Editorial: Moving on in biomicrofluidics

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Citation: Biomicrofluidics **7**, 010401 (2013); doi: 10.1063/1.4775344
View online: http://dx.doi.org/10.1063/1.4775344
View Table of Contents: http://bmf.aip.org/resource/1/BIOMGB/v7/i1
Published by the American Institute of Physics.

Editorial: Moving on in biomicrofluidics

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(Received 21 December 2012; accepted 21 December 2012; published online 31 January 2013)

[http://dx.doi.org/10.1063/1.4775344]

Looking back as *Biomicrofluidics* approaches the close of its sixth year, we see how the journal has progressed since its launch in 2007 in ways beyond our expectations—a tribute to the contributions of our authors, readers, and editorial team. A relative latecomer to the field, *Biomicrofluidics* has nevertheless steadily grown from 21 papers in 2007 to 136 papers in 2012 on the back of the meteoric rise of microfluidics in the last two decades. A rough search revealed that the number of peer-reviewed journal articles published on the subject has grown from just a handful (<10) of papers annually from 1990 to 1996 to almost 4000 in 2008 (Fig. 1). It is perhaps too early to tell whether a peak was experienced in 2008 followed by a small decrease and leveling off to date, or if the growth has been more gradual and almost linear from the early 2000s with the 2008 data simply representing an anomaly in the trend.[1] What is nevertheless more apparent is that the field appears to have matured considerably and is entering a new phase.

From its inception, we at *Biomicrofluidics* together with many others in the community have believed that microfluidic devices are best suited for applications in biotechnology and medicine (and analytical sciences to a lesser extent), given the clear rationale for manipulating cells, molecules and other biological entities at scales commensurate with their dimensions in addition to the many advantages that small scale operation has to offer.[2–4] Indeed, of the 238 microfluidic companies and startups that have been launched, over 55% are devoted to medical and biotechnological applications, mainly point-of-care diagnostics, with the remaining 45% comprising a mix of MEMS/microfluidic foundries, component manufacture, consultancies, and companies dedicated to the development of instrumentation for chemical analysis and sensors.[5] Like the field of microfluidics itself, these commercial startups are spurred by new technologies that exploit the unique advantages that can be derived from small scale phenomena. To date, *Biomicrofluidics* has been a proponent of advances in several of these new technologies through its publications, including electrokinetics, acoustofluidics, optofluidics, nanocolloids and magnetic beads, and, chemical/biological surface modification, amongst others, together with advanced fabrication methods, molecular/continuum simulation theories, and, imaging and characterization methods.

Nevertheless, despite the large number of attempts to commercialize microfluidic devices, and a limited number of successes to date, widespread deployment of microfluidic devices continues to prove elusive. One possible reason for the slow uptake that we[4] and others[6] have identified is the perspective of end-users who are held back by "inertia" in adopting new technologies in their current processes, in part, due to poor understanding of the benefits associated with the technology, but also due to even the slightest difficulties that make the effort (either perceived or actual) of learning and adopting the new process beyond worthwhile. Another possible reason is the lack of device integration for true on-chip functionality. The hype surrounding microfluidics (particularly originating from the late 1990s when it was claimed as a solution for just almost every chemical and biological laboratory process)[6] aside, a key hurdle that has

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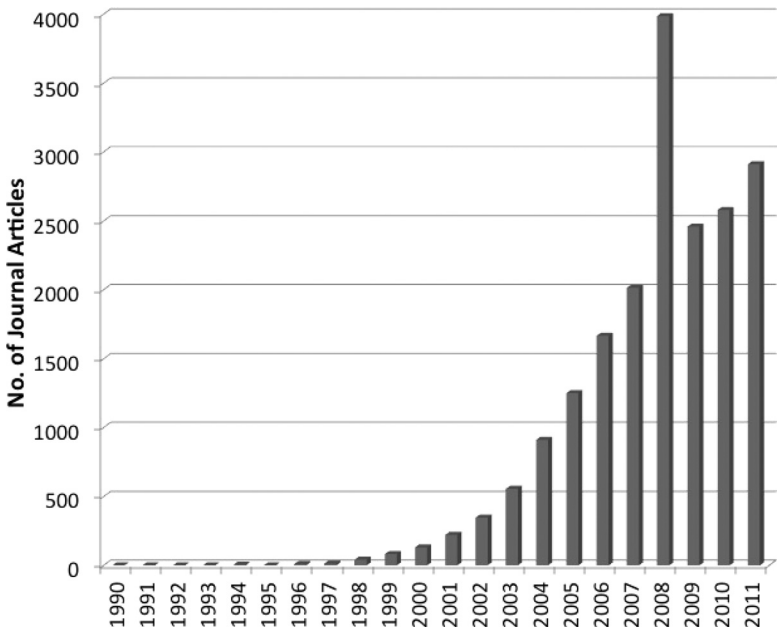

FIG. 1. Annual trend of peer-reviewed journal publications on microfluidics. The data were obtained by searching the Scopus® database for journal articles with "microfluidic" or "microfluidics" in the article title, abstract or keywords. Note that the data shown is only an indication of the growth trends in the subject area since there are a large number of publications on microfluidics that do not contain these search phrases, especially more recent publications which have tended to focus on more specific sub-areas.

yet to be overcome is the inability to incorporate and automate a complete set of microfluidic components that carry out a process from start (e.g., sample injection and preparation) to finish (e.g., detection) all within a single device at costs that are acceptable to manufacturers, which are hence reflected in the cost of goods sold to the consumer.[4] Thus, despite the many developments contributing to the microfluidic component tool set to date, commercially viable but simple solutions for a microfluidic pump and driver circuit, or a sensitive on-chip detection platform, that are small enough to be integrated, for example, have yet to be found. We therefore anticipate further work in this area to translate fairly mature techniques such as electrokinetics, as well as less mature ones such as acoustofluidics and optofluidics, into practical technologies that are readily integrable onto the chip-based platform.

Further to this, it is our opinion that the next phase we are currently about to enter in microfluidic research will largely center around the theme of device integration. We therefore anticipate that the future will also yield exciting new developments in ***application*** areas such as biomolecular sensing, single cell assays, rapid gene sequencing, tumor cell sorting, stem cell transfection, and smart cell culture platforms, amongst others.

In fact, we believe that a truly transformative application in which microfluidic technology will make a significant contribution awaits. The discovery of protein and microRNA biomarkers for disease detection requires rapid quantification of a large number of small molecules, which has and will continue to benefit from microfluidic technologies. Once the biomarker library is sufficiently large—and this is a near certainty—a revolution in healthcare is likely to occur that is uniquely suited for utilization of microfluidic technologies. Such a revolution will possibly involve the rapid expansion of the point-of-care diagnostics market for home monitoring of disease biomarkers, with the potential for wireless transmission of the acquired results to centralized data monitoring facilities. Online data monitoring not only facilitates the ability to track an individual's health over time but also allows correlation with other datasets to capture geographical, ethnic and socioeconomic risk factors for better disease profiling with the aim of early diagnosis, epidemic control, and personalized drug administration. A major technological breakthrough in this area, nevertheless, relies heavily on advanced technologies such as

microfluidics for the production of low cost consumer devices that can be handled by untrained users for the rapid detection of a large number of molecular targets precisely within a minimal sample volume. At *Biomicrofluidics*, we are adapting to these new directions, and also hope to continue to offer ***perspectives*** in other future directions with the help of our authors, readers and the wider microfluidics community. Two examples[7,8] of such perspectives are published in the current issue.

What remains unchanged, however, is that the design and integration of new microfluidic technologies for these applications needs to be underpinned by a strong ***fundamental*** understanding of the underlying physicochemical and hydrodynamic mechanisms. Whilst it was commonplace for individual technologies to be developed empirically in the past, this may no longer be a luxury when developing multiple technologies that are required to be integrated into complete devices. At *Biomicrofluidics*, we will continue to publish papers with novel applications that are supported by fundamental theories—a characteristic that has become a trademark of the journal. As such, we seek papers that report not only research breakthroughs but also inspire new ones, and papers that not only demonstrate the feasibility of a particular device but also provide deep physical insight into its workings. In addition, we welcome detailed fundamental analyses of a technique that are crucial for important applications.

It is this emphasis on the collective combination of ***fundamentals*** and ***applications***, together with ***perspectives*** on new subfields and tomorrow's challenges, that we believe will continue to allow the journal to maintain its position at the forefront of microfluidics, and to serve the microfluidic community in its future directions. To reflect this emphasis as we adjust to a more mature microfluidics community, we have added a new tagline to the journal title. Other exciting developments are also planned, in addition to special focus issues in the new research directions. Beginning 2013, we will increase the frequency of journal issues from quarterly to bi-monthly (six times per subscription year). *Biomicrofluidics* will also continue to be the official journal of the Advances in Microfluidics and Nanofluidics (AMN) meetings. Following very successful meetings in Hong Kong (2009), Singapore (2011), and Dalian, China (2012), AMN2013 will be held at Notre Dame, Indiana, USA in May 2013 (www.amn2013.org) with an exciting lineup of leading keynote and invited speakers that reflects the journal focus on fundamentals, perspectives, and applications. We look forward to seeing you there.

[1]Interestingly, and correspondingly, the number of patent applications (international Patent Cooperation treaty (PCT) applications filed with the keywords "microfluidic" or "microfluidics") per year has grown from 1 or 2 between 1991 and 1996 to above 150 between 2006 and 2010 with a similar, albeit less sharp, peak in 2007 and 2008.
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