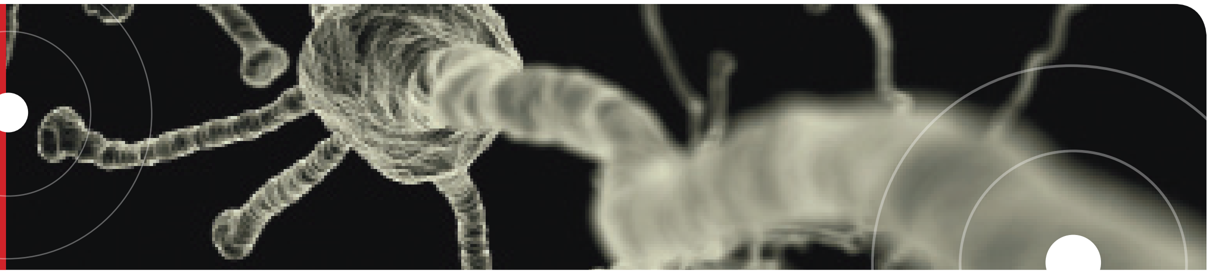
ON OUR RADAR



EXPLOITING PHYSIOLOGICAL INTELLIGENCE

By Kevin P. O'Connell

What do we mean by "physiological intelligence"? An internet search for the term points readers to a psychological definition: an understanding of one's own body, in the same way that "emotional intelligence" suggests a kind of self-awareness. In this issue of IQT Quarterly, however, we are drawing from the bleeding edge of 21st century science to greatly expand this definition.

In our context, we mean actionable information about human identity and experience that have always been of interest to the Intelligence Community. Obtaining this information is now being made possible by an increasingly deep understanding of human physiology, driven by advances in molecular biology, genomics, microfluidics, chemical instrumentation, and material science. Put another way, physiological intelligence is the Measurement and Signature Intelligence (MASINT) of the human body at a level of resolution not previously accessible, but from which a wealth of information might be obtained.

What is the sample space for physiological intelligence? The classic cartoon strip Peanuts occasionally featured a character called "Pig-Pen," a perpetually dirty waif whose cloud followed him around constantly. While Pig-Pen's cloud is noxiously obvious, it turns out to be a vivid analogy for an emerging realization: even the most fastidious persons emanate a "cloud" of biological, chemical, and physical signatures that, while insensible to us, are becoming exploitable at increasing distances. The signatures range from the familiar (electrocardiograms, electroencephalograms) to those only recently discovered (patterns of expression for thousands of genes) that are being analyzed in ways beyond what was conceivable only five years ago. Such analyses can reveal surprising and useful information.

Human Identity: Answers to the questions "Who is this?" and "To whom is this person related?" are critical in security, forensics, family law, and healthcare, not to mention the basic sciences of genetics and anthropology. Beginning in the 1980s, human geneticists devised means of extracting unique signatures from the human genome to address these questions. To date, however, obtaining the answers for individuals has required large, expensive, sophisticated laboratories and highly trained personnel. Only recently have engineers and molecular biologists begun to synergistically create fieldable solutions that will enable non-specialists to quickly and unambiguously collect and exploit DNA-based human identity and relationship data. Beyond DNA and literal fingerprints, there are efforts underway to exploit other biological signatures, such as electrocardiogram (ECG) signals. ECG may contain finer-resolution waveform information beyond the state of a person's cardiac health, perhaps even to the extent of uniqueness from person to person.

Human Exposure: Most travellers who fly regularly within the United States will have had their hands or carry-on baggage swabbed by airport security personnel to test for the presence of explosives residue. To the DNA-based methods mentioned previously (so-called "-omics" such as genomics, proteomics) we can now add "metabolomics": the study of trace compounds in the body resulting from the metabolism of chemicals that have been breathed in, eaten, or absorbed through the skin. Metabolomics researchers are identifying, among other signatures, chemical compounds from humans that are uniquely correlated with both disease states (such as stomach ulcers) and environmental exposure (such as jet fuel, hospital anesthetics). Combined with ever-more-sensitive chemical analytics, the analysis of breath is progressing far beyond the familiar traffic stop breathalyzer. As spin-offs of medical applications of this concept emerge, we believe there will soon be "chem-int" collection and exploitation at increasing distances from a subject. For example, as a bomb-maker passes through a portal (more advanced than the "puffers" sometimes used in airports), traces of chemicals on the breath or emanating from the skin will alert authorities to his or her presence.

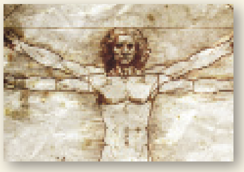
Similarly, toxicology and pathology are advancing far past the observation of tissues under a microscope, towards an understanding of the effects of disease-causing microorganisms and toxic chemicals on humans at the level of the genome itself. The genetic signatures for exposure to chemical or biological weapons are becoming evident. Likewise, the ability to detect and quantify the expression of thousands of genes simultaneously is getting faster and cheaper. These capabilities combined constitute a science of detecting whether a person has been exposed to chemical or biological weapons, in concentrations well under harmful levels. Persons who have been handling chemical or biological weapons will not be able to "wash" away these signatures; their own physiology will betray them to the well-equipped observer.

Human Experience: Just as Pig-Pen's cloud emanates from him, his cloud also contains dirt from his playground. Similarly, our world clings to us just as we leave bits of ourselves behind, offering clues as to where we've been. A current example of this is the forensic analysis of pollen grains, which is used to associate persons or objects with locations in which those pollen grains are native. At a much finer level of resolution, the DNA contained in microorganisms in a person's gut or on a person's skin may contain sequences that indicate a particular geographical origin. In order to make such determinations, an exhaustive knowledge of the diversity of normal human microbial flora, called the Human Microbiome Project, is currently being funded by the National Institutes of Health. Early results suggest that the human microbiome is far more diverse than traditional microbiology has been able to reveal, and continued work is expected to reveal additional geographical, intra- and inter-personal microbial diversity that can be mined for forensic and intelligence applications.

Three Common Features

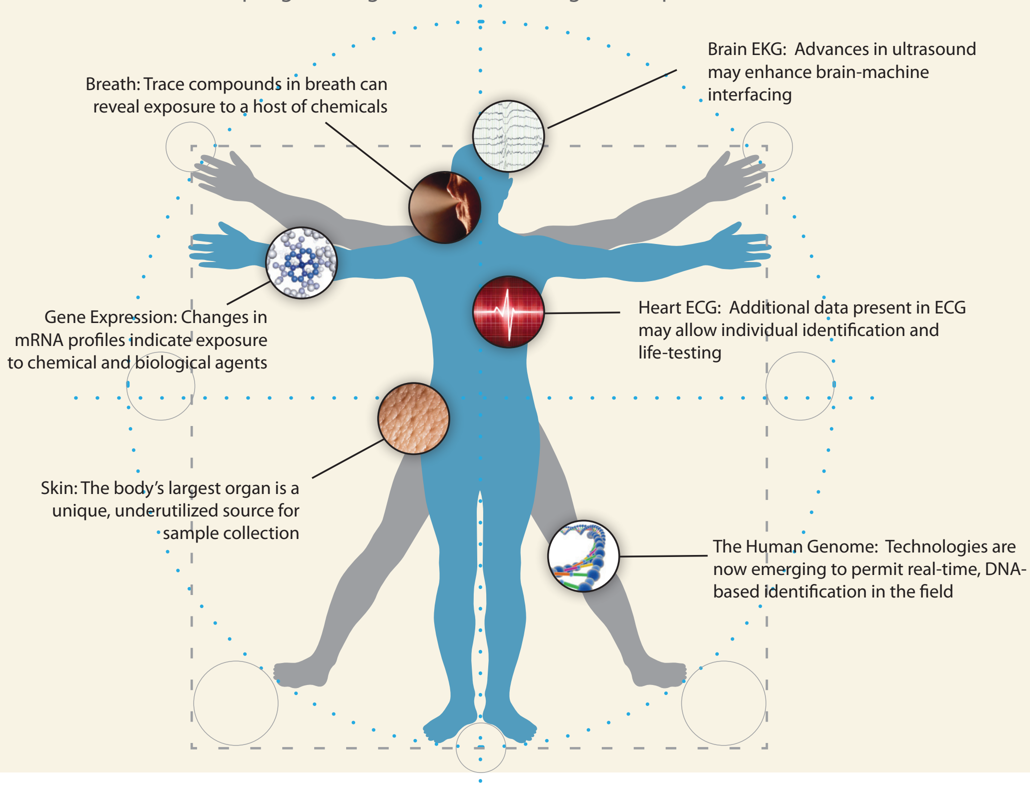
The technologies that are providing these emerging intelligence capabilities are derived primarily from new applications in medical diagnostics and therapeutics, or genome-based or personalized medicine. All such advances, as well as the derivatives that will create intelligence capabilities, share three common features. First is the requirement for signatures with very strong correlations to states or conditions of interest. To identify a person, what do you look for in an ECG signal? In a DNA sequence? To know whether a person has been working with explosives or nerve agent, what do you look for in the breath or on the skin? In medical research, such signatures are termed "biomarkers," and finding biomarkers that correlate with a particular disease is a major emphasis of research. The mis-association of biomarkers in medicine will lead to misdiagnosis, continued illness, and death, and their mis-association in the realm of intelligence would have no less serious consequences. Medical advances in biomarker discovery may be leveraged by the Intelligence Community, as both the medical community and Homeland security interests are driving the search for biomarkers than indicate WMD exposure for purposes of diagnosis, border screening, and disaster mitigation and response. These medical advances in biomarker discovery may be leveraged by the Intelligence Community.

Second, once biomarkers for conditions of interest to medicine or to the Intelligence Community (IC) are identified, how does one collect, sample, and detect the biomarker? While patients demand and reasonably expect privacy in medical practice, there is commonly little need for secrecy between patients and practitioners in sample collection or processing. In the event that a second test must be done, additional and abundant samples can usually be collected from a patient. In intelligence use cases, however, samples may have to be collected without a subject's knowledge. This requirement may dictate that sample quantities are small, and that there will be only a single opportunity to collect a sample. Here is where technological needs in sample collection, processing, and analysis for the IC diverge from those of the medical community: the IC requires methods and technologies that work on very little, perhaps degraded material. Because there may be only very brief exposure to the subject, the methods must be accurate, and require only one collection. Unlike in medical practice, a subject may necessarily be at some distance from the collection technology. These differences between



Anatomy of Physiological Intelligence

The articles in this issue of IQT Quarterly are focused on two core themes in the pursuit of an increasingly deep understanding of human physiology: first, understanding the human genetic and biochemical response to disease or environmental exposure to chemicals or organisms; and second, new modalities for sampling, sensing, and understanding that response.



applications mean that significant challenges remain for leveraging advances in sample collection and biomarker detection from medical technology for the IC.

Lastly, there are inescapable ethical considerations. In the medical use of biomarkers of all sorts, a patient's consent is obtained before samples are collected, and there are legal protections and procedures governing topics that range from sample use to privacy. The very nature of intelligence collection on individuals, however, may preclude consent. Issues that will need consideration include striking appropriate balances between revelations of a subject's personal information and the legitimate needs of a mission.

What might the future hold for physiological intelligence? What advances are possible? Because biomarker discovery is inherently a basic research problem, it is difficult to say when biomarkers for a given state or condition of interest are likely to be uncovered. However, what is certain is that the overall rate at which new discoveries are being made that have direct application to physiological intelligence is accelerating. For example, the drop in the cost of DNA sequencing over time is currently outpacing Moore's Law advances in microprocessor power. At IQT, physiological intelligence is itself one of four impact areas in the Physical and Biological Technologies Practice. As the strategic investor for the Intelligence Community, we are focusing efforts on identifying small companies that will embody the capability to collect, analyze, and exploit advances in physiological intelligence, finding overlap between commercial markets and IC needs. Q

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