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PERSPECTIVES: GENOMICS

A Crisis in Postgenomic Nomenclature

Stanley Fields and Mark Johnston

We all know what a genome is, and we think we understand the term proteome, but can anyone tell us the constituents of a functome? As the availability of complete genome sequences has spawned analyses of entire complements of proteins, RNAs, metabolites, and other cellular constituents, there has arisen a need for a terminology expansive enough to encompass the global scale of the data. A sensible suffix was appropriated for this purpose, but now is proliferating uncontrollably: genome, proteome, transcriptome, metabolome, interactome, even phenome, with many more 'omes sure to be in various stages of gestation. Perhaps it is not completely coincidental that 'ome is also the anglicized form of 'oma (*1*), commonly used to name such unwelcome intrusions as sarcoma, lipoma, and fibroma. This metastatic growth of the 'ome is spreading imprecision and confusion. Meanwhile, research summaries in the front of major scientific weeklies with titles like *'Ome Sweet 'Ome*, and *'Ome…'Ome…'Ome: The Genomicist's New Mantra*, and our personal favorite, *The 'Ome: A Pièce de Résistance*, only serve to confuse us further. Because a clear and widely accepted nomenclature is essential for the health of any discipline, a systematic solution to this problem is urgently needed.

It is often instructive to look to the past for guidance. A now familiar nomenclature grew up around the related suffix 'some (for which 'ome is sometimes mistaken), meaning "body," which has been used to name various intracellular particles. "Chromosome" dates back more than 100 years, "ribosome" and "lysosome" are nearly half a century old, and "nucleosome" and "replisome" originated more than a quarter century ago (*1*). Even "spliceosome" and "proteasome" are approaching two decades of service. This relatively modest growth in the application of the suffix 'some contrasts with that for 'ome. Although "genome" was coined by German scientists ("genom") in 1920 and first used in English in 1930 (*1*), none of the other 'omes can lay claim to more than a few years of history.

There are two underappreciated and so far unresolved predicaments with the 'ome terminology. First, there is a problem with its scope. Whereas the extent of the genome is clear (all the genetic material of a cell), what constitutes a transcriptome is not so obvious. Is it just the mRNAs, or does it include the transcripts produced by RNA polymerases I and III? What about transcripts that end up in the enzymes telomerase or RNaseP, or in ribonucleoprotein particles such as snRNPs? The precise constituents of an 'ome are often not well specified.

A second, and much more severe, problem is the conditional nature of some 'omes. The genome—notwithstanding the occasional hop of a transposon or rearrangement of an immunoglobulin gene—is a relatively fixed entity, and reasonable people can agree on its definition. But the proteome present in a cell at one moment will differ drastically from that in the same cell moments after it has been heated to 65°C. Or, if we define a cell's glycosylome at time zero, and seconds later the cell undergoes programmed cell death, its carbohydrate moieties are likely to give up the ghost nonuniformly, with some persisting to the last. At what point in this process do we define the glycosylome?

To circumvent these difficulties and others sure to emerge, we propose some simple rules. First, considerable precision can be gained by a more circumscribed representation of the 'ome's constituents, for example, phospholipidome rather than lipidome; inositol phospholipidome rather than phospholipidome. Of course, this has the potential to be abused and to lead to absurdly finer subdivisions. For example, do we want the transcription factorome to be subdivided into the transcriptional activatorome and the transcriptional repressorome? Does not the transcriptional activatorome then include the zincfingerome, which itself includes the Cys-His zincfingerome and the Cys-Cys zincfingerome? To avoid this pitfall, we propose that the minimum number of similar cellular constituents that constitute an 'ome be clearly defined. Seven or eight seems to us a conservative yet valuable cutoff. Thus, there can be no "nucleicacidome" (there's only DNA and RNA, after all), but there certainly is a "nucleotideome" (A, T, G, C, U, I, plus myriad modified purines and pyrimidines); no "actinome," of course (humans have only six actin isoforms), but definitely a "tubulome" (multiple α and β tubulin isotypes, not to mention γ, δ, ε, ζ, and η tubulins).

Second, it would be helpful if the state of the cells for which an 'ome is defined were apparent in the nomenclature. If initially we use basic parameters like temperature, pH, cell cycle stage, and subcellular

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localization, we can obtain a definition such as, "the 37°-7.4-G1-Golgi-N-but-not-O-linked glycosylome." This system has enormous versatility and can be suitably expanded to incorporate other parameters, including cell source, developmental timing, and much more. Perhaps at first this may seem a bit cumbersome. But please remember that this nomenclature is no more intricate than the (±)-*N*-methyl-γ-[4-(trifluoromethyl)phenoxy]-benzenepropanamine used so effectively by chemists and many others. As a more wieldy alternative, we also propose that an Enzyme Commission (E.C.)–style nomenclature should be established that allows the incorporation of as many specifications as needed. In this format, the particular glycosylome mentioned above has been provisionally designated the 4.7.5.3.8ome. We expect that these numerical names, after a sufficient number of citations, will become as familiar as many E.C. numbers.

The adoption of our simplified system means that as new technologies emerge enabling the assay of yet more cellular constituents, the nomenclature is already in hand to deal with the discoveries. Which brings us to a final thought. As biologists approach a definition of all of the various machines that carry out life's basic processes, we should be able to define the ultimate 'ome, the collection of all of these machines: the "someome." Others might prefer to call this the "omesome," given that it defines the machine comprising all the 'omes. Either one is a vast improvement over their imprecise and prosaic synonym currently in wide use: the cell.

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RETROSPECTIVE

Willibald Jentschke (1911–2002)

Albrecht Wagner

Willibald Jentschke, founder of Germany's particle physics laboratory DESY near Hamburg and former director general of CERN, passed away on 11 March 2002, a few months after his 90th birthday.

Born in Vienna in 1911, Jentschke obtained his Ph.D. in nuclear physics at the age of 24. He continued to work in Vienna until 1951, when he moved to the University of Urbana, Illinois, to become the director of the cyclotron laboratory.

When the University of Hamburg offered him the chair for experimental physics in 1955, he requested funds to create a modern nuclear physics research facility in Germany. After intense negotiations, during which Jentschke became famous for his negotiating skills and persistence, the Hamburg government offered him the high sum of DM 7.5 million for the construction of a particle accelerator. He accepted the offer and became a faculty member in 1956.

Jentschke had initially considered building a 2-GeV proton synchrotron, but after debating the question with his university colleagues in Germany, he decided to build a 7.5-GeV electron synchrotron instead. The Deutsches Elektronen-Synchrotron (DESY) was founded on 18 December 1959. Jentschke became its first director, and remained in this position until 1970.

The decision to build an electron synchrotron was driven by the wish to create complementary research facilities in Europe, especially given that the European Organization for Nuclear Research (CERN) was building a proton synchrotron near Geneva. Soon after high-energy physics experiments with accelerated electrons began at DESY, research with synchrotron radiation, emitted by the electrons during acceleration, became the second strong research area of the laboratory. For over 40 years, it has remained DESY's mission to build accelerators for particle physics and synchrotron radiation and do experiments with them.

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Jentschke fostered strong links to universities and laboratories in Germany. He started the first international collaborations at DESY, a nationally funded institution. This cooperative approach later became very important, leading, for example, to the "HERA model" of international collaboration, where other nations contributed through accelerator components to the realization of the HERA collider. He also attracted excellent scientists to join him in Hamburg, together with whom he gave the laboratory its present form.

Once the DESY research program was up and running, Jentschke had to decide which machine to build next. Given the knowledge of particle physics during the sixties, the idea of building an electron-positron collider, DORIS, offered few prospects for exciting discoveries. A bigger synchrotron seemed a safer bet. But after intense discussions with advocates for either machine, Jentschke decided in favor of DORIS, of exploring new territory. We know today that this was the right choice, not only for particle physics but also for the future of synchrotron radiation.

From 1971 to 1975, Jentschke served as director general of CERN Laboratory I (the original Meyrin site). He oversaw the exploitation of important new research investments, notably the Intersecting Storage Rings (ISR), high-intensity proton beams, and an ambitious research program for neutrino physics. In 1973, this effort enabled physicists using the Gargamelle bubble chamber to discover the neutral currents of the weak interaction. Faced with such a major discovery, scientists at CERN were nervous, but Jentschke ensured that the CERN result was duly recognized. The discovery remains one of CERN's greatest achievements.

After his time at CERN in Geneva, Jentschke spent a sabbatical year at the Stanford Linear Accelerator Center before returning to Hamburg, where he became a professor emeritus in 1979. He remained interested in the developments at DESY, where he celebrated his 90th birthday with old friends and colleagues.

The secret of Willibald Jentschke's success lay in his personality, which was a unique blend of knowledge, competence, vision, ideas, charm, courage, and the talent to recognize and attract excellent colleagues. He listened and talked to the people working with him, always asking questions and generating ideas. He wanted a team and people to fit into it. This spirit is still present at DESY today.

As director general of CERN, Jentschke wrote in 1975: "I believe that we must base our future plans on international collaboration, certainly within Europe, or perhaps, if conditions eventually permit, within a wider context." That this vision is becoming a reality today is his testament.

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