ELECTRONIC PILL: A REVOLUTIONARY MEDICINE IN PHARMACEUTICAL SCIENCE

[1]Ashika Madhavi, [2]Rashmi Wani, [3]Amit Pandey, [4]Suvarna Bhadane, [5]Ujwala Dube

[1]B. Pharm Student, Ideal College of Pharmacy and Research, Kalyan- 421306, Maharashtra, India

[2]Assistant Professor, Department of Pharmaceutical Chemistry, Ideal College of Pharmacy and Research, Kalyan – 421306, Maharashtra, India

[3]B. Pharm Student, Ideal College of Pharmacy and Research, Kalyan–421306, Maharashtra, India

[4]Assistant Professor, Department of Quality Assurance, Ideal College of Pharmacy and Research, Kalyan–421306, Maharashtra, India

[5]Assistant Professor, Ideal College of Pharmacy and Research, Kalyan–421306, Maharashtra, India

ABSTRACT: -

The purpose of this paper is to provide the information about the innovation of new device called Micro Electronic Pill in the field of Bio-Medical Measurement; this is mainly used for diagnosis of internal part mainly gastrointestinal system which cannot be easily done with the help of normal endoscope. It can be electronically tracked and instructed to deliver a drug to a predetermined location in the gastrointestinal tract. This technology can help in diagnosis and imaging of various diseases and body organs in the gastrointestinal system. The electronic pill travels to the digestive system, collects data and sends it into the computer with a distance of 1 meter and more. Capsule endoscopy is considered to be a very safe method to determine an unknown cause of a gastrointestinal bleed. The Applications and the future scope of this technology have been mentioned in this paper. This paper provides the basic idea of the Electronic pills which is giving information regarding its history, construction, applications, advantages and disadvantages, on-going research and possible future scope of this technology. The following data contains various images for better understanding. It is modern wireless type of endoscopic monitoring system. It is a technology which can bring a drastic evolution in the world of Pharmaceutical and Medical Sciences.

KEYWORDS:-

Electronic Pills, Capsule Endoscopy, Implants, ASIC, Esophagogastroduodenoscopy

INTRODUCTION:-

The microelectronic pill is a small capsule shaped electronic pill that can be comfortably swallowed by any normal patient. It consists of lens, antenna, transmitters, camera or sensors and battery. It can reach regions such as small intestine and provides the video wirelessly to the receiving device connected to the monitoring system outside the human body and kept at distance of 1 meter. The transmission of data takes place through the radio communication between electronic pill transmitter and external receiver. Parameters such as temperature, pH and pressure of gastrointestinal tract can be measured, for the detection of diseases and disturbance in gastro intestinal system which prevents the entry of conventional endoscopic tube, a micro pill with single channel radio telemetric function is preferred. The invention of semiconductors provides ease in development of concise electronic pill capable to carry and transmit huge amount of data at a time without affecting the human body. [1]

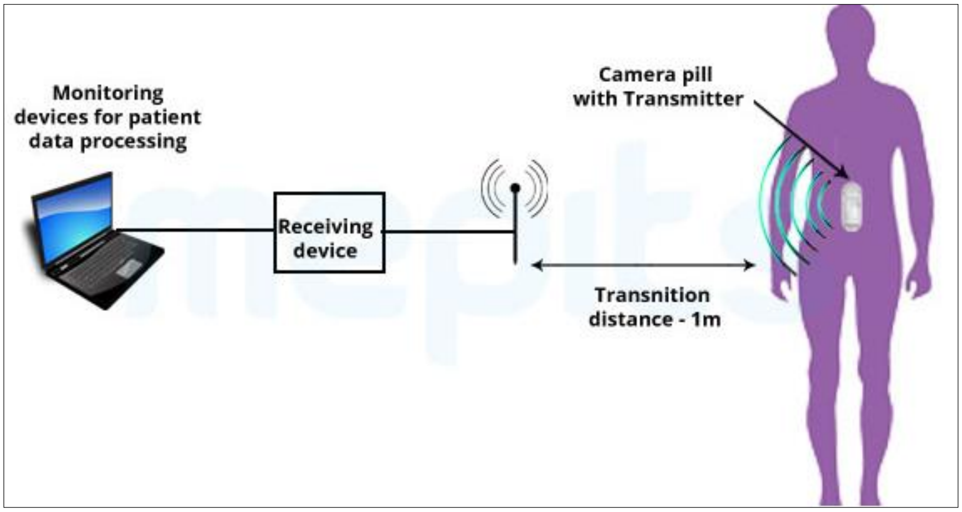


Figure 1: Wireless video transmission between transmitter and receiver

Electronic pills are the holy grail of healthcare technology. Ever since the first microelectronic pill was developed by Professor Jon Cooper and Dr. Erik Johanessen from Glasgow University in 1972, they've enjoyed unprecedented improvements.

WORKING:-

Basically, an electronic pill is a multichannel sensor use for remote biomedical measurements in the body. They can specifically deliver drugs to certain parts of the body to target different types of cancer, stimulate damaged tissues, track gastric problems, and measure biomarkers.

In order to carry out these functions, it is powered by a battery and equipped with the appropriate sensors. The battery is built to be edible yet it is expected to act as a conventional electronic battery. It is important that the materials used are not toxic to humans as it can cause significant complications if it gets into the digestive tract.

HISTORY:-

Jerome Schentag, professor of pharmaceutical science at the University of Buffalo, invented the computer-controlled "smart pill," which can be electronically tracked and instructed to deliver a drug to a predetermined location in the gastrointestinal tract. David D'Andrea was the co-inventor.

UB reporter Ellen Goldbaum describes the smart pill as a combination of microminiature electronics, mechanical and software engineering, and pharmaceutical sciences. "This capsule represents a significant advance in medical technology," said D'Andrea to UB reporters, "With the Smart Pill, we have been able to miniaturize a complex electronic system and put it into a capsule about one inch long. You're not just taking a pill, you're swallowing the instrument.

David D'Andrea is the president and chief executive officer of Gastrotarget, Inc. the manufacturers of the Smart Pill. Jerome Schentag is the company's vice president of research and development. D'Andrea is also the director of Millard Fillmore Hospital's Engineering and Devices Laboratory.

The name of smart pill now refers to any pill that can deliver or control its delivery of medicine without the patient having to take action beyond the initial swallow.

The phrase smart pill became popular after the computer controlled medical device was patented by Jerome Schentag and David D'Andrea, and named one of the top inventions of 1992 by Popular Science magazine. However, now the name has become generic and many companies are using the name smart pill.

CONSTRUCTION:-

It is a medical monitoring system. Measurement parameters of electronic pills include temperature analysis, pH measurements, conductivity and dissolved oxygen. And they can also capture images and sent it into a system. Electronic pills are swallowable. It has a 16mm diameter, a length of 55mm and 5gram weight. This pill is covered by chemically resistant polyether-terketone (PEEK) coating.

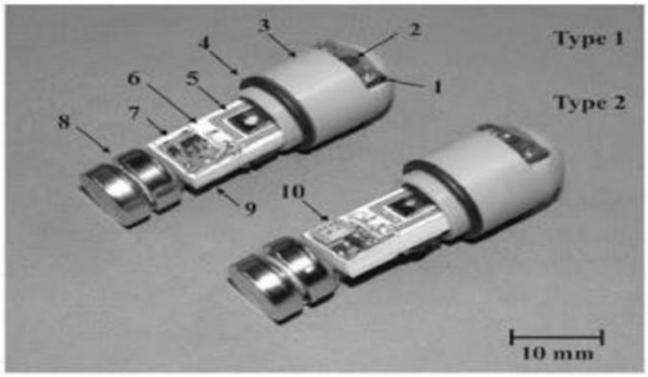


Figure 2: Construction of electronic pill

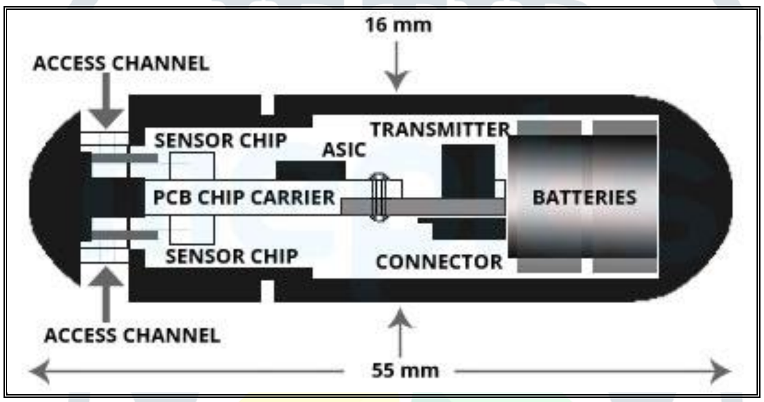


Figure 3: Micro- electronic pill

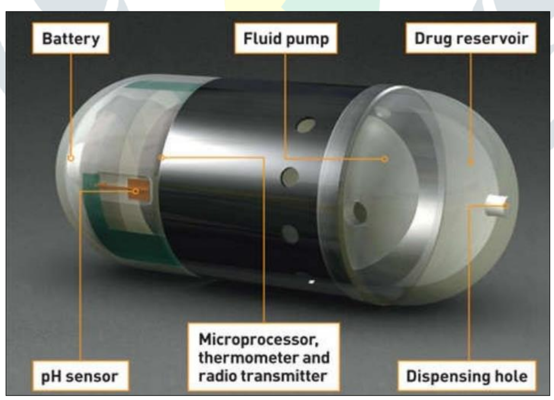


Figure 4: Diagram of Microelectronic pill

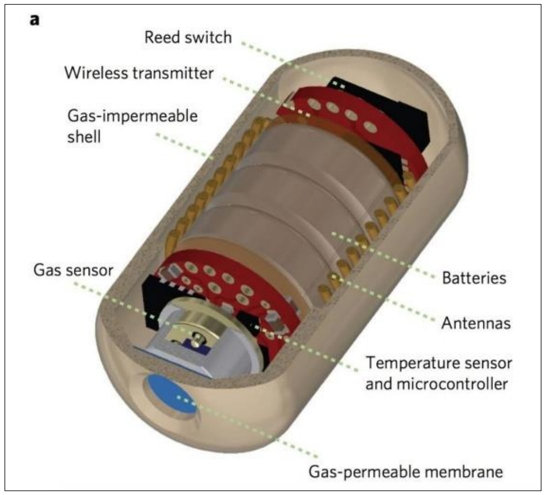
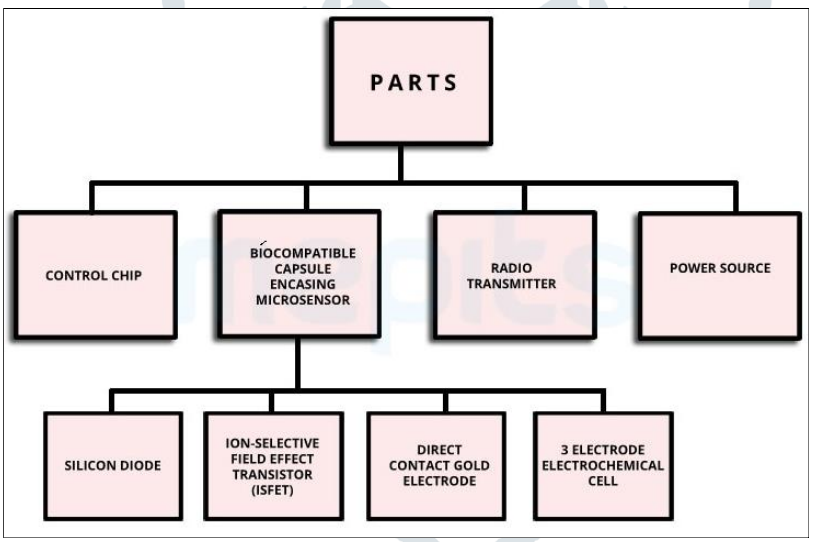


Figure 5: Construction of Electronic Pill

When it moves through gastro-intestinal track it starts to detect diseases and abnormalities. A small electronic pill can easily reach areas such as small intestine and large intestine and can deliver real time information to an external system. Total information will be displayed in a monitor. The electronic pill travels to the digestive system, collects data and sends it into the computer with a distance of 1 meter and more. Main parts of electronic pills are four **sensors**, an ASIC chip, a **radio transmitter** and a **power source**.[1]

Table No.1: Block Diagram of Parts of Electronic Pill



This device consists of 4 microelectronic sensors. First one is Silicon Diode: which is used to identify the body temperature. Silicon diodes are the commonly used temperature sensors in electronic equipments. This temperature sensor is attached in the substrate. The main advantage of this sensor is that, it is a silicon integrated circuit at very low cost. Second one is ISFET (Ion-Sensitive Field-Effect Transistor). ISFET is used for measuring ion concentration in solution. There are so many diseases which occur due to abnormal pH level. They are; reflux of oesophagus, inflammatory bowel disease, hypertension, activity of fermenting bacteria, pancreatic disease, level of acid excretion and effect of GI specific drugs on target organs. Another one is a Direct Contact Gold Electrode. It helps to measure conductivity. Gold has the best conductivity compared to other elements, so it gives accurate value. Conductivity measures are done by measuring the contents of water and salt absorption, breakdown of organic compounds into charged colloids and the bile secretion.

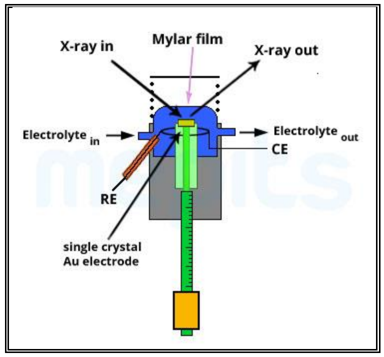
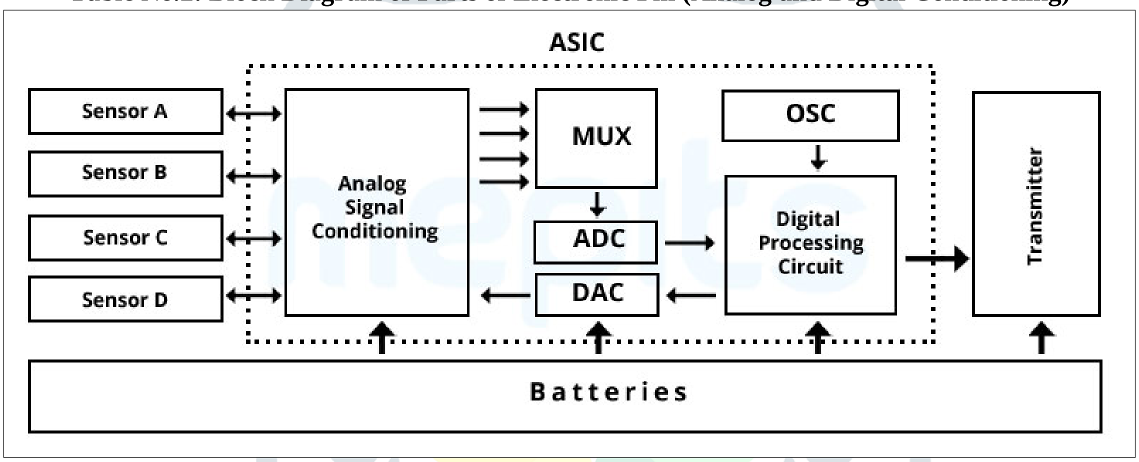


Figure 6: gold electrodes

Three-Electrode Electrochemical Cell is the fourth sensor in electronic pill. It is used to calculate rate of dissolved oxygen and identify the activity of aerobic bacteria in small intestine and large intestine. All these sensors are controlled by application specific integrated circuit. Also, all the other components of the electronic pills are connected to ASIC.

Table No.2: Block Diagram of Parts of Electronic Pill (Analog and Digital Conditioning)



ASIC consist of analog signal conditioning, 10bit analog to digital convertor/digital to analog convertor, relaxation oscillator circuit (OSC) and digital signal processing circuit. All these circuits are powered by two SR48 Ag2O batteries. It has 35 hours working capacity and supply voltage is about 3.1 V. Power consumption is 15.5 mW. Sensors are fabricated on two silicon chips that are located at the front end of the capsule. Both pH and oxygen sensors are enclosed by two separate 8 nL electrolyte chambers containing a 0.1 KOH solution retained in a 0.2% calcium alginate gel. Oxygen sensor is covered by 12 µm thick film of teflon and the pH sensor is covered by 12 µm thick film of nafion. Both sensors are protected by a 15 µm thick dialysis membrane of polycarbonate. All the datas are collected by ASIC and are send it into the base station. From this base station doctors identify the problem. Here the radio transmitter transmits all the datas to the receiving end. Size of the radio transmitter is about 8x4x3 mm. Frequency shift Keying is the modulation scheme used in this radio transmitter. Data transfer rate is 1 Kbps. Frequency is about 40.01 KHz at 20^{o} C. 10 KHz is the bandwidth of the signal that was generated by the radio transmitter. It consumes 2.2 mA of current at 6.8 mW power. [1]

ADVANTAGES OF ELECTRONIC PILLS:-

When we talk about revolutionary technologies, electronic pills top the list. The New York Times made a statement that rather than the doctor advising patients to take a pill and then call back after using it, the electronic pill will be doing the calling.

Apart from improving the existing methods of diagnosis, some of the other advantages of electronic pills are presented in the paragraphs that follow.

1. Localized Drug Delivery is Possible

Think of the possibilities; smaller doses of drugs and then fewer complications resulting from the drug's movement through the bloodstream. This means that the side effects of the drug are minimized and the therapeutic value is maximized. We can also expect the drug to take effect quicker since it dispenses the medicine at specific locations even along the way.

2. Instant Response is allowed

An electronic pill is equipped with microprocessors, batteries, antenna, and other components. This means that it is possible for medical staffs to get a real-time alert about the patient's behavior to the drug. If the doctor then observes any anomaly, certain commands can be sent to ensure that the delivery is halted.

DISADVANTAGES OF ELECTRONIC PILLS:-

As good as they are, some significant drawbacks persist which limit the widespread application. Until these issues are attended to, electronic pills can as well be considered as sci-fi rather than reality. Some of these limitations are discussed below.

1. Electronic Pills are exorbitantly priced

If you've only seen electronic pills on the internet and not in a pharmacy near you, it's because of the cost barrier. Electronic pills, at the moment, are products of significant investments in research and development. As such, it is not available for commercial consumption in many countries. However, with advances in printing and nanotechnology, it is expected that the cost of production will reduce in the coming years.

2. The Application is Limited

Because it is still a relatively new technology, the applications are still restricted to certain areas. For instance, it cannot be used to detect radiation abnormalities; neither can it be used to carry out radiation treatment. It is also not available to little kids yet because complications may arise from issues with digestion.[2]

They also suffered from poor reliability, low sensitivity and short lifetimes of the devices. This led to the application of single-channel telemetry capsules for the detection of disease and abnormalities in the GI tract where restricted area prevented the use of traditional endoscopy.

They were later modified as they had the disadvantage of using laboratory type sensors such as the glass pH electrodes, resistance thermometers, etc. They were also of very large size. The later modification is similar to the above instrument but is smaller in size due to the application of existing semiconductor fabrication technologies. These technologies led to the formation of "MICROELECTRONIC PILL".[3]

Microelectronic pill is basically a multichannel sensor used for remote biomedical measurements using micro technology. This is used for the real-time measurement parameters such as temperature, pH, conductivity and dissolved oxygen. The sensors are fabricated using electron beam and photolithographic pattern integration and were controlled by an application specific integrated circuit (ASIC).

Capsule endoscopy is done in India. It is a capsule with camera and transmitter inside. It is swallowed by patient. It takes photographs inside the gut, in parts where a regular endoscope can't reach.[4] [5]

APPLICATIONS:-

- Determine body temperature.
- Determine pH value of our blood.
- Measure dissolved oxygen level.
- Determine pancreatic disease.
- Measure value of acid excretion.
- Determine activity of fermenting bacteria.

CAPSULE ENDOSCOPY:-

Capsule endoscopy is a procedure used to record internal images of the gastrointestinal tract for use in medical diagnosis. The capsule (aka pill cam) is similar in shape to a standard pharmaceutical capsule, although a little larger, and contains a tiny camera and an array of LEDs powered by a battery. After a patient swallows the capsule, it passes along the gastrointestinal tract taking a number of images per second which are transmitted wirelessly to an array of receivers connected to a portable recording device carried by the patient. The primary use of capsule endoscopy is to examine areas of the small intestine that cannot be seen by other types of endoscopy such as colonoscopy or esophagogastroduodenoscopy (EGD).[6]

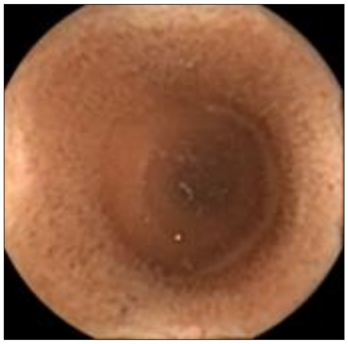


Image of intestine by capsule

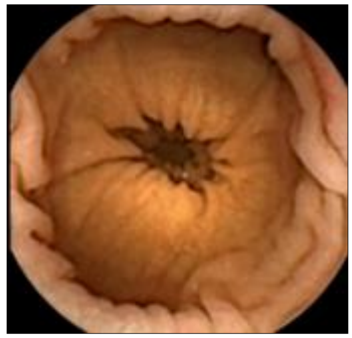


Image of colon by capsule endoscopy

Figure 7: Capsule endoscopy

MEDICAL USE:-

Esophagogastroduodenoscopy (EGD), employs a camera attached to a long flexible tube to view the upper portion of the gastrointestinal tract, namely the esophagus, the stomach and the beginning of the first part of the small intestine called the duodenum, and a colonoscope, inserted through the rectum, can view the colon and the distal portion of the small intestine, the terminal ileum, however, these two types of endoscopy cannot visualize the majority of the middle portion of the small intestine. Capsule endoscopy is used to examine parts of the gastrointestinal tract that cannot be seen with other types of endoscopy. It is useful when disease is suspected in the small intestine, and can sometimes be used to find the site of gastrointestinal bleeding or the cause of unexplained abdominal pain, such as Crohn's disease. However, unlike EGD or colonoscopy it cannot be used to treat pathology that may be discovered. Common reasons for using capsule endoscopy include diagnosis of unexplained bleeding, iron deficiency, or abdominal pain, searching for polyps, ulcers and tumors of small intestine, and diagnosis of inflammatory bowel disease.[5] The images collected by the miniature camera during a session are transferred wirelessly to an external receiver worn by the patient, using any one of a band of appropriate frequencies. The collected images are then transferred to a computer for display, review and diagnosis.[6] A transmitted radio-frequency signal can be used to accurately estimate the location of the capsule and to track it in real time inside the body and gastrointestinal tract.[7] It is unclear if capsule endoscopy can replace gastroscopy for those with cirrhosis.

As of 2014 research was targeting additional sensing mechanisms and localization and motion control systems to enable new applications for the technology, for example, drug delivery. Wireless energy transmission was also being investigated as a way of providing a continuous energy source for the capsule.[8]

SIDE EFFECTS:-

Capsule endoscopy is considered to be a very safe method to determine an unknown cause of a gastrointestinal bleed. [9] The capsule is usually excreted with the feces within 24–48 hours. There has been a report of retention of the capsule for almost four and a half years although the patient was asymptomatic. [9] However, the risk of bowel obstruction may be countered by abdominal X-ray to locate the device for removal by endoscopy or surgery.

Risk of retention:-

In a review of 22,840 cases, the capsule was retained 1.4% of the time, with Crohn's disease a common cause; most were surgically removed.

ELECTRONIC PILLS IN GASTROINTESTINAL TRACT:-

In a paper published in Nature Electronics, a group of researchers describe a successful study in which five participants swallowed a capsule that could track aspects of the gaseous content in their gut, and relay that information to an external sensor every five minutes. They could measure the time the capsule took to go through the gastrointestinal system, and could even pick up on increases in fiber content in participants' diets over three days. Ideally, the capsules could one day be used as a diagnostic tool for digestive disorders, or a monitoring tool to see if a dietary change is an effective treatment.

Kalantar-Zadeh et al., 2018

The capsules are an inch long and just under half an inch wide, which is as large as swallow-able pills can get. Within each, there's a tiny thermometer, radio transmitter (to send information to an external device that fits in a pocket), a battery, and sensors that detect oxygen, hydrogen, and carbon dioxide within the gut. We're full of other gases including nitrogen, methane, and what the authors of this paper call "odoriferous gas and vapor species" (AKA farts), but doctors can learn a lot by tracking the three gases these capsules can sense.

Oxygen is used like a locational device: it shows where the body is breaking down contents aerobically (with oxygen) or anaerobically (without it). Carbon dioxide levels can give insight into a person's gut microbiome: the bacteria in our gut microbiomes release CO2 as a byproduct of their metabolism, and the right amount of CO2 in the gut shows our microbiome is alive and thriving. (We all need these microbes, although too much of certain species can be a bad thing.) Hydrogen is possibly the most important gas to track from a clinical standpoint, because it shows when foods are being broken down through fermentation. That happens; when the normal gut processes fail to break down food, and is a sign more generally that a patient's body can't handle certain foods.

This study was small, and just a proof of concept. But it was highly successful: The capsules make the journey through the digestive tract in about a day (the researchers tracked the progress of the capsule using an ultrasound) before they are excreted like any other indigestible food. The researchers took fecal samples and were able to confirm food was being broken down as the capsules reported.

Two of the patients were put on high-fiber (about 33 grams per day), and two were put on low-fiber diets; the fifth was tested at both a low- and high-fiber diet. In all of them, data from the capsule reflected expected changes in the gut microbiomes of a high-fiber diet: different species flourished after a couple of high-fiber days. Fiber is one of those components of food that gut bacteria love—after a couple of days eating more fiber, microbiomes are typically more robust, which is healthier for their host humans.

In addition, none of the participants experienced any adverse effects from these capsules. That included Kourosh Kalantar Zadeh, an engineering professor at the Royal Melbourne Institute of Technology and lead author of the paper, who was happy to test out his own device, according to NPR.[8] [9]

ELECTRONIC PILLS AS AN IMPLANT:-

It is now a few years that drugs dispensers can be implanted under the skin to release substances gradually. More recently electronic dispensers have been implanted. They contain a microprocessor and can sense their environment to detect a need for releasing a certain amount of medicine, like insulin. Most are in an experimental phase, but there is great expectation that they may help in much better dosage, and just in time, of drugs. The problem with these chips is that they need to be first implanted and then once their lifetime is over they need to be explanted. Both requires a surgical (although in most cases minimal) operation. Now researchers at Tuft University in cooperation with researchers at the University of Illinois at Champaign-Urbana have manage to create a chip that can dissolve in the body once its life cycle is completed, and they have demonstrated its viability by implanting it in mice. The "chip" consists of a coil made of magnesium that serve as an antenna for both receiving signals and energy to power the chip. An external coil serves as transmitting point. It might be embedded in any kind of device, including a cell phone. In the demonstration the researchers had a mouse with a tissue infected with S. Aureus. Using the implanted chip they heated the tissue killing the S. Aureus, with just two sequential treatments each ten minutes long. In principle the implanted chip could have been loaded with specific drugs and the signals could instruct the chip to release these drugs at certain times in specific quantities. Interestingly, after being used, the chip started to dissolve in the tissue leaving no trace behind. After fifteen days there was no trace of it, including the magnesium coil.

Also very important, the tissue showed no sign of inflammation, a typical reaction when tissues detect the presence of a foreign body. The dissolution is protected, and governed, by a silk protein pouch in which the chip and the coil are embedded. Once this pouch wears out the chip starts to dissolve. We can expect in the future to see many more implanted "pills" with electronics regulating the dosing, either through externally received signals or through a self assessment of needs based on sensors detecting specific conditions in the surrounding tissue. [10]

RECENT RESEARCH OUTCOMES ON ELECTRONIC PILLS:-

Table No.3: Recent research outcome on Electronic Pills

References	Image Resolution	Image sensor	Frequency	Data Rate	Modu-lation	Transmission Power	Physical Dimension	Power Supply	Current Power
Thone,2009	640 X 4S0pixels	MT9V013 (VGA)	144 MHz	Mbps	FSK	18 dBm	ot finalized	3 V coin cell	NA(2 mW forTx)
Chen.2009	7,200pixels	GA, 0-2 fps	433 MHz	267 Kbps	FSK	NA	1.3x26.7 mmxmm	2x1.5V silver-oxide	8 mA(24 mW)
Wang.2008	0X480pixels	PO1200 CMOS	NA	NA	AM	High variable)	10x190 mmxmm	3V, wireless	25 mW
Kfonri,2007	768 X 494pixels	CDICX228 AL	UHF	250 Kbps	—	NA	20X100 mmxmm	Li-ion battery	—
Park. 2002	510X492 pixels	OV7910 CMOS	315 MHz	NA	AM	NA	10X7 mmxmm	5 V	NA
Johannessen, 2006	pH and Temperature	ensory: pH and emperature	433 MHz	Kbps	ASK	NA, lm	2x36mm, 8g	2x1.5V SR48 Ag_2O	15.5 mW
Valdastri, 2004	Multi-channel	Sensors	433 MHz	Kbps	ASK	6 mW, 5 m	7x19x19 mm^3	3-V coin cell (CR1025)	—
Mackay.1957	pH, temperature, oxygen level	Sensors	100 KHz	—	FM	—	—	—	—

CURRENT PRODUCTS IN THE MARKET:-

1. ***Philips' intelligent pill***

This electronic pill is a plastic capsule which is usually taken with solid food or water. Normally, it is meant to be transported through the digestive system in a natural manner. This is usually done within 24 hours and as this is done, the drug is dispensed to different parts of the body. The size is about that of a plump multivitamin and the drug can even carry out specialized actions based on the pH level of the patient.

Figure 8: Philips' intelligent pill

1. ***IntelliCap drug***

IntelliCap Capsule is rightly described as an electronic pill acting as a drug delivery and a monitoring device. It is made up of a drug reservoir, wireless communication systems, electronic controllers, sensors, and a delivery pump. It takes a very minuscule form and upon ingestion, it travels through the gastrointestinal tract. The presence of onboard electronics means that the drug delivery is both precise and flexible.[11] [12]

Figure 9: IntelliCap drug

NEW ELECTRONIC PILLS CAN COMMUNICATE WIRELESSLY:-

A research team led by MIT scientists has developed an ingestible capsule that can be controlled using Bluetooth, a widely adopted wireless protocol. Manufactured using 3D-printing technology, the capsule could be deployed to deliver drugs to treat a variety of diseases. It could also be designed to sense infections, allergic reactions, or other events, and then release a drug in response.

Kong et al designed an ingestible sensor that can lodge in the stomach for a few weeks and communicate wirelessly with an external device. Image credit: Kong et al.

Figure 10: Wireless electronic pill

"Our system could provide closed-loop monitoring and treatment, whereby a signal can help guide the delivery of a drug or tuning the dose of a drug," said study co-lead author Dr. Giovanni Traverso, a visiting scientist in MIT's Department of Mechanical Engineering.

"We are excited about this demonstration of 3D printing and of how ingestible technologies can help people through novel devices that facilitate mobile health applications," added MIT Professor Robert Langer, co-lead author of the study.

For the past several years, the team as been working on a variety of ingestible sensors and drug delivery capsules, which they believe would be useful for long-term delivery of drugs that currently have to be injected.

They could also help patients to maintain the strict dosing regimens required for patients with HIV or malaria.

In the latest study, the researchers set out to combine many of the features they had previously developed.

In 2016, they designed a star-shaped capsule with six arms that fold up before being encased in a smooth capsule.

After being swallowed, the capsule dissolves and the arms expand, allowing the device to lodge in the stomach.

Similarly, the new device unfolds into a Y-shape after being swallowed. This enables the device to remain the stomach for about a month, before it breaks into smaller pieces and passes through the digestive tract.

One of these arms includes four small compartments that can be loaded with a variety of drugs, which can be packaged within polymers that allow them to be released gradually over several days.

The scientists also anticipate that they could design the compartments to be opened remotely through wireless Bluetooth communication.

The device can also carry sensors that monitor the gastric environment and relay information via a wireless signal.

In previous work, the researchers designed sensors that can detect vital signs such as heart rate and breathing rate.

In the new study, they demonstrated that the capsule could be used to monitor temperature and relay that information directly to a smart phone within arm's length.

"The limited connection range is a desirable security enhancement," said study first author Dr. Yong Lin Kong, a researcher at the University of Utah.
"The self-isolation of wireless signal strength within the user's physical space could shield the device from unwanted connections, providing a physical isolation for additional security and privacy protection."
To enable the manufacturing of all of these complex elements, the study authors decided to 3D print the capsules.
This approach allowed them to easily incorporate all of the various components carried by the capsules, and to build the capsule from alternating layers of stiff and flexible polymers, which helps it to withstand the acidic environment of the stomach.
"Multimaterials 3D printing is a highly versatile manufacturing technology that can create unique multicomponent architectures and functional devices, which cannot be fabricated with conventional manufacturing techniques," Dr. Kong said.
"We can potentially create customized ingestible electronics where the gastric residence period can be tailored based on a specific medical application, which could lead to a personalized diagnostic and treatment that is widely accessible."[13]

FUTURE SCOPE:-

A scientist has called for the development of digestible batteries made of materials already found in the human body so that theoretical electronic pills can be made a reality.
Such pills, which would be able to detect problems in the digestive tract and release suitable medication accordingly, are possible to create, but at present cannot be achieved with a safe power source, according to Christopher Bettinger, assistant professor of materials science and biomedical engineering at Carnegie Mellon University.
Writing in the journal *Trends in Biotechnology*, Bettinger highlighted current digestible electronic devices – the forefathers to these electronic pills – which can be used to capture footage of the intestines or collect data about how the body is breaking down a drug.
However, these devices use regular batteries like the ones found in consumer electronics, and so pose a risk if they fail to pass through the digestive system.
"The primary risk is the intrinsic toxicity of these materials, for example, if the battery gets mechanically lodged in the gastrointestinal tract – but that's a known risk. In fact, there is very little unknown risk in these kinds of devices," he said.
"The breakfast you ate this morning is only in your GI tract for about 20 hours – all you need is a battery that can do its job for 20 hours and then, if anything happens, it can just degrade away."

- ***An ingestible camera in use today for endoscopies:-***

One solution that Bettinger has proposed is the development of electronics that are powered by electrolytes found in our own digestive tracts.
While this may sound bizarre, the technology has already been demonstrated in lab settings, with such electronics found to dissolve in water within three months.
There's also considerable evidence that such devices could be approved by regulators such as the US' FDA; a number of ingestible medical devices, including 3D printed pills, have successfully jumped through the regulatory hoops in recent years, so the FDA is certainly open to approving atypical devices.[14] [15]
These electronic pills could perform functions like targeted drug delivery for certain types of cancer, stimulate damaged tissue, measure biomarkers or monitor gastric problems. But before these pills are actually possible, an edible power source is needed to charge the pills. That's where Bettinger and his fellow researcher Jay Whitacre, a professor of materials science and engineering, come in.
Bettinger and Whitacre have created an edible battery that is taken in the form of a pill that produces the same kind of currency as a regular battery that powers, let's say, a wrist watch. But the pill battery is made entirely of biodegradable material that is already found in the human body.[16] [17] [18]

Future Development:-

Further developments depend upon the photo pattern able to gel electrolyte and oxygen and cation selective membrane. Also in the future these measurements will be used to perform physiological analysis of GI tract for e.g. temperature sensors can be used to measure the body core temperature, also locate any changes corresponding to the ulcer or tissue inflammation, pH sensors can be used to determine the presence of pathological conditions associated with abnormal pH level etc. [19]

Future challenges:-

In the future, one objective would be to produce a device, analogous to micro total analysis system (μTAS) or lab on a chip sensor which is not only capable of collecting and processing the data, but which can transmit it from remote location. The overall concept would be to produce an array of sensor devices distributed throughout the body or environment, capable of transmitting high quality information in real time.[20] [21] [22] [23] [24]

- ***Electronic pills in replacement of laxatives:-***

Electronic pills can be used in the treatment of constipation. Created by a startup in Israel, the so-called Vibrant capsule promises a “chemical-free and safe treatment” for patients suffering from, err, blockages.

They work by vibrating inside the GI tract, thereby inducing peristalsis, the muscular contractions that take place as your waste is moved through the digestive tract toward the rectum. The capsule’s vibration schedule is controlled by an algorithm, predefined by Vibrant’s research and development team and gastroenterologists. It is activated by a base unit that transfers the data to the capsule. Once the “problem” has been solved, the capsule is washed out of the body with the bowel movement.

While the idea of swallowing a vibrating pellet sounds, frankly, a bit crazy, it does actually work, according to some researchers who recently put it through tests in the U.S. Satish Rao and colleagues from Georgia’s Augusta University tested it in two clinical trials and found that it is able to relieve constipation as advertised.

“Two randomized sham-controlled studies were performed in nearly 250 patients with chronic constipation using single or multiple vibrations per day,” Rao, professor of medicine at Augusta, told Digital Trends. “In both trials, subjects took five capsules per week, on five separate days. Patients receiving vibrant capsules had significantly greater bowel movements than sham group. Specifically, we noted that Vibrant augments normal colonic biorhythm, and the increased bowel movements coincided with, or around the time of, vibrant activation.”

The majority of participants did not report feeling any vibrating sensation in their gut while the smart pills were doing their thing. Nor were any major side effects reported by participants. The results of the study are set to be presented this week at the annual meeting of the American College of Gastroenterology. [25]

- ***With electronic pill, we can track gaseous environment in intestine in real time on our phone:-***

The team developed an ingestible electronic capsule to monitor gas levels in the human gut. When it’s paired with a pocket-sized receiver and a mobile phone app, the pill reports tail-wind conditions in real time as it passes from the stomach to the colon. The researchers, led by Kourosh Kalantar-Zadeh of RMIT University and Peter Gibson of Monash University, reported their invention Monday in Nature Electronics.

The authors are optimistic that the capsule’s gas readings can help clear the air over the inner workings of our intricate innards and the multitudes of microbes they contain. Such fume data could clarify the conditions of each section of the gut, what microbes are up to, and which foods may cause problems in the system. Until now, collecting such data has been a challenge. Methods to bottle it involved cumbersome and invasive tubing and inconvenient whole-body calorimetry.

Popping the electronic pill is a breeze in comparison. And early human trials have already hinted that the pill can provide new information about intestinal wind patterns and gaseous turbulence from different foods.[26]

Figure 11: Ingestible electronic capsule

- ***E. Coli in an Electronic Pill Can Detect Bleeding in the Stomach:-***

Researchers at MIT have developed an ingestible chip containing genetically engineered E. coli. When swallowed, the bacteria can detect blood in the stomach, and produce light. The chip containscomponents that measure the amount of light produced and relays this information to a nearby smartphone, allowing a simple and non-invasive diagnosis of gastrointestinal bleeding.

In the past ten years, researchers have made progress in creating genetically modified bacteria that can respond to external stimuli. The MIT research team took this approach one step further to a real-world application, and cleverly packaged the bacteria in a diagnostic chip that can be swallowed.

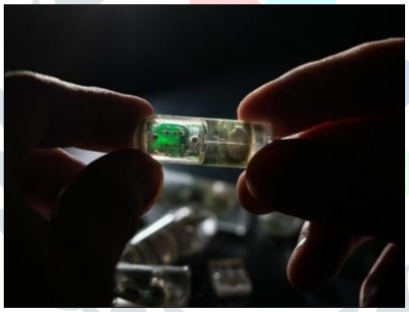


Figure 12: Ingestible chip containing E. coli

"Our idea was to package bacterial cells inside a device," said Phillip Nadeau, a researcher involved in the study. "The cells would be trapped and go along for the ride as the device passes through the stomach."
The researchers engineered bacteria to produce light when they encounter heme, a component of blood. The device consists of a 1.5 inch cylinder, which contains the bacteria in wells that are covered by a semi-permeable membrane. This membrane allows components from the stomach to interact with the bacteria, but keeps the bacteria themselves safely enclosed.
By including a phototransistor under each well that can measure the light emitted by the bacteria, and incorporating additional components to relay data wirelessly to a nearby smartphone, the researchers created a device that can detect gastrointestinal bleeding non-invasively. They also developed an android app to display this diagnostic information.
So far, the research team has shown that the chip can detect gastrointestinal bleeding in pigs. However, the system also has significant potential for a range of other diagnostic applications. "Most of the work we did in the paper was related to blood, but conceivably you could engineer bacteria to sense anything and produce light in response to that," said Mark Mimee, another researcher involved in the study. "Anyone who is trying to engineer bacteria to sense a molecule related to disease could slot it into one of those wells, and it would be ready to go." [27]

- ***Ingestible electronic pill could be the future of non-surgical drug delivery:-***

Scientists have developed a small electronic capsule that can be ingested and controlled wirelessly to deliver drugs. Researchers at the Massachusetts Institute of Technology believe that the device could be used to provide drugs to users for a variety of diseases that require medication over longer periods of time, especially those that require strict and regular doses.

The 3D-printed pill can be controlled externally using Bluetooth, and could be developed further to detect infections or an allergic reaction in the future.

MIT researchers have designed an ingestible sensor that can lodge in the stomach for a few weeks and communicate wirelessly with an external device. See SWNS story NNpill; A robotic pill that releases drugs by bluetooth commands from a smartphone promises to do away with injections, scientists revealed. The electronic device designed to sit in the stomach for at least a month can also detect illnesses early relaying a diagnosis wirelessly. The devices made by 3-D printing can be programmed to sense infections, allergic reactions, or other events, and then release a drug in response.

MIT researchers have designed an ingestible sensor that can lodge in the stomach for a few weeks and communicate wirelessly with an external device.

'Our system could provide closed-loop monitoring and treatment, whereby a signal can help guide the delivery of a drug or tuning the dose of a drug,' said Professor Giovanni Traverso, co-author of the research, which was published in the Advanced Materials Technologies journal.

Scientists also believe such a device could work with other health wearables and implants to send the information to the patient's phone or their doctor.

The capsule dissolves when consumed, allowing arms to expand and lodge itself in the stomach for around a month, before it begins to break apart and leaves the body through the digestive tract.

Lead author of the paper, Professor Yong Lin Kong, said the limited connection range serves as a desirable security enhancement. Doctor explains why he looks at dead patient's Facebook profiles before telling their parents they're dead getty. Doctors would be able to administer drugs wirelessly by connecting to the pill in your stomach.

'The self-isolation of wireless signal strength within the user's physical space could shield the device from unwanted connections, providing a physical isolation for additional security and privacy protection,' he explained.

At the moment, a small silver oxide battery powers the device but alternatives, such as an external antenna or using stomach acid are being explored. The group's latest work builds on previous attempts to create an ingestible pill. In 2016, they designed a star-shaped capsule with six arms that fold up. It is hoped that humans will be able to test ingestible sensors within two years. [28]

- ***Electronic pill that helps you slim by tricking your tummy:-***

The experimental pill works in the same way as gastric pacemakers to suppress appetite.

A gastric pacemaker is an implant that is surgically placed in the stomach and wired to the vagus nerve. This nerve carries signals from the stomach to the hypothalamus, the area of the brain responsible for regulating appetite. The pacemaker has a sensor that detects when food is entering the stomach.

The experimental pill works in the same way as gastric pacemakers to suppress appetite. It then fires low-level electrical pulses into the vagus nerve to fool the brain into thinking the stomach has no more room.

Gastric pacemakers cost around £10,000 and are usually reserved for patients who don't respond to dieting, or who aren't suitable for more drastic gastric bypass surgery. They are not currently available on the NHS. The latest invention, developed by Israeli firm MelCap Systems, can simply be swallowed with water and although the price has not been announced, it's likely to be much cheaper than a pacemaker. [29]

- ***Type 2 diabetes: Electronic pill could 'mimic the effects of surgery':-***

Researchers have engineered a material that temporarily coats the small intestine and reduces the amount of glucose that enters the bloodstream during digestion.

When they tested the material which is called Luminal Coating of the Intestine (LuCI) on rats, they found that it reduced "glucose response" by almost half.

The scientists developed the material because they wanted to find a non-invasive treatment for reversing type II diabetes, which is as effective as surgery. The intention is that once swallowed and in the gut, LuCI forms a temporary coating and then dissolves harmlessly a few hours later.

A paper now published in the journal Nature Materials reports how the material temporarily coated the intestine in rats, acted as a partial barrier to nutrient absorption, and prevented blood sugar "spikes" following a meal.

"We envision a pill," notes co-senior study author Prof. Jeff Karp, who is a bioengineer and principal investigator from Brigham and Women's Hospital in Boston, MA, "that a patient can take before a meal that transiently coats the gut to replicate the effects of surgery."[30]

CONCLUSION:-

We have therefore described about multichannel sensor, which has been implemented in remote biomedical using micro technology. The microelectronic pill which is designed to perform real time measurements is the GI tract providing the best in vitro wireless transmitter, multichannel recordings of analytical parameters.

SUMMARY:-

Human body is very sensitive even for small changes. Many times the doctors fail to interpret the diseases and abnormalities which make the curing of diseases more difficult, so the Micro Electronic pill is developed by the scientists to overcome from this problem and quick diagnosis is possible by this innovation. To carry out above process efficiently a radio system of high capacity is needed for this technology to get real time video of digestive system wirelessly, this requires Upper Wide Bandwidth Transmitter and Receiver. But tissue damage at high frequency limited its usage. Research work is carried out to get the detailed images of internal parts through high frequency transmission and reception of data without damage to tissues of human body.

CONFLICT OF INTEREST

There is no conflict of interest. The authors alone are responsible for content and writing of this article.

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