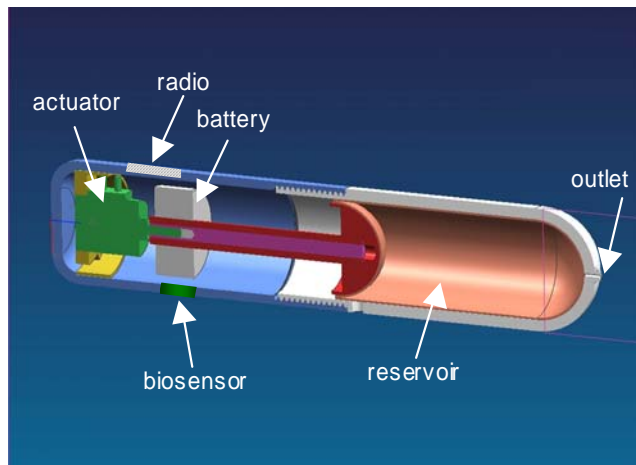


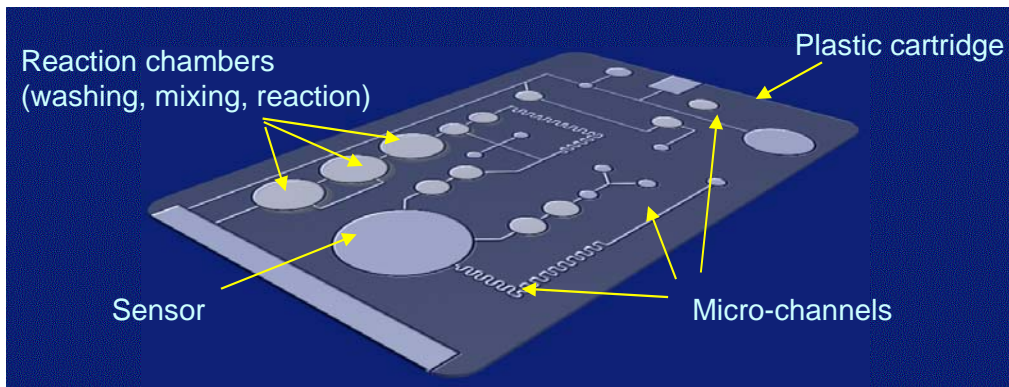
## Some applications of micro-fluidics

*Micro-fluidics* is the science and technology of manipulating and analyzing fluid flow in structures of sub-millimeter dimensions. This field will be essential in a variety of future high-tech applications, such as micro-channel cooling for electronics, inkjet printing for displays and biomedical applications, controlled drug delivery systems, pharmaceutical and chemical high-throughput testing, and biosensors. Considering the various applications, the fluids to be manipulated may be quite complex, such as blood, saliva, urine, or polymer solutions.



**Figure 1: Artist's impression of an "electronic pill". The pill is steered through the body, and releases, in a controlled way, medicine at a desired location and at the precisely controlled dose.**

One example is **controlled drug delivery**. In this application, a drug delivery system is either implanted in the human body, or attached to the skin, and medicine is released in a controlled way into the body. Another option is to encapsulate the medicine in a micrometer-sized container that is introduced into the human body, and which is subsequently directed to a specific location where the medicine is released (the "electronic pill"). Artificial cilia may well be a suitable means of achieving an actively controlled drug release system. Important features that could be enabled are electronic pill propulsion, and accurate dosing of liquids, for example to achieve correct mixing ratios between two substances, or a deterministic amount of reagents.

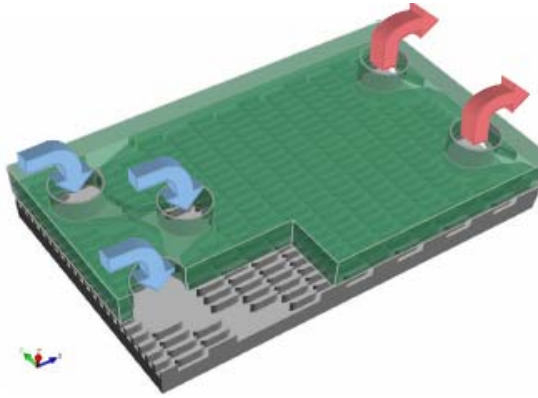


**Figure 2: Artist's impression of a disposable cartridge, a key component of a biosensor device, containing micro-fluidic structures.**

Another example of a biomedical applications are **biosensors**. The purpose of a biosensor device is to carry out a rapid and sensitive detection of specific bio-molecules such as certain proteins or DNA, present in biological fluids (e.g. blood). On the basis of the detection results, a medical diagnosis concerning the presence and/or progression of a disease may be established. A key component of the device is a disposable cartridge, schematically shown in Figure 2. It contains micro-channels through which the fluid must be transported, reaction chambers and other structures in which various required actions must take place (washing, separation of molecules, mixing, chemical reactions) and, finally, a sensor at which the detection is done. The latter can be based on various physical principles, for example optical, magnetic, or electrical detection. A characteristic of this integrated device is that it is relatively small, typically of credit-card size, in order to minimize the required amounts of test fluid and chemical species, to speed up the detection time, and to create a well-controlled environment. The typical cross-sectional dimensions of the micro-fluidic channels and structures are between 10 and 100  $\mu\text{m}$ . The importance of getting the fluid at the right time at the right position is obvious. In addition, the process requires that mixing flows (in reaction chambers), or special flow patterns (e.g. at the sensing location) be generated locally. Controlled fluid manipulation at these small scales, i.e. the domain of micro-fluidics, is therefore indispensable for the development of biosensor devices.

The development of biosensors and related molecular diagnostics is a major contribution to addressing one of the most important societal issues in the world today, which is that of health and medical care, in relation to economic boundary conditions. Compared to conventional central laboratory testing for medical diagnosis, the biosensor approach will lead to lower costs, and much faster and targeted diagnosis. The availability of actively controlled drug delivery systems would open new ways to treat diseases in a targeted and effective way. In particular for biosensor-type applications, which belong to the category of "molecular diagnostics devices", the projected market growth is very large. At the moment some initial applications are on the market, e.g. for glucose level testing, or for drug-of-abuse testing. The total biosensor market in 2000 was 550 MEuros. The predictions now are that in a few years the total market value will be over 3.5 billion Euros, corresponding to an annual growth of 35%.

In addition, **applications of micro-fluidics** can for example be found in the areas of micro-channel cooling for electronics, inkjet printing for displays and biomedical applications, and pharmaceutical and chemical (high-throughput) testing in the chemical and food industries.



**Figure 3: Micro-channels for cooling are integrated in electronic devices.**

The micro-fluidics, obviously, is essential in all these developments. Often, not only transport of the fluid is needed, also local mixing (for example in micro-reaction chambers), or specific flow pattern generation (for example near the biosensor detection site), are desired. Various actuation mechanisms have been and are being developed. Some of these are arrived at by simply scaling down established macroscopic concepts to smaller dimensions, as e.g. in most micro-fabricated mechanical valves or pumps. The smallest sizes achieved mostly are still on the order of millimeters or several hundreds of micrometers, so that a true integration in a micro-fluidic device is not possible. Others use physical effects that are predominant at small scales, such as surface tension.