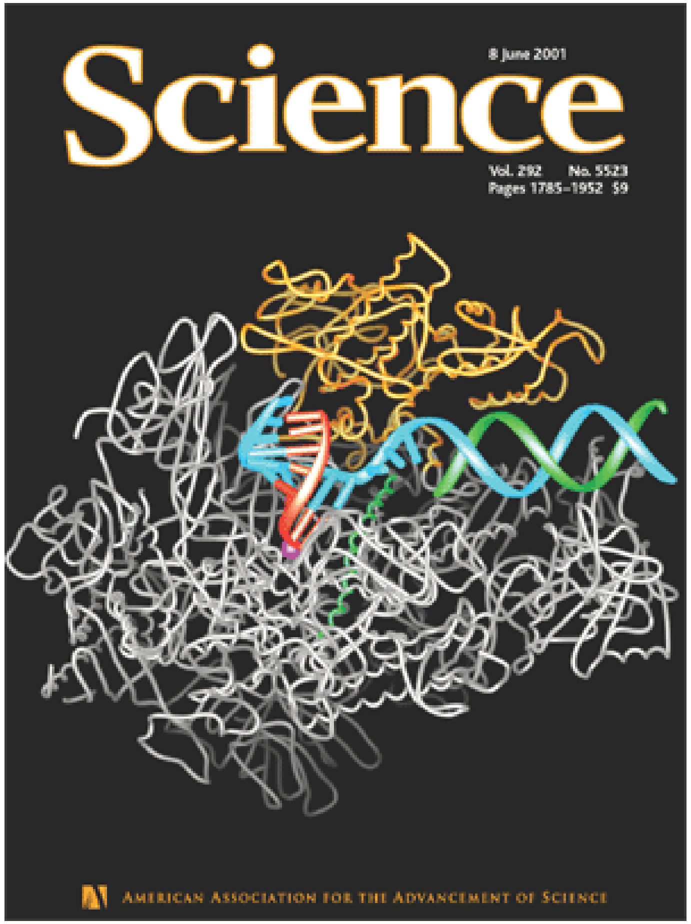


Electron density map
Protein Structure

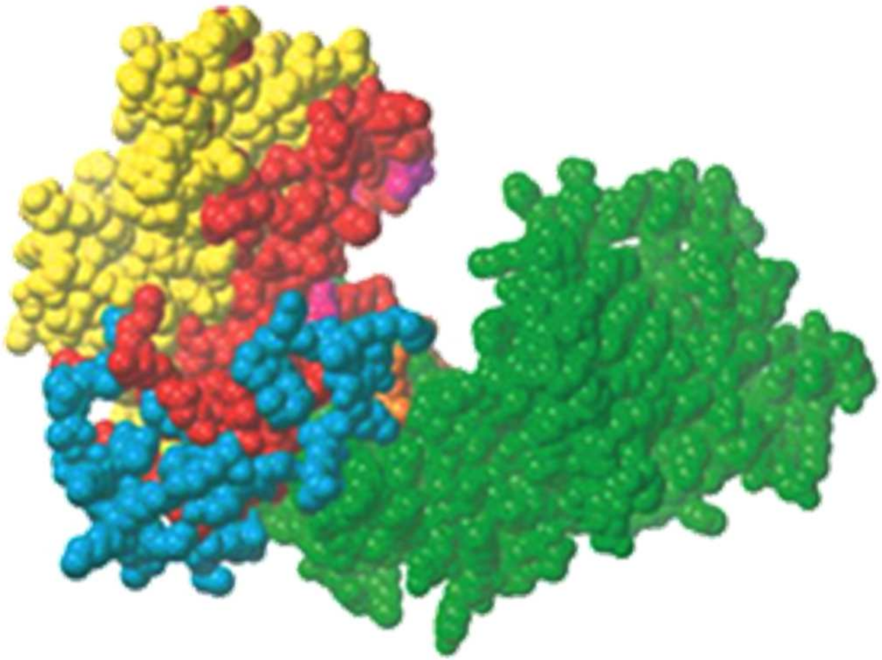
- From a X-ray diffraction experiment on protein crystal one can derive the 3D structure of the protein at the atomic level, so that it becomes possible to speculate on the exact reaction mechanism
- If the protein is involved in a disease, this information can be used to design molecules that can block the protein active site and act as specific drugs

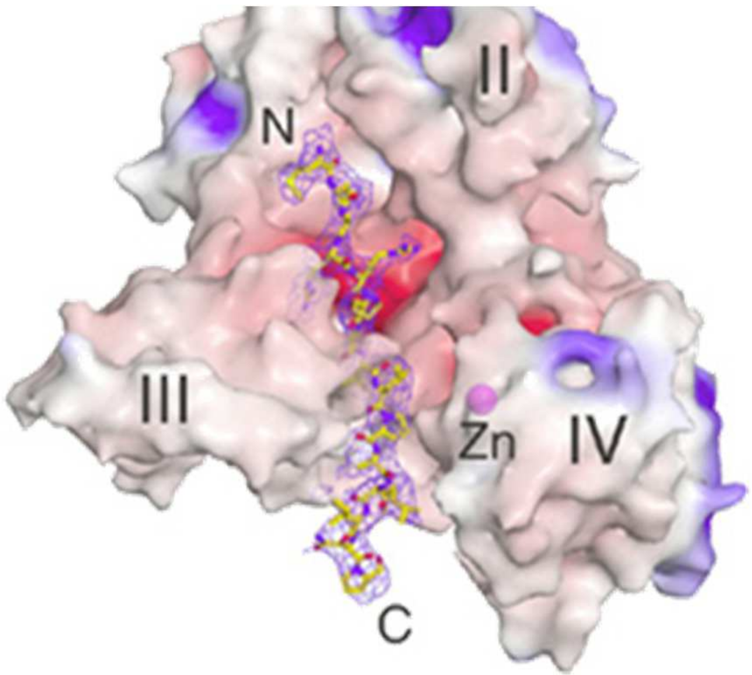
Understanding the Molecular Machines of Life. All cells contain remarkable cellular "machines," that decode genes to make proteins. Using data from the synchrotron, scientists have now determined the structures of two of these remarkable multi-component complexes (called polymerase and ribosome). Besides the remarkable discovery, these structural insights are leading to more effective strategies for designing new antibiotics.



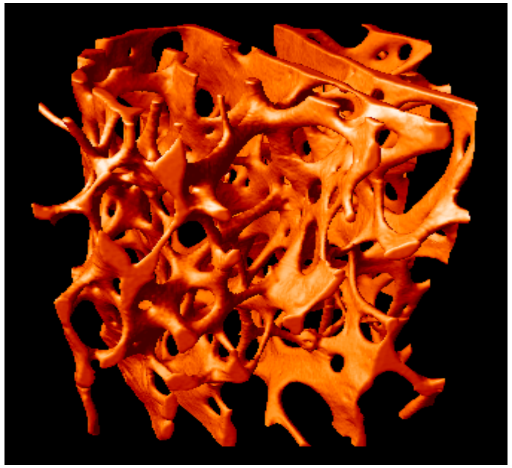


Countering Bioterrorism. Using the NSLS, SSRL and APS, researchers have determined the structures of two of the three components that constitute the anthrax toxin: proteins called Lethal Factor and Edema Factor. These structures give molecular insight into how anthrax causes infection and directly guide development of new drugs to defeat the anthrax threat.





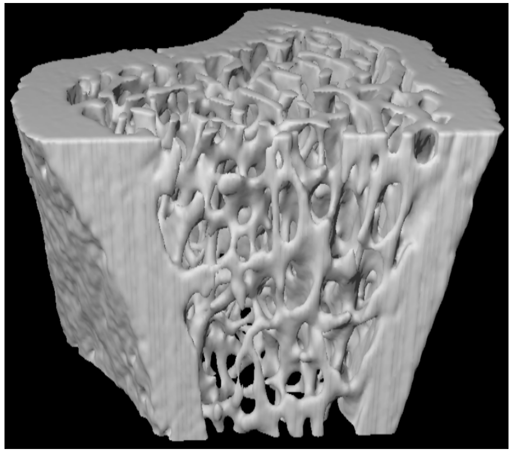
Osteoporosis Research - Understanding Loss of Bone Mass



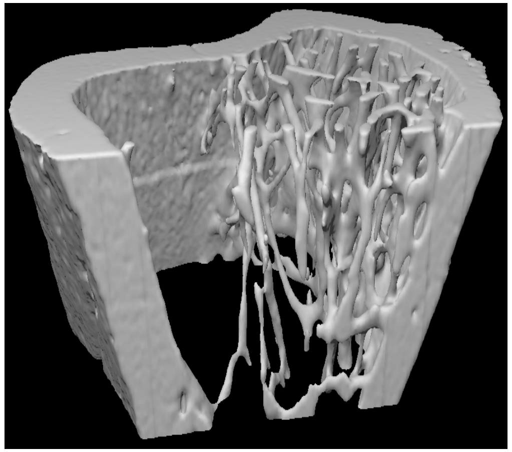
X-ray tomograph of trabecular bone in the human femoral neck taken with synchrotron radiation by LLNL scientists using synchrotron radiation at SSRL

Osteoporosis is a major public health problem

- **1.3 million osteoporotic fractures each year**
- **50% of women over 70 have had at least one fracture**
- **a disease which strikes without warning**
- **responsible for more deaths than breast cancer**



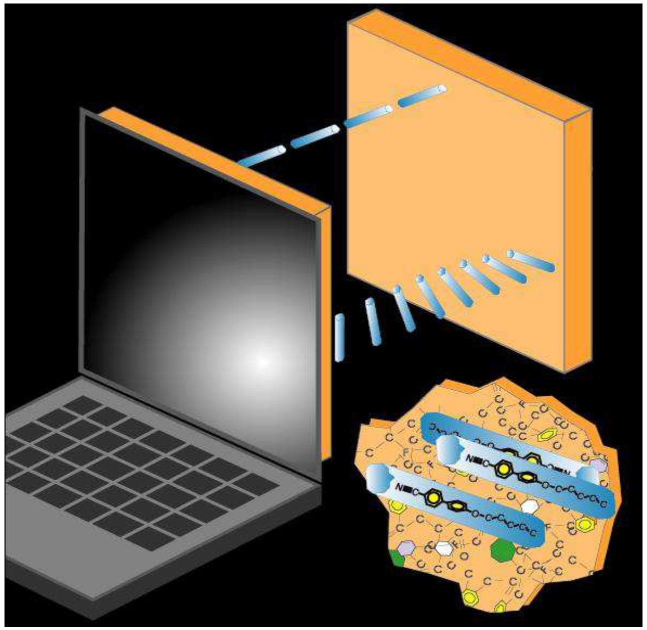
before estrogen loss



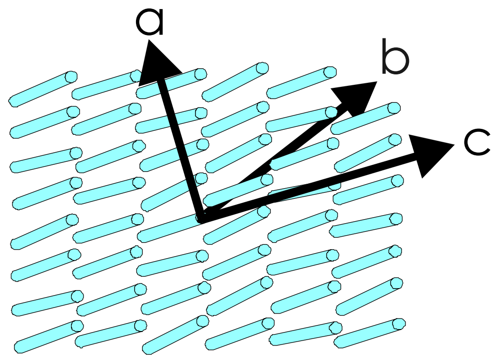
after estrogen loss

Estrogen deficiency induces rapid bone loss and altered architecture. This can be visualized in living beings using non-invasive X-ray synchrotron tomography imaging.

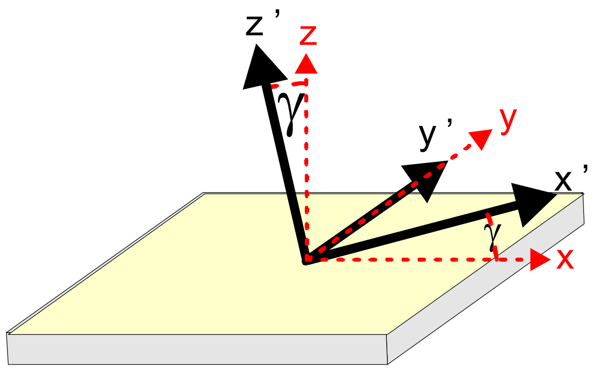
Development of New Process for Manufacture of Flat Panel Displays: Today's laptop computers utilize flat panel displays where the light transmission from the back to the front of the display is modulated by orientation changes in liquid crystal (LC) molecules. One of the key steps in the manufacture of the displays is the alignment of the liquid crystal molecules in the display. Over the past years a great challenge of this multi-billion $ industry has been to devise an alternative method of liquid crystal alignment.



Liquid crystal orientation

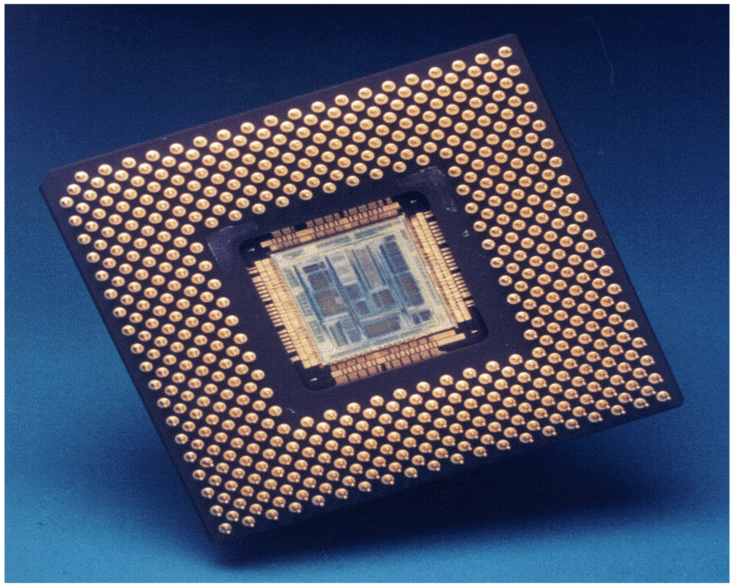


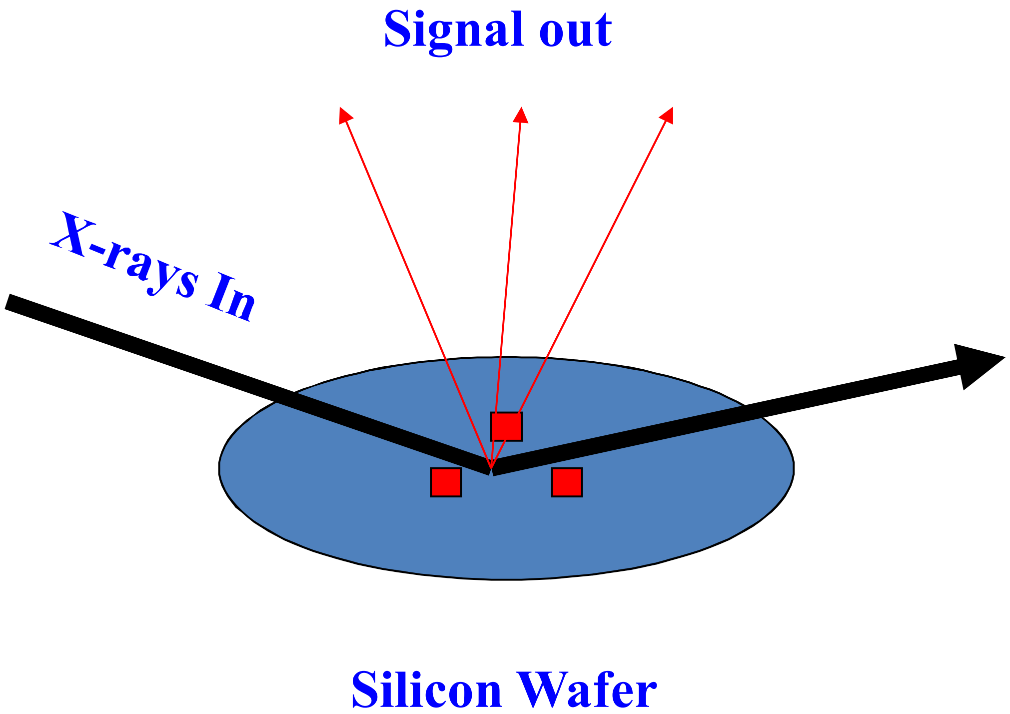
Molecular surface orientation



Polarization and surface sensitive spectroscopy measurements at SSRL by IBM scientists have been used to solve this puzzle.

Metal Contamination on Silicon Wafer Surfaces: Increasing the speed and complexity of integrated circuits requires advanced processes that put extreme constraints on the level of metal contaminants on silicon wafer surfaces. Synchrotron radiation from SSRL has been used to excite X-ray fluorescence from the metal contaminants with sensitivities as low as one metal atom per 107 silicon atoms. This is 100 times better than conventional techniques.





SESAME PHASE – I BEAMLINES

Beamline	Energy Range	Source
Protein Crystallography *(PX)*	4 – 14 keV	Bending Magnet
X-ray Absorption Fine Structure & X-ray Fluorescence *(XAFS/XRF)*	3 – 30 keV	Bending Magnet
Infra-red Spectro-microscopy *(IR)*	0.01 – 1 eV	Bending Magnet
Powder Diffraction *(PD)*	3 – 25 keV	MPW
Soft X-ray	0.05 – 2 keV	EPU
Small and Wide Angle X-ray Scattering *(SAXS/WAXS)*	8 – 12 keV	Bending Magnet
Extreme Ultraviolet *(EUV)*	10 – 200 eV	Bending Magnet

SESAME DAY-ONE BEAMLINES

- **PX Beamline – IMCAN**
  - International Macromolecular CrystAllography Nexus
- **XRF/XAFS Beamline – BASEMA**
  - Beamline for Absorption Spectroscopy for Environment and Material Applications
- **IR Beamline – EMIRA**
  - ElectroMagnetic Infrared Radiation
- **PD Beamline – SUSAM**
  - SESAME USers Application for Material Science

SUMMARY

- Fortunate to work for CERN & SESAME – essential goals:
  - – World-class science
  - – Science for Peace
- CERN created 1954 under very difficult political conditions – Dream came true
- SESAME – A dream coming true:
  - – Hope to produce world class science in ME
  - – Bridging gaps, brining people together

THANK YOU!