Zepto and Yocto: The Missing Marx Brothers

Gabor B. Levy

As the need for prefixes for 10^{-21} and 10^{-24} arose, "zepto" and "yocto" surfaced. Professor Dovichi, a leader in ultramicroanalytical techniques, jokingly suggested that these units have been named in honor of two lesser known Marx brothers. Indeed, the habits of the International Committee of Weights and Measures are mysterious, as the bastardized Scandinavian femto and atto (10^{-15} and 10^{-18}) had already proved. Joke aside, the need for having units as small as 10^{-15} and 10^{-24} is a serious and dramatic development. After all, a yoctomole is less than a single molecule. It makes sense only as a probability in a quantum mechanical context. It is instructive to visualize the full range of dimensions. The table shown by Dovichi at the Eastern Analytical Conference may be helpful.

The Scales of Chemistry

Process Chemistry	1 L =	$1\ dm^3$	Balloon
Analytical Chemistry	1 mL =	$1\ cm^3$	Thimble
Microchemistry	1 μL =	$1\ mm^3$	Raindrop
Nanochemistry	1 nL =	$(100\ \mu m)^3$	Grain of sand
Picochemistry	1 pL =	$(10\ \mu m)^3$	Red blood cell
Femtochemistry	1 fL =	$1\ \mu m^3$	Bacterium
Attochemistry	1 aL =	$(100\ nm)^3$	Smoke
Zeptochemistry	1 zL =	$(10\ nm)^3$	Virus
Yoctochemistry	1 yL =	$1\ nm^3$	Hydrated proton

The need for such incredibly small units has developed only during the past decade. Laser-induced fluorescence was one of the techniques used by Dovichi and his associates that enabled them to detect anagram quantities as early as 1982. During the intervening ten years, they pushed the limit down to fractional zeptomole range, to some 300 molecules of analyte. This matches the high resolution of capillary electrophoresis with more than a million theoretical plates that is used to analyze DNA sequencing fragments. To use the vernacular of the younger set, "This is awesome!"

The push for smaller and smaller quantities is essential in the analysis of biological materials. The tagging technique of radioimmunoassay paved the way to extremely sensitive detection. Another approach was to amplify the signal by enzyme tags. In this type of analysis, a minute amount of analyte could be related to a change in substrate that could be amplified until it was easily measurable by conventional instrumentation. The newest amplification technique reproduces the analyte itself. In polymerase chain reaction, amplification by a million is obtainable - and it is the "hottest" new technique in molecular biology and diagnostics. As we advance deeper and deeper into molecular biology we are in the world of zepto- and yoctochemistry, and these techniques enable us to forge ahead.

Another new development is the scanning tunneling microscope and its variants. It not only serves to visualize surfaces on an atomic scale but even allows us placing or displacing individual atoms. Who can forget the picture of IBM spelled out a few years ago by lines drawn with single atoms? At the same time, semiconductor very-large-scale integration has come into being. It brought with it miniscule individual circuit elements. The manufacturing experiences spilled over to mechanical arts and a new field of "nano-fabrication" followed. It has already produced on laboratory scale astonishing minute optical elements, gears, turbines, and an array of marvelous mechanical devices.

A special section of the November 29, 1991, issue of *Science* was devoted to these dramatic developments. They add up to a revolutionary wave in all fields of science and technology. They are driven by what IBM calls "the discontent ... to go beyond." The issue of *Science* mentioned, quotes Feynman who foresaw

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COMING EVENTS

✓ First Wed. of Each Month in '96: **New Strategies & Tactics in Image Analysis.** Iowa City, IA. Dr. J.K. Beddow, (319)337-2427, Fax: (319)337-2474.

✓ **Orientation Imaging Microscopy Workshops** (TexSEM Labs), Provo, UT. (801)344-8990, Fax: (801)344-8997.
Feb. 24/28 '97
June 23-27 '97
Sept. 29/Oct. 3 '97

✓ **Marine Biological Laboratory Courses** Woods Hole, MA:
May 8/16 '97: Analytical & Quantative Light Microscopy
May 20/27 '97: Microinjection Techniques in Cell Biology
Oct. 8/16 '97: Optical Microscopy & Imanging in the Biomedical Sciences.
Carol Hamel: (508)289-7401, eMail: admissions@mbl.edu

✓ Jan. 8/11 '97: **Atomic Structure of Interfaces Winter Workshop** (Arizona State Univ.) Tempe, AZ. Sharon Willison: (602)965-4424, Fax: (602)965-9004

✓ Jan. 23 - May 8 '97: ***Scanning Electron Microscopy* Spring 1997 Course** (Nassau Community College) Garden City (Long Island), NY. Stephen J. Beck: (516)572-7829

✓ February 3/7 '97: **4th Biennial Symposium on SEM Inaging and Analysis: Applications and Techniques.** Melbourne, Australia http://www.minerals.csiro.au/microscopy/amas/amas.htm

✓ February 8/14 '97: **Photonics West '97.** (SPIE). San Jose, CA. Marilyn Gorsuch: (360)676-3290, Fax: (360)647-1445.

✓ February 24/28 '97: **LIM Academy: Course in Orientation Imaging Microscopy.** (TSL). Klaus Behnert: (801)344-8990, Fax: (801)344-8997/

✓ March 16/21 '97: **PITTCON '97** - Atlanta, GA. (412)825-3220, Fax: (412)825-3224.

✓ March 31 - April 4 '97: **Workshop on Specimen Preparation for TEM of Materials - IV.** (MRS Spring Meeting). San Francisco, CA. Scott Walck: (513)255-5791, Fax: (513)255-9019.

✓ March 31 - April 4 '97: **Materials Reliability in Microelectronics VII.** (MRS Spring Meeting). San Francisco, CA. Robert Keller, (303)497-7651, Fax: (303)497-5030.

✓ April 4/6 '97: **16th Southern Biomedical Engineering Conference.** (Mississippi State Univ. & Univ. of Mississippi Medical Ctr.) Biloxi, MS. Dr. Joel D. Bumgardner: (601)325-3282, Fax: (601)325-3853.

✓ April 19/22 '97: **SCANNING '97** (FAMS, Inc.) Monterey, CA. Mary K. Sullivan, (201)818-1010, Fax: (201)818-0086

✓ April 27 - May 1 '97: **19th International Conference on Cement Microscopy.** Cincinnati, OH. Louis Jany: (610)261-4429, Fax: (610)261-4430.

✓ May 10/15 '97: **30th Anniversary Scanning Microscopy and Cells and Materials 1997 Meeting.** (Scanning Microscopy International). Chicago, IL. (847)524-6677, Fax: (847)985-6698.

✓ May 15/17 & May 19/21 '97: **Quantitative Image Analysis Short Course.** (N.C. State Univ.) Raleigh, NC. (919)515-2261.

✓ May 19/23 & 26/30 '97: **PASEM 97 SEM Short Course.** (Univ. of Maryland). College Park, MD. Tim Maugel: (301)405-6898, Fax: (301)314-9358.

✓ May 30 - June 2 '97: **Korea International Scientific Instruments Exhibition '97** Seoul, Korea. Tel: 82-2-551-1112, Fax: 82-2-551-1311

✓ June 4/7 '97: **24th Annual Meeting of the Microscopical Society of Canada.** Edmonton. Ray Egerton: (403)492-5095, Fax: (403)492-0714.

LEHIGH UNIVERSITY MICROSCOPY COURSES:

✓ June 9/13 '97: SEM and X-ray Microanalysis

✓ June 16/19 '98:
Advanced Scanning Electron Microscopy with Digital Image Processing
Quantitative X-ray Microanalysis of Bulk Specimens & Particles
June 17/20 :97: Atomic Force Microscopy & other Scanned Probe Microscopies.
Bethelem, PA. David B. Williams, (610)758-5133, Fax: (610)758-4244.

✓ June 4/7 '97: **24th Annual Meeting of the Microscopical Society of Canada.** Edmonton, Canada. Ray Egerton: (403)492-5095, Fax: (403)492-0714.

✓ June 9/14 '97: **ACHEM 97** - International Meeting on Chemical Engineering, Environmental Protection and Biotechnology. Frankfurt am Main. +49(69)7564-280, Fax: +49(69)7564-201.

✓ June 16/19 '96: **Quantitative Image Analysis Short Course** (N.C. State Univ.) Taastrup, Denmark (919)515-2261

✓ June 19/20 '97: **3D Microscopy of Living Cells Short Course and NEW post-course workshop.** (Univ of WI & Univ of B.C.) Vancouver, B.C. James Pawley: (608)263-3147, fax: (608)265-5315

✓ June 23/27 '97: **13th Annual Short Course on Molecular Microspectroscopy.** (Miami University) Oxford, OH. (513)529-2874, Fax: (513)529-7284

✓ July 6/9 '97: **CRYO '97 - Low Temperature Microscopy and Analysis.** (Royal Microscopical Society). Univ. of York, RMS: +44(0)1865 248768, Fax: +44(0)1865 791237

✓ Aug 10/15 '97: **MSA/MAS Annual Meeting.** Cleveland, OH. MSA Business Office: (800)538-3672. Fax: (508)548-9053

Children's Books on Microscopy: A Bibliography

is now available at the MSA website:
http://www.MSA.microscopy.com.ProjectMICRO/books.html

Here is a beginner's list of websites that will lead you to other resources for K-12 microscopy education:

Ask a Microscopist:
http://www.MSA.microscopy.com/Ask-A-

3D Images:
http://www.peo.philips.com/art/3d.html

"What is it?"
http://www.uq.oz.au/nanoworld/whatisit.html

Images Online:
Http://www.mwrn.com/subject/images.html

K-12 microscopy resources:
http://www.mwrn.com/feature/educatio.html

Amateur microscopy:
http://www.microscopy-uk.org.uk

Home-made microscope:
http://www.mos.org/sin/sem/myomicro.html

and if it is too dilute the particles will be difficult to find on the support film. The correct dilution can only be established by trial and error.

Specimen Storage

A Petri dish is adequate for temporary storage, say between preparing the specimen and deciding whether it is worth keeping. A piece of filter paper in the bottom can be marked into areas with a pencil and several specimens can be stored. It is possible to buy an insert for 50 and 90 mm dishes which is divided into numbered squares separated by raised ridges designed to minimize the risk of grids being mixed up.

Some sort of grid box is needed for permanent storage. The problems to be avoided are electrostatic charging of the grid, specimen, or box and mechanical damage to the specimen while it is inserted or removed from the holder. Several designs of plastic box with slits for 50 or 100 grids are available commercially. Grids can also be stored individually in gelatine capsules (diameter 5 mm) since only the edges of the grid or disc then touch the capsule and the risk of damage is minimized. Individual capsules can be stuck to a piece of card for labeling and storage. Some workers believe that the gelatine capsules can contribute to specimen-borne contamination in the microscope but the present author has seen no evidence of this.

The golden rules concerning specimen storage are: LABEL IT and DO NOT LEAVE SPECIMENS IN THE MICROSCOPE ROOM. (They will disappear). ■

* *This article is from Specimen Preparation for Transmission Electron Microscopy of Materials, Royal Microscopical Society Microscopy Handbook Series. It is available from Microscopy Today at $21.00 plus $5.00 shipping and handling.*

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this direction as early as 40 years ago. He referred to "a staggering small world that is below." There is this powerful intellectual challenge to move where there is "plenty of room at the bottom." But there is an additional powerful force, perhaps not always recognized. On our overcrowded planet we are in danger of running out of energy, out of accessible raw materials, out of space. Short of throttling our activities, we must resort to smaller and smaller scale.

So, while the next generation may well forget Groucho, Harpo, and Zeppo, they will have to live with zepto and yocto. ■

This article is one of a series of Dr. Gabor B. Levy's essays on science and society containing thought-provoking editorials previously published in International Scientific 'Communications' journals. The book expresses the author's point of view on such subjects as Our Society, Our Economy, Ethics, Lawyers and the Law, Health and Medicine, Statistics, Science. Pseudoscience, Metrology, and New Directions. Size 8½" x 5½". Price only $10.99 plus $3.50 for shipping and handling. Order now by check or money order, as supplies are limited. International Scientific Communications, Inc., 30 Controls Drive, Shelton, CT 06484.