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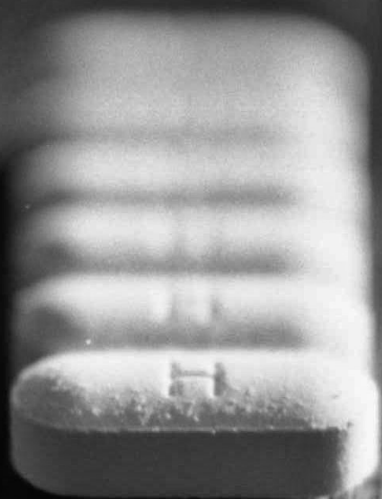
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Undergraduate

DRUG DELIVERY: STEPS TOWARD REPLACING THE PILL

BY SHIVALI BAVEJA



Be it through your bloodstream or the lining of your intestinal tract, the human body uses a multitude of pathways to deliver molecules to their appropriate destinations. For example, the aspirin you took to dull your splitting headache travels through multiple networks in order to inhibit the enzymes that propagate your pain. Drug delivery, the process of getting medications to their intended targets, is a complex and constantly evolving field with a goal of making treatments faster, safer, and more effective. With the advent of new tools and techniques such as biodegradable microspheres and ultrasound-mediated delivery, current developments in biotechnology offer a promising outlook on simplifying and improving patients' relationships with their medication.

The majority of research in the field today centers on finding new ways to localize drug delivery. By preventing medication from deviating from its intended target,

some of the negative consequences of drug interactions can be minimized. One of the most rapidly growing areas of development is that of transdermal drug delivery, or drug delivery through the skin. By passing molecules painlessly through the skin, this form of delivery tends to be more efficient as it requires lower doses of medication. The development of biosensors that measure the release of drugs has further allowed transdermal delivery systems to closely monitor the intake of molecules.² This brings us to one of the greatest advantages of drug delivery: patient-specific treatment plans. By maintaining closed-loop systems which have the ability to control the rate of medications delivered, treatments can be tailored not only to the patient as a whole, but also to variations in their daily life.⁴

Transdermal patches offer further advantages in their ease of delivery as they do not have to be ingested or injected. Since the patches require little effort to use, they

are expected to significantly increase levels of patient compliance.⁸ Behind the scenes of transdermal delivery, techniques for electroporation are at work. Electroporation, a method of administering medications using extremely small electrical impulses, makes it easier for water-insoluble medications to make it past the protective barrier of the skin.⁹ This technique reduces the resistance molecules face and is necessary for the permeation of medications inside the bloodstream and body. In instances where transdermal delivery is not feasible, other alternative techniques are in development.

Conditions such as macular degeneration, which affect the eye, are instances where patches no longer are a viable treatment option. Instead, researchers are experimenting with biodegradable microspheres. These microspheres are essentially little bubbles carrying drugs which "pop," or break down over time, and release their enclosed medications at a steady rate. As a

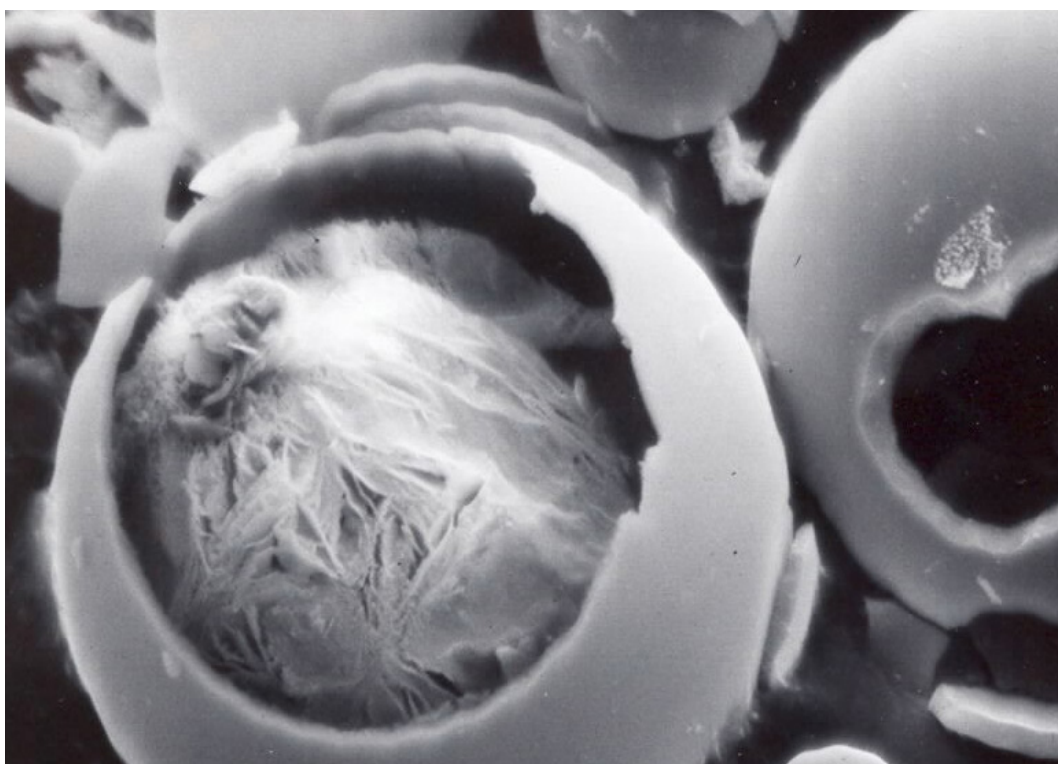


Figure 1. Recent developments with glass biodegradable microspheres have allowed for the delivery of drugs in small controlled quantities that can be released over regular periods of time.¹¹

result, this technique offers a means for sustained delivery with less frequent intervention.¹ Ultrasound-mediated drug delivery, another technique utilizing bubbles of medication, uses high frequency waves to release the medications as opposed to having them break down on their own. The use of a closed-loop feedback system also offers the possibility of bursting bubbles when a relevant

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stimulus in the body leads to "popping" the bubbles.⁵ *In vivo* results of the use of ultrasound during application with swines' gastrointestinal tracts has resulted in successful dispersal of medication and is a promising indication of future application in humans.¹⁰

Just as innovation erupts in the field of delivery, tools to refine these mechanisms develop alongside it. The process of delivering medications relies on two distinct components: the molecules themselves and the mechanisms of their entry and regulation. Developments in the field of microfluidics have led to the design of micro- and nano-particles that have been engineered to affect only localized areas in the body. One of the greatest advantages of microfluidics is its ability to model biological systems, a tool which is helpful in *in vitro* models that simulate an organism's response to and interaction with a substance. Thus, this tool is likely to be integrated into *in vitro* drug delivery models in the development of medications and transport systems to effectively speed up the delivery of micro- and nano-particles in the body.⁶

Another tool being utilized in the specialization of the drug delivery process is mi-

crochips. The precision of these small computers allows doctors to walk the fine line between doses that are too low to be effective and those which are high enough to be toxic to patients. Microchip technology can be applied to improve treatments for cancer and other conditions such as osteoporosis, which require regular feedback-based delivery of medications.³ Clinical studies on the healing process with microchips have shown that minimal disturbances occurred after implantation, and this is promising regarding their use in future drug delivery mechanisms. To this extent, prior *in vitro* studies have corroborated these findings.³

Despite knowing that many tools and techniques are being developed, it is still important to recognize the obstacles which some of these strategies will likely face in the future. First, the patient-specific nature of many of these models makes them very time- and labor-intensive to develop and implement. As a result, the feasibility of such techniques on the larger scale may be diminished, and use in the mass market may take much more time and optimization.² Additionally, continued research is necessary to investigate the long-term ef-

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fects of some carrier techniques such as those in biodegradable microspheres and ultrasound-mediated delivery. Further clinical studies on such mechanisms must occur before conclusions can be drawn about their impacts on human health.^{7,9} It is only after clinical studies are underway that we can hope to see such revolutionary technology make it into the hands of patients. Finally, even with the technology we have already developed, these methods must be perfected *in vivo* before they can be effectively translated to the healthcare setting.¹⁰

Based on today's potential avenues for drug delivery, such techniques offer enormous scope for revolutionizing the way medications are administered. If the current research is soon translated to further clinical trials, such tools will likely reach everyday consumers within the next decade and forever alter the relationship between individuals and their drugs. Perhaps in a few years from now, pill bottles will have permanently become a thing of the past

and individuals will be taking lower doses of drugs to treat their conditions. Until then, the field of drug delivery will continue progressing to make this future a reality.

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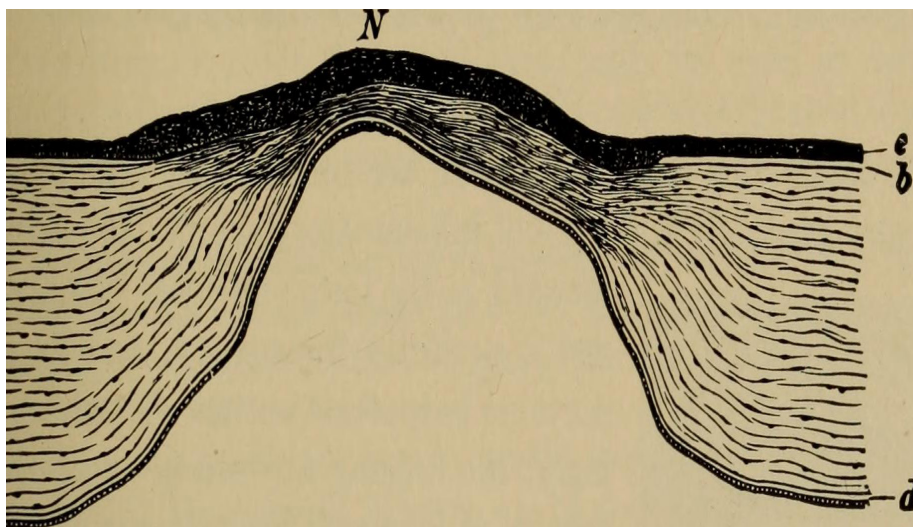


Figure 2. The cornea as visualized here reveals the membrane through which biodegradable microspheres must be delivered.¹

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