BIO AND MEDICAL ENGINERING: IMPACTS OF TECHNOLOGY ON BIOLOGY AND MEDICINE.

What is Biomedical Engineering?

Biomedical engineering is the discipline that applies engineering principles, design concepts, problem solving skills to biology, medicine and healthcare to improve human health and quality of life.

In simple terms, it is engineering applied to the human body and healthcare systems.

Doctors understand the body and disease. Engineers understand systems, materials and machines. Biomedical engineers combine both to create solutions like pacemakers, artificial limbs, MRI scanners and dialysis machines.

For most of human history, medicine was based on observation, physical examination, and trial-and-error treatment. Biology was studied by dissecting dead organisms and looking through basic microscopes. However, Technology changed that. The relationship is two-way:

1. Technology impacts biology and medicine: New tools let us see, measure, treat, and understand the body in ways that were impossible before.

2. Biology impacts technology: Studying how the body works inspires new engineering designs.

In this lecture, we will focus on how technology has transformed biology and medicine, especially in diagnosis, treatment, research, and public health.

The Three Waves of Technological Impact on Medicine

Wave	**Period**	**Key technologies**	**Impact**
1st wave(mechanical)	1800s-1940s	Stethoscope Microscope X-ray thermometer	Allowed doctors to see and measure inside the body without surgery
2nd wave(electronic)	1950s-1990s	ECG,EEG Dialysis machine Pacemaker CT scan	Allowed doctors to monitor and replace organ function
3rd wave(digital & biological)	2000s-now	MRI, AI, Telemedicine, robotic surgery	Allows doctors to predict, personalize and remotely manage health

Major Impacts of Technology on Medicine

1**. Revolution in Diagnosis.** Before technology, diagnosis depended on symptoms and physical exam. Now we can see disease at the molecular level. Key examples include;

i. **Imaging Technologies**

- X-ray (1895): First way to see bones without cutting. Still used for fractures.

- CT Scan (1970s): Combines X-ray with computer to make 3D images of organs.

- MRI (1980s): Uses magnetic fields to image soft tissue like brain, muscles and tumors without radiation.

- Ultrasound (1950s): Uses sound waves to see fetus, heart and abdomen. Safe for pregnancy.

Impact: Faster diagnosis, less exploratory surgery, better treatment planning.

ii. **Laboratory Diagnostics**

- PCR (Polymerase Chain Reaction): Amplifies tiny amounts of DNA to detect COVID-19, HIV and tuberculosis in hours instead of days.

- Biosensors: Small devices that measure glucose, malaria antigens, pregnancy hormones from a drop of blood.

- Automated Analyzers: Machines that run 100 blood tests per hour.

Impact: Early detection of disease, faster results, reduced human error.

2. **Advances in Treatment**. Technology moved medicine from “managing symptoms” to “fixing or replacing function”. Key examples are:

i. Medical Devices for Organ Support

- Pacemaker: Sends electrical pulses to regulate heartbeat.

- Dialysis Machine: Filters blood when kidneys fail.

- Ventilator: Takes over breathing for patients in ICU.

- Insulin Pump: Automatically delivers insulin for diabetic patients.

ii. Surgical Technology

- Minimally Invasive Surgery: Laparoscopy uses small cuts and cameras. Faster recovery, less pain.

- Robotic Surgery: Da Vinci robot allows surgeon to operate with more precision through tiny incisions.

- Laser Surgery: Uses focused light to cut tissue, treat eye disease, remove tumors.

iii. Drug Delivery & Biomaterials

- Implants: Artificial hip joints, dental implants, heart valves made from titanium and polymers.

- Controlled Drug Release: Patches and implants that release medicine slowly over weeks.

Impact: Longer life expectancy, better quality of life, reduced hospital stay.

3. **Transformation of Research in Biology.** Technology turned biology from a descriptive science into a quantitative, data-driven science. Key examples are:

1. DNA Sequencing: The Human Genome Project (2003) mapped all 3 billion DNA bases in humans. Now sequencing costs dropped from $3 billion to <$500. This allows personalized medicine.

2. Microscopy: Electron microscopes can see viruses. Fluorescence microscopes can track individual proteins in living cells.

3. Bioinformatics: Computers analyze millions of DNA sequences to find genes linked to cancer, sickle cell, malaria resistance.

4. Cell Culture & Tissue Engineering: Scientists grow human cells and tissues in the lab to test drugs without using animals.

Impact: Accelerated drug discovery, understanding of genetic diseases, and development of gene therapy.

4. **Public Health and Telemedicine**. Telemedicine is delivery of healthcare services (including, diagnosis, treatment and consultation) remotely via telecommunications technology such as video calls, phone or secure apps. Technology is extending healthcare beyond the hospital. Key examples:

1. Telemedicine: Video consultation, remote monitoring of blood pressure, ECG. Critical in rural Nigeria where specialists are scarce.

2. Mobile Health (m Health): is a technology that allows certain software to be installed in electronic devices (smartphones, tablets, wearable and patient monitoring devices) to track user data and provide healthcare services. Apps for appointment reminders, health education, symptom tracking. WhatsApp is used by Nigerian doctors to share X-rays and consult.

3. Disease Surveillance: Is an early warning system to detect outbreaks, monitor trends in infectious and chronic diseases and guide actions to reduce mortality and morbidity. E.g. Mobile phones and AI track disease outbreaks in real-time. Used during Ebola and COVID-19 in Nigeria.

4. Vaccines & Cold Chain: Solar-powered refrigerators and temperature sensors ensure vaccines stay effective in off-grid areas.

Impact: Improved access to care, faster outbreak response and better health education.

Positive Impacts Summarized

Area	Before technology	After technology
Diagnosis	Based on symptoms only	Imaging, lab tests, genetic tests allow early, accurate diagnosis
Treatment	Limited to drugs and surgery	Devices can replace organ function, robots enable precise surgery.
Surgery	High risk, long recovery	Minimally invasive, faster recovery
Access to care	Only in cities	Telemedicine and mobile clinics reach rural areas

Challenges and Negative Impacts

Technology is not perfect. It's important to see both sides.

1. Cost and Access Inequality: MRI and robotic surgery are expensive. Most PHCs in Nigeria cannot afford them. This creates a gap between urban and rural care.

2. Over-reliance on Technology: This can reduce core clinical skills, reduce clinical thinking and introduce risks from device malfunctions or data breaches. Some doctors order too many tests instead of using clinical judgment. Excessive dependence on automated tools can lead to diagnostic errors and diminished patient-provider empathy.

3. Device Safety and Maintenance: The high sophistication of digital equipment makes the repair difficult which will in turn need experienced biomedical engineers. Software defects are common reasons for medical device recalls. In Nigeria, 40–70% of medical devices are non-functional due to poor maintenance and power issues.

4. Data Privacy: the storage and transmission of sensitive patient data, particularly via internet connected devices (IoT) and cloud platforms creates high value targets for cybercriminals. Breaches can expose clinical, personal and financial data leading to identity theft. Electronic medical records and telemedicine raise concerns about patient data security. Nigeria's Data Protection Act 2023 now addresses this.

5. Ethical Issues: Genetic testing, gene editing, and AI diagnosis raise questions about consent, privacy, and fairness.

Biomedical engineers must design technology that is affordable, robust for our environment, and safe.

Examples of Technology Impact.

Technology has transformed healthcare, diagnostics keep improving every year and there is always a new, cutting edge treatment with the processes becoming more precise, effective and accessible.

1. Real time monitoring using wearable. Previously, clinicians relied solely on bulky equipment and frequent blood tests for vital sign monitoring. They can now use wearable sensors to continuously track vital signs. These compact devices collect real time data, providing a detailed picture of a patient's health. Examples include; smart wearable patches that track sleep patterns, heart rate variability and also skin temperature. Portable ultrasound devices allow midwives to detect pregnancy complications without sending patients 100 km to a city hospital.
2. Surgery precision through robotics. Health professionals can now use robotic arms to their advantage in procedures like eye surgery. This method minimizes chances for errors and speeds up patient recovery. Other ways are surgeons use robotic arms to perform a laparoscopic cholecystectomy and remove the gall bladder.
3. Streamlined care via EHRs. Electronic health records are used in facilities to compile patient information from doctor's notes to lab results and medication lists so that clinicians can get a detailed view. This has improved patient care by lowering chance of medical error. In addition, supplying health information reduces duplication of tests and delays in treatment.
4. Solar-Powered PHCs: UNICEF and FMOH are installing solar systems and solar refrigerators in PHCs across northern Nigeria. This keeps vaccines viable and allows night-time deliveries.
5. NAFDAC's E-Registration: Online system for registering medical devices has reduced fake and substandard equipment in the market.
6. COVID-19 Response: PCR machines, oxygen plants, and telemedicine platforms were rapidly deployed across Nigeria in 2020–2021.

The Future of technology: Where Is This Going?

1. Artificial Intelligence in Medicine: This uses machine learning, data analysis and algorithms to support clinical decision-making, diagnostics and patient care. AI that reads X-rays, predicts sepsis, and helps diagnose skin diseases on a phone camera.

2. Wearable & Implantable Sensors: Wearable sensors are devices that monitor physiological parameters e.g. smart watches that detect irregular heartbeat, smart patches that monitor

glucose continuously. Implantable sensors are devices inserted into the body to monitor internal biochemical changes e.g. continuous glucose monitors (CGM) under the skin.

3. 3D Printing: Is an additive manufacturing process used to build three dimensional structures from computer aided design (CAD) models in a layer by layer fashion. E.g. Printing prosthetic limbs, surgical guides, and even skin tissue in Nigeria.

4. Gene Therapy & CRISPR: Is a revolutionary, and precise gene editing technology that allows scientist to edit genes by acting as molecular scissors to cut, delete or replace scientific genetic sequences and potentially cure sickle cell disease, which affects 2–3% of Nigerians.

5. Internet of Medical Things (IoMT): Is a connected infrastructure of medical devices, software applications and health systems that collect, analyze and transmit health data over the internet. i.e. all devices are connected to hospital network for real-time monitoring.

In conclusion,

1. Technology transformed medicine from observation-based to data-driven, from reactive to preventive.

2. Key impacts: Faster diagnosis, better treatment, longer life expectancy, wider access to care.

3. Challenges exist: Cost, maintenance, ethics, and inequality, especially in Nigeria.

4. As a biomedical engineer, your job is to create and manage technology that solves Nigerian health problems in a safe, affordable, and sustainable way.

One-line takeaway: Technology gives medicine the eyes to see disease, the hands to treat it, and the reach to extend care to everyone.