SRI LAKSHMI NARAYANA INSTITUTE OF MEDICAL SCIENCES

Osudu, Agaram Village, Villianur commune, Kuduppakkam Post, Pudhucherry-605 502

Date: 16/07/2018

From

Dr. Somashekar I Tolanur
Professor and Head,
Department of Anatomy,
Sri Lakshmi Narayana Institute of Medical Sciences,
(BIHER University),
Puducherry-2.

To

The Dean,
Sri Lakshmi Narayana Institute of Medical Sciences,
(BIHER University),
Puducherry-2.

Sub: Permission to conduct value-added course: 3D printing in Anatomy Education & its applications – reg.

Dear Madam,

With reference to the subject mentioned above, the department proposes to conduct a value-added course titled: 3D **printing in Anatomy Education & its Applications** for 1st MBBS students of 2018-2019 batch. We solicit your kind permission for the same.

Kind Regards,

PROF & HOD OF ANATOMY
SRI LAKSHMI NARAYANA INSTITUTE OF MEDICAL SCIENCES
Osudu Agaram Village, Pondicherry-605 502

FOR THE USE OF DEAN'S OFFICE

Names of Committee members for evaluating the course:

The Dean: **Dr. Jayalakshmi. G**
The HOD: **Dr. Somashekar I Tolanur**
The Expert: **Dr. S Shanthini**

The committee has discussed about the course and is approved.

Dean (Sign & Seal)	Subject Expert (Sign & Seal)	HOD (Sign & Seal)

Dr. G. JAYALAKSHMI, BSc., MBBS., DICD., Ph.D
DEAN
Sri Lakshmi Narayana Institute of Medical Sciences
Osudu, Agaram, Kudapakkam Post
Villianur Commune, Puducherry - 605502

PROF & HOD OF ANATOMY
SRI LAKSHMI NARAYANA INSTITUTE OF MEDICAL SCIENCES
Osudu Agaram Village, Pondicherry-605 502

OFFICE OF THE DEAN
Sri Lakshmi Narayana Institute of Medical Sciences
OSUDU, AGARAM VILLAGE, VILLIANUR COMMUNE, KUDAPAKKAM POST,
PUDUCHERRY - 605 502.
[Recognised by Medical Council of India, Ministry of Health letter No. U/12012/249/2005-ME (P -II) dt. 11/07/2011]
[Affliated to Bharath University, Chennai - TN]

Circular

23.07.2018

Sub: Organizing Value-added Course on "3D printing in Anatomy Education & its applications" – Reg.

With reference to the above mentioned subject, it is to bring to your notice that Sri Lakshmi Narayana Institute of Medical Sciences, Puducherry affiliated to Bharath Institute of Higher Education and Research University is organizing a value added course on "**3D printing in Anatomy Education & its applications**" during September 2018 for Ist year M.B.B.S students (2018 – 2019 Batch). The course content for the same is enclosed below."

Dean
(Dr.G Jayalakshmi)

Dr. G. JAYALAKSHMI, BSC., MBBS., DTCD., M.D.,
DEAN
Sri Lakshmi Narayana Institute of Medical Sciences
Osudu, Agaram, Kudapakkam Post,
Villianur Commune, Puducherry - 605502

Encl: Copy of Course content

COURSE CONTENT

Particulars	Description
Course Title	3D printing in Anatomy Education & its applications
Course Code	AN100
Topics	1. Introduction to 3D printing 2. Terminology in 3D printing 3. History of 3D printing 4. General principles in 3D printing 5. Modeling 6.Printing 7.Finishing 8. Materials used for 3D printing 9. Multimaterial 3D printing 10. Processes and Printers 11. Applications in Anatomy 12. Video demonstration of 3D printing 13. Health & safety 14.Hazard control 15. Legal aspects – Intellectual property
Further learning opportunities	4D printing
Key Competencies	On successful completion of the course the students will have better understanding of complex human anatomical structures which helps in better learning & understanding of anatomy
Target Student	1st MBBS Students
Duration	30hrs, September 2018
Theory Session	28 hrs
Practical Session	2hrs
Assessment Procedure	Short answer questions

Course Proposal

Course Title:

3D printing in Anatomy Education & its applications

Course Objective:

1. Introduce the students to 3d anatomical models
2. To learn complex anatomical structures with better understanding and orientation

Course Outcome:

Gain knowledge on 3d oriented anatomical structures for better understanding and easy learning

Course Audience: 1st year MBBS

Course Coordinator: Dr.Somashekar I Tolanur

Course Faculties with Qualification and Designation:

1. Dr. B Rajesh, M.Sc., Ph.D, Professor/Anatomy
2. Dr. S Shanthini, M.B.B.S, M.D, Assistant Professor/Anatomy
2. Dr. B Anitha, M.B.B.S, M.D, Assistant Professor/Anatomy

Course Curriculum/subtopics with schedule (30 hours)

Sl.No	Date	Topic	Time	Hours	Faculty Name
1.	01.09.2018	Introduction to 3D printing	2-4p.m	2	Dr S Shanthini
2.	03.09.2018	Terminology used in 3D printing	4-6p.m	2	Dr. B Rajesh
3.	04.09.2018	History of 3d printing	4-6p.m	2	Dr. B Anitha
4.	05.09.2018	General principles in 3d printing	4-6p.m	2	Dr.S Shanthini
5.	06..09.2018	Modeling	4-6p.m	2	Dr. B Rajesh
6.	07.09.2018	Printing	4-6p.m	2	Dr. B Anitha
7.	08.09.2018	Finishing	2-4p.m	2	Dr. S Shanthini
8.	10.09.2018	Materials used for 3D printing	4-6p.m	2	Dr. B Rajesh
9.	11.09.2018	Multimaterial 3D printing	4-6p.m	2	Dr. B Anitha
10.	12.09.2018	Processes & Printers	4-6p.m	2	Dr. B Rajesh
11.	13.09.2018	Applications in Anatomy	4-6p.m	2	Dr. B Anitha
12.	15.09.2018	Video Demonstration of 3D printing	2-4p.m	2	Dr. S Shanthini
13.	19.09.2018	Health & safety	4-6p.m	2	Dr. B Anitha
14.	21.09.2018	Hazard control	4-6p.m	2	Dr. B Rajesh
15.	29.09.2018	Legal aspects – Intellectual property	4-6p.m	2	Dr. S Shanthini
			Total Hours	30	

REFERENCE BOOKS/ARTICLES:

1. Ye, Z., Dun, A., Jiang, H. *et al.* The role of 3D printed models in the teaching of human anatomy: a systematic review and meta-analysis. *BMC Med Educ* 20, 335 (2020). https://doi.org/10.1186/s12909-020-02242-x.
2. Sharma SGS. 3D printing and its future in medical world. J Med Res Innov. 2019;3(1):e000141.
3. Garas M, M V, G N, K M-D, J H. 3D-Printed specimens as a valuable tool in anatomy education: A pilot study. Ann Anat. 2018;219:57–64.
4. Mogali SR, WY Y, HKJ T, GJS T, PH A, N Z, N L-B, MA F. Evaluation by medical students of the educational value of multi-material and multicolored three-dimensional printed models of the upper limb for anatomical education. Anat Sci Educ. 2018;11(1):54–64.
5. M V, V P. 3D printing: a valuable resource in human anatomy education. Anat Sci Int. 2015;90(1):64–5.
6. AbouHashem Y, Dayal M, Savanah S, Strkalj G. The application of 3D printing in anatomy education. Med Educ Online. 2015;20.
7. McMenamin PG, MR Q, CR M, JW A. The production of anatomical teaching resources using three-dimensional (3D) printing technology. Anat Sci Educ. 2014;7(6):479–86.

VALUE ADDED COURSE

1. **Name of the programme & Code**

   3D printing in Anatomy Education & its applications (Code - AN100)

2. **Duration & Period**

   30 hrs & September 2018

3. **Information Brochure and Course Content of Value Added Courses**

   Enclosed as Annexure- I

4. **List of students enrolled**

   Enclosed as Annexure- II

5. **Assessment procedures:**

   Short Answer Questions - *Enclosed as Annexure- III*

6. **Certificate model**

   Enclosed as Annexure- IV

7. **No. of times offered during the same year:**

   1 time - September 2018

8. **Year of discontinuation:** 2019

9. **Summary report of each program year-wise**

Value Added Course - September 2018					
Sl. No	**Course Code**	**Course Name**	**Resource Persons**	**Target Students**	**Strength & Year**
1	Code - AN100	3D printing in Anatomy Education & its applications	Dr. S Shanthini Dr. B Rajesh Dr. B Anitha	Ist M.B.B.S (2018 – 2019 batch)	20 / September 2018

10. **Course Feed Back**

    Enclosed as Annexure- V

COORDINATOR
(Dr. Somasekar I Tolanur)

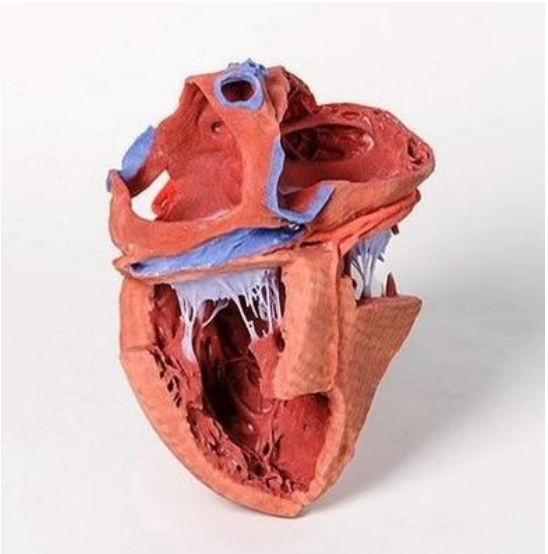
PROF & HOD OF ANATOMY
SRI LAKSHMI NARAYANA INSTITUTE OF MEDICAL SCIENCES
Osudu Agaram Village, Pondicherry-605 502

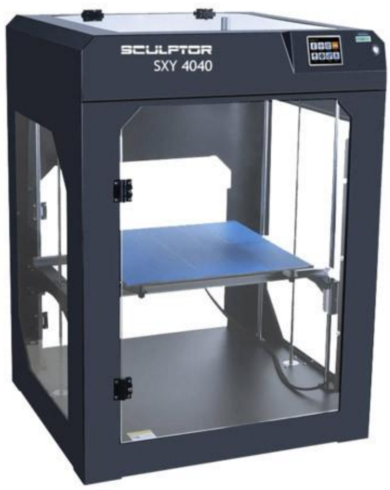
RESOURCE PERSONS

1. **(Dr. S Shanthini)**
2. **(Dr. B Rajesh)**
3. **(Dr. B Anitha)**

Annexure 1

3D Printing in Anatomy Education & its Applications





PARTICIPANT HAND BOOK

BIHER SLIMS

COURSE DETAILS

Particulars	Description
Course Title	3D printing in Anatomy Education & its applications
Course Code	AN100
Topics	1. Introduction to 3D printing 2. Terminology in 3D printing 3. History of 3D printing 4. General principles in 3D printing 5. Modeling 6.Printing 7.Finishing 8. Materials used for 3D printing 9. Multimaterial 3D printing 10. Processes and Printers 11. Applications in Anatomy 12. Video demonstration of 3D printing 13. Health & safety 14.Hazard control 15. Legal aspects – Intellectual property
Further learning opportunities	4D printing
Key Competencies	On successful completion of the course the students will have better understanding of complex human anatomical structures which helps in better learning & understanding of anatomy
Target Student	1st MBBS Students
Duration	30hrs September 2018
Theory Session	28 hrs
Practical Session	2hrs
Assessment Procedure	Multiple choice questions

Introduction:

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of **material** until the object is created.

The umbrella term *additive manufacturing (AM)* gained popularity in the 2000s, inspired by the theme of material being added together (in any of various ways). In contrast, the term *subtractive manufacturing* appeared as a retronym for the large family of machining processes with material *removal* as their common process. The term *3D printing* still referred only to the polymer technologies in most minds, and the term *AM* was more likely to be used in metalworking and end-use part production contexts than among polymer, inkjet, or stereolithography enthusiasts. Inkjet was the least familiar technology even though it was invented in 1950 and poorly understood because of its complex nature. The earliest inkjets were used as recorders and not printers. As late as the 1970s the term recorder was associated with inkjet. Continuous Inkjet later evolved to On-Demand or Drop-On-Demand Inkjet. Inkjets were single nozzle at the start and now have thousands of nozzles for printing in each pass over a surface.

By the early 2010s, the terms *3D printing* and *additive manufacturing* evolved senses in which they were alternate umbrella terms for additive technologies, one being used in popular language by consumer-maker communities and the media and the other used more formally by industrial end-use part producers, machine manufacturers, and global technical standards organizations. Until recently, the term *3D printing* has been associated with machines low in price or in capability. *3D printing* and *additive manufacturing* reflect that the technologies share the theme of material addition or joining throughout a 3D work envelope under automated control. Peter Zelinski, the editor-in-chief of *Additive Manufacturing* magazine, pointed out in 2017 that the terms are still often synonymous in casual usage, but some manufacturing industry experts are trying to make a distinction whereby additive manufacturing comprises 3D printing plus other technologies or other aspects of a manufacturing process.

Terminology:

Terms that have been used as synonyms or hypernyms have included *desktop manufacturing*, *rapid manufacturing* (as the logical production-level successor to rapid prototyping), and *on-demand manufacturing* (which echoes on-demand printing in the 2D sense of *printing*). Such application of the adjectives *rapid* and *on-demand* to the noun *manufacturing* was novel in the 2000s reveals the prevailing mental model of the long industrial era in which almost all production manufacturing involved long lead times for laborious tooling development. Today, the term *subtractive* has not replaced the term *machining*, instead complementing it when a term that covers any removal method is needed. Agile tooling is the use of modular means to design tooling that is produced by additive manufacturing or 3D printing methods to enable quick prototyping and responses to tooling and fixture needs. Agile tooling uses a cost-effective and high-quality method to quickly respond to customer and market needs, and it can be used in hydro-forming, stamping, injection molding and other manufacturing processes.

History:

1950s

The general concept of and procedure to be used in 3D-printing was first described by Raymond F. Jones in his story, "Tools of the Trade," published in the November 1950 issue of Astounding Science Fiction magazine. He referred to it as a "molecular spray" in that story.

1970s

In 1971, Johannes F Gottwald patented the Liquid Metal Recorder, US3596285A, a continuous Inkjet metal material device to form a removable metal fabrication on a reusable surface for immediate use or salvaged for printing again by remelting. This appears to be the first patent describing 3D printing with rapid prototyping and controlled on-demand manufacturing of patterns.

The patent states " As used herein the term printing" is not intended in a limited sense but includes writing or other symbols, character or pattern formation with an ink. The term ink as used in is intended to include not only dye or pigment-containing materials, but any flowable substance or composition suited for application to the surface for forming symbols, characters, or patterns of intelligence by marking". The preferred ink is of a Hot melt" type. The range of commercially available ink compositions which could meet the requirements of the invention are not known at the present time. However, satisfactory printing according to the invention has been achieved with the conductive metal alloy as ink."

"But in terms of material requirements for such large and continuous displays, if consumed at theretofore known rates, but increased in proportion to increase in size, the high cost would severely limit any widespread enjoyment of a process or apparatus satisfying the foregoing objects." "It is therefore an additional object of the invention to minimize use to materials in a process of the indicated class." "It is a further object of the invention that materials employed in such a process be salvaged for reuse."

"According to another aspect of the invention, a combination for writing and the like comprises a carrier for displaying an intelligence pattern and an arrangement for removing the pattern from the carrier." In 1974, David E. H. Jones laid out the concept of 3D printing in his regular column Ariadne in the journal New Scientist.

1980s

Early additive manufacturing equipment and materials were developed in the 1980.

In April 1980, Hideo Kodama of Nagoya Municipal Industrial Research Institute invented two additive methods for fabricating three-dimensional plastic models with photo-hardening thermoset polymer, where the UV exposure area is controlled by a mask pattern or a scanning fiber transmitter. He filed a patent for this XYZ plotter, which was published on 10 November 1981. (JP S56-144478). His research results as journal papers were published in April and November in 1981. However, there was no reaction to the series of his publications. His device was not highly evaluated in the laboratory and his boss did not show any interest. His research budget was just 60,000 yen or $545 a year. Acquiring the patent rights for the XYZ plotter was abandoned, and the project was terminated. A Patent US

4323756, Method of Fabricating Articles by Sequential Deposition, Raytheon Technologies Corp granted 6 April 1982 using hundreds or thousands of 'layers' of powdered metal and a laser energy source is an early reference to forming "layers" and the fabrication of articles on a substrate.

In 2 July 1984, American entrepreneur Bill Masters filed a patent for his Computer Automated Manufacturing Process and System (US 4665492). This filing is on record at the USPTO as the first 3D printing patent in history; it was the first of three patents belonging to Masters that laid the foundation for the 3D printing systems used today.

On 16 July 1984, Alain Le Méhauté, Olivier de Witte, and Jean Claude André filed their patent for the stereolithography process.[18] The application of the French inventors was abandoned by the French General Electric Company (now Alcatel-Alsthom) and CILAS (The Laser Consortium). The claimed reason was "for lack of business perspective"

In 1983, Robert Howard started R.H. Research, later named Howtek, Inc. in Feb 1984 to develop a color inkjet 2D printer, Pixelmaster, commercialized in 1986, using Thermoplastic (hot-melt) plastic ink. A team was put together, 6 members from Exxon Office Systems, Danbury Systems Division, an inkjet printer startup and some members of Howtek, Inc group who became popular figures in 3D Printing Industry. One Howtek member, Richard Helinski patent US5136515A, Method and Means for constructing three-dimensional articles by particle deposition, application 11/07/1989 granted 8/04/1992 formed a New Hampshire company C.A.D-Cast, Inc, name later changed to Visual Impact Corporation (VIC) on 8/22/1991. A prototype of the VIC 3D printer for this company is available with a video presentation showing a 3D model printed with a single nozzle inkjet. Another employee Herbert Menhennett formed a New Hampshire company HM Research in 1991 and introduced the Howtek, Inc, inkjet technology and thermoplastic materials to Royden Sanders of SDI and Bill Masters of Ballistic Particle Manufacturing (BPM) where he worked for a number of years. Both BPM 3D printers and SPI 3D printers use Howtek, Inc style Inkjets and Howtek, Inc style materials. Royden Sanders licensed the Helinksi patent prior to manufacturing the Modelmaker 6 Pro at Sanders prototype, Inc (SPI) in 1993. James K. McMahon who was hired by Howtek, Inc to help develop the inkjet, later worked at Sanders Prototype and now operates Layer Grown Model Technology, a 3D service provider specializing in Howtek single nozzle inkjet and SDI printer support. James K. McMahon worked with Steven Zoltan, 1972 drop-on-demand inkjet inventor, at Exxon and has a patent in 1978 that expanded the understanding of the single nozzle design inkjets(Alpha jets) and help perfect the Howtek, Inc hot-melt inkjets. This Howtek hot-melt thermoplastic technology is popular with metal investment casting, especially in the 3D printing jewelry industry. Sanders (SDI) first Modelmaker 6Pro customer was Hitchner Corporations, Metal Casting Technology, Inc in Milford, NH a mile from the SDI facility in late 1993-1995 casting golf clubs and auto engine parts.

On 8 August 1984 a patent, US4575330, assigned to UVP, Inc., later assigned to Chuck Hull of 3D Systems Corporation was filed, his own patent for a stereolithography fabrication system, in which individual laminae or layers are added by curing photopolymers with impinging radiation, particle bombardment, chemical reaction or just ultraviolet light lasers. Hull defined the process as a "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed,". Hull's contribution was the STL (Stereolithography) file format and the digital slicing and infill strategies common to many processes today. In 1986, Charles "Chuck" Hull was granted a patent for this system, and his company, 3D Systems Corporation was formed and it released the first commercial 3D printer, the SLA-1. later in 1987 or 1988. The technology used by most 3D printers to date—

especially hobbyist and consumer-oriented models—is fused deposition modeling, a special application of plastic extrusion, developed in 1988 by S. Scott Crump and commercialized by his company Stratasys, which marketed its first FDM machine in 1992.

1990s

AM processes for metal sintering or melting (such as selective laser sintering, direct metal laser sintering, and selective laser melting) usually went by their own individual names in the 1980s and 1990s. At the time, all metalworking was done by processes that are now called non-additive (casting, fabrication, stamping, and machining); although plenty of automation was applied to those technologies (such as by robot welding and CNC), the idea of a tool or head moving through a 3D work envelope transforming a mass of raw material into a desired shape with a toolpath was associated in metalworking only with processes that removed metal (rather than adding it), such as CNC milling, CNC EDM, and many others. But the automated techniques that *added* metal, which would later be called additive manufacturing, were beginning to challenge that assumption. By the mid-1990s, new techniques for material deposition were developed at Stanford and Carnegie Mellon University, including microcasting and sprayed materials. Sacrificial and support materials had also become more common, enabling new object geometries.

The term *3D printing* originally referred to a powder bed process employing standard and custom inkjet print heads, developed at MIT by Emanuel Sachs in 1993 and commercialized by Soligen Technologies, Extrude Hone Corporation, and Z Corporation. The year 1993 also saw the start of an inkjet 3D printer company initially named Sanders Prototype,Inc and later named Solidscape, introducing a high-precision polymer jet fabrication system with soluble support structures, (categorized as a "dot-on-dot" technique). In 1995 the Fraunhofer Society developed the selective laser melting process.

2000 - 2020

Fused Deposition Modeling (FDM) printing process patents expired in 2009

As the various additive processes matured, it became clear that soon metal removal would no longer be the only metalworking process done through a tool or head moving through a 3D work envelope, transforming a mass of raw material into a desired shape layer by layer. The 2010s were the first decade in which metal end use parts such as engine brackets and large nuts would be grown (either before or instead of machining) in job production rather than obligately being machined from bar stock or plate. It is still the case that casting, fabrication, stamping, and machining are more prevalent than additive manufacturing in metalworking, but AM is now beginning to make significant inroads, and with the advantages of design for additive manufacturing, it is clear to engineers that much more is to come.

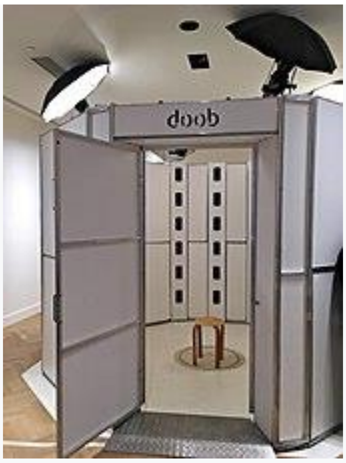
One place that AM is making a significant inroad is in the aviation industry. With nearly 3.8 billion air travellers in 2016, the demand for fuel efficient and easily produced jet engines has never been higher. For large OEMs (original equipment manufacturers) like Pratt and Whitney (PW) and General Electric (GE) this means looking towards AM as a way to reduce cost, reduce the number of nonconforming parts, reduce weight in the engines to increase fuel efficiency and find new, highly complex shapes that would not be feasible with the antiquated manufacturing methods. One example of AM integration with aerospace was in 2016 when Airbus was delivered the first of GE's LEAP engine. This engine has integrated 3D printed fuel nozzles giving them a reduction in parts from 20 to 1, a 25% weight reduction and reduced assembly times. A fuel nozzle is the perfect in road for additive manufacturing in a jet engine since it allows for optimized design of the complex internals and it is a low stress, non-rotating part. Similarly, in 2015, PW delivered their first AM parts in the Pure Power PW1500G to Bombardier. Sticking to low stress, non-rotating parts, PW selected the compressor stators and synch ring brackets to roll out this new manufacturing technology for the first time. While AM is still playing a small role in the total number of parts in the jet engine manufacturing process, the return on investment can already be seen by the reduction in parts, the rapid production capabilities and the "optimized design in terms of performance and cost". As technology matured, several authors had begun to speculate that 3D printing could aid in sustainable development in the developing world.

In 2012, Filabot developed a system for closing the loop with plastic and allows for any FDM or FFF 3D printer to be able to print with a wider range of plastics. In 2014, Benjamin S. Cook and Manos M. Tentzeris demonstrate the first multi-material, vertically integrated printed electronics additive manufacturing platform (VIPRE) which enabled 3D printing of functional electronics operating up to 40 GHz. The term "3D printing" originally referred to a process that deposits a binder material onto a powder bed with inkjet printer heads layer by layer. More recently, the popular vernacular has started using the term to encompass a wider variety of additive-manufacturing techniques such as electron-beam additive manufacturing and selective laser melting. The United States and global technical standards use the official term additive manufacturing for this broader sense. The most-commonly used 3D printing process (46% as of 2018) is a material extrusion technique called fused deposition modeling, or FDM.[4] While FDM technology was invented after the other two most popular technologies, stereolithography (SLA) and selective laser sintering (SLS), FDM is typically the most inexpensive of the three by a large margin, which lends to the popularity of the process.

General Principles:

Modeling:

3D printable knee joint implant



3D photo booth

3D printable models may be created with a computer-aided design (CAD) package, via a 3D scanner, or by a plain digital camera and photogrammetry software. 3D printed models created with CAD result in relatively fewer errors than other methods. Errors in 3D printable models can be identified and corrected before printing. The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting. 3D scanning is a process of collecting digital data on the shape and appearance of a real object, creating a digital model based on it.

CAD models can be saved in the stereolithography file format (STL), a de facto CAD file format for additive manufacturing that stores data based on triangulations of the surface of CAD models. STL is not tailored for additive manufacturing because it generates large file sizes of topology optimized parts and lattice structures due to the large number of surfaces involved. A newer CAD file format, the Additive Manufacturing File format (AMF) was introduced in 2011 to solve this problem. It stores information using curved triangulations.

Printing:

Before printing a 3D model from an STL file, it must first be examined for errors. Most CAD applications produce errors in output STL files, of the following types:

1. holes;
2. faces normals;
3. self-intersections;
4. noise shells;
5. manifold errors.

A step in the STL generation known as "repair" fixes such problems in the original model. Generally STLs that have been produced from a model obtained through 3D scanning often have more of these errors]as 3D scanning is often achieved by point to point acquisition/mapping. 3D reconstruction often includes errors.

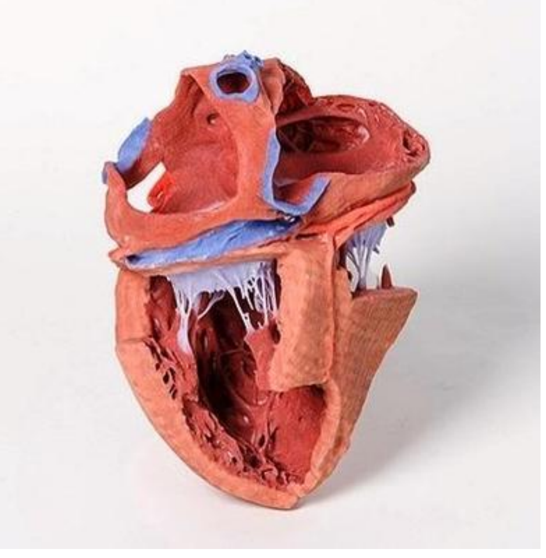
Once completed, the STL file needs to be processed by a piece of software called a "slicer," which converts the model into a series of thin layers and produces a G-code file containing instructions tailored to a specific type of 3D printer (FDM printers). This G-code file can then be printed with 3D printing client software (which loads the G-code, and uses it to instruct the 3D printer during the 3D printing process).

Printer resolution describes layer thickness and X–Y resolution in dots per inch (dpi) or micrometers (µm). Typical layer thickness is around 100 µm (250 DPI), although some machines can print layers as thin as 16 µm (1,600 DPI). X–Y resolution is comparable to that of laser printers. The particles (3D dots) are around 50 to 100 µm (510 to 250 DPI) in diameter. For that printer resolution, specifying a mesh resolution of 0.01–0.03 mm and a chord length ≤ 0.016 mm generate an optimal STL output file for a given model input file. Specifying higher resolution results in larger files without increase in print quality.

Construction of a model with contemporary methods can take anywhere from several hours to several days, depending on the method used and the size and complexity of the model. Additive systems can typically reduce this time to a few hours, although it varies widely depending on the type of machine used and the size and number of models being produced simultaneously.

Finishing:

Though the printer-produced resolution is sufficient for many applications, greater accuracy can be achieved by printing a slightly oversized version of the desired object in standard resolution and then removing material using a higher-resolution subtractive process. The layered structure of all Additive Manufacturing processes leads inevitably to a stair-stepping effect on part surfaces which are curved or tilted in respect to the building platform. The effects strongly depend on the orientation of a part surface inside the building process. Some printable polymers such as ABS, allow the surface finish to be smoothed and improved using chemical vapour processes based on acetone or similar solvents.



3D printed Heart Model

Some additive manufacturing techniques are capable of using multiple materials in the course of constructing parts. These techniques are able to print in multiple colors and color combinations simultaneously, and would not necessarily require painting. Some printing techniques require internal supports to be built for overhanging features during construction. These supports must be mechanically removed or dissolved upon completion of the print. All of the commercialized metal 3D printers involve cutting the metal component off the metal substrate after deposition. A new process for the GMAW 3D printing allows for substrate surface modifications to remove aluminium or steel.

Materials used for 3D printing:

Traditionally, 3D printing focused on polymers for printing, due to the ease of manufacturing and handling polymeric materials. However, the method has rapidly evolved to not only print various polymers but also metals and ceramics, making 3D printing a versatile option for manufacturing. Layer-by-layer fabrication of three-dimensional physical models is a modern concept that "stems from the ever-growing CAD industry, more specifically the solid modeling side of CAD. Before solid modeling was introduced in the late 1980s, three-dimensional models were created with wire frames and surfaces." but in all cases the layers of materials are controlled by the printer and the material properties. The three-dimensional material layer is controlled by deposition rate as set by the printer operator and stored in a computer file. The earliest printed patented material was a Hot melt type ink for printing patterns using a heated metal alloy.

A drawback of many existing 3D printing technologies is that they only allow one material to be printed at a time, limiting many potential applications which require the integration of different materials in the same object. Multi-material 3D printing solves this problem by allowing objects of complex and heterogeneous arrangements of materials to be manufactured using a single printer. Here, a material must be specified for each voxel (or 3D printing pixel element) inside the final object volume.

Type	Material
Composites	ABS, nylon (polyamide), polycarbonate, PP, epoxies, glass-filled polyamide, windform, polystyrene, polyester, and polyphenylesulfone
Metallic Materials	Plain carbon steel, tool steel, stainless steel, aluminum, copper, titanium, bronze, and nickel alumides
Bio-Compatible Materials	Polycaprolactone (PCL), polypropylene-tricalcium phosphate, (PP-TCP), PCL-hydroxyapatite (HA), polyetheretherketone-hydroxyapatite, (PEEK-HA), tetra calcium phosphate (TTCP), beta-tricalcium phosphate (TCP), and polymethyl methacrylate (PMMA)
Others	Sand, ceramics, elastomers, tungsten, wax, starch, and plaster

The process can be fraught with complications, however, due to the isolated and monolithic algorithms. Some commercial devices have sought to solve these issues, such as building a Spec2Fab translator, but the progress is still very limited. Nonetheless, in the medical industry, a concept of 3D printed pills and vaccines has been presented. With this new concept, multiple medications can be combined, which will decrease many risks. With more and more applications of multi-material 3D printing, the costs of daily life and high technology development will become inevitably lower. Metallographic materials of 3D printing is also being researched. By classifying each material, CIMP-3D can systematically perform 3D printing with multiple materials.

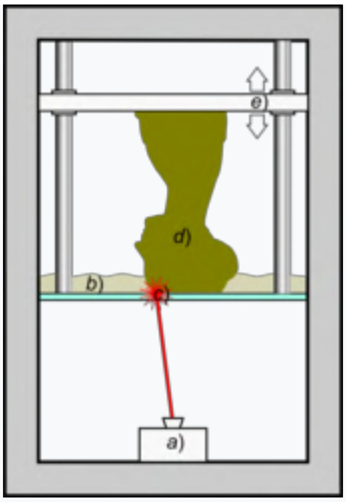
Processes & Printers:

There are many different branded additive manufacturing processes,that can be grouped into seven categories:

- Vat photopolymerization
- Material jetting
- Binder jetting
- Powder bed fusion
- Material extrusion
- Directed energy deposition
- Sheet lamination

- The main differences between processes are in the way layers are deposited to create parts and in the materials that are used. Each method has its own advantages and drawbacks, which is why some companies offer a choice of powder and polymer for the material used to build the object. Others sometimes use standard, off-the-shelf business paper as the build material to produce a durable prototype. The main considerations in choosing a machine are generally speed, costs of the 3D printer, of the printed prototype, choice and cost of the materials, and color capabilities. Printers that work directly with metals are generally expensive. However less expensive printers can be used to make a mold, which is then used to make metal parts.
- ISO/ASTM52900-15 defines seven categories of Additive Manufacturing (AM) processes within its meaning: binder jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination, and vat photopolymerization.
- The first process where three-dimensional material is deposited to form an object was done with Material Jetting or as it was originally called particle deposition. Particle deposition by inkjet first started with Continuous Inkjet technology (CIT) (1950's) and later with drop-On-Demand Inkjet technology.(1970's) using Hot-melt inks. Wax inks were the first three-dimensional materials jetted and later low temperature alloy metal was jetted with CIT. Wax and thermoplastic hot-melts were jetted next by DOD. Objects were very small and started with text characters and numerals for signage. An object must have form and can be handled. Wax characters tumbled off paper documents and inspired a Liquid Metal Recorder patent to make metal characters for signage in 1971. Thermoplastic color inks (CMYK) printed with layers of each color to form the first digitally formed layered objects in 1984. The idea of investment casting with Solid-Ink jetted images or patterns in 1984 led to the first patent to form articles from particle deposition in 1989, issued in 1992.
- Some methods melt or soften the material to produce the layers. In Fused filament fabrication, also known as Fused deposition modeling (FDM), the model or part is produced by extruding small beads or streams of material which harden immediately to form layers. A filament of thermoplastic, metal wire, or other material is fed into an extrusion nozzle head (3D printer extruder), which heats the material and turns the flow on and off. FDM is somewhat restricted in the variation of shapes that may be fabricated. Another technique fuses parts of the layer and then moves upward in the working area, adding another layer of granules and repeating the process until the piece has built up. This process uses the unfused media to support overhangs and thin walls in the part being produced, which reduces the need for temporary auxiliary supports for the piece. Recently, FFF/FDM has expanded to 3-D print directly from pellets to avoid the conversion to filament. This process is called fused particle fabrication (FPF) (or fused granular fabrication (FGF) and has the potential to use more recycled materials.
- Powder Bed Fusion techniques, or PBF, include several processes such as DMLS, SLS, SLM, MJF and EBM. Powder Bed Fusion processes can be used with an array of materials and their flexibility allows for geometrically complex structures, making it a go to choice for many 3D printing projects. These techniques include selective laser sintering, with both metals and polymers, and direct metal laser sintering. Selective laser melting does not use sintering for the fusion of powder granules but will completely melt the powder using a high-energy laser to create fully dense materials in a layer-wise method that has mechanical properties similar to those

of conventional manufactured metals. Electron beam melting is a similar type of additive manufacturing technology for metal parts (e.g. titanium alloys). EBM manufactures parts by melting metal powder layer by layer with an electron beam in a high vacuum. Another method consists of an inkjet 3D printing system, which creates the model one layer at a time by spreading a layer of powder (plaster, or resins) and printing a binder in the cross-section of the part using an inkjet-like process.
With laminated object manufacturing, thin layers are cut to shape and joined together. In addition to the previously mentioned methods, HP has developed the Multi Jet Fusion (MJF) which is a powder base technique, though no laser are involved. An inkjet array applies fusing and detailing agents which are then combined by heating to create a solid layer.



- Schematic representation of Stereolithography; a light-emitting device *a)* (laser or DLP) selectively illuminate the transparent bottom *c)* of a tank *b)* filled with a liquid photo-polymerizing resin; the solidified resin *d)* is progressively dragged up by a lifting platform

- Other methods cure liquid materials using different sophisticated technologies, such as stereolithography. Photopolymerization is primarily used in stereolithography to produce a solid part from a liquid. Inkjet printer systems like the *Objet PolyJet* system spray photopolymer materials onto a build tray in ultra-thin layers (between 16 and 30 µm) until the part is completed. Each photopolymer layer is cured with UV light after it is jetted, producing fully cured models that can be handled and used immediately, without post-curing. Ultra-small features can be made with the 3D micro-fabrication technique used in multiphoton photopolymerisation. Due to the nonlinear nature of photo excitation, the gel is cured to a solid only in the places where the laser was focused while the remaining gel is then washed away. Feature sizes of under 100 nm are easily produced, as well as complex structures with moving and interlocked parts. Yet another approach uses a synthetic resin that is solidified using LEDs.

- In Mask-image-projection-based stereolithography, a 3D digital model is sliced by a set of horizontal planes. Each slice is converted into a two-dimensional mask image. The mask image is then projected onto a photocurable liquid resin surface and light is projected onto the resin to cure it in the shape of the layer. Continuous liquid interface production begins with a pool of liquid photopolymer resin. Part of the pool bottom is transparent to ultraviolet light (the "window"), which causes the resin to solidify. The object rises slowly enough to allow resin to flow under and maintain contact with the bottom of the object. In powder-fed directed-energy deposition, a high-power laser is used to melt metal powder supplied to the focus of the laser beam. The powder fed directed energy process is similar to Selective Laser Sintering, but the metal powder is applied only where material is being added to the part at that moment.

- As of December 2017, additive manufacturing systems were on the market that ranged from $99 to $500,000 in price and were employed in industries including aerospace, architecture, automotive, defense, and medical replacements, among many others. For example, General Electric uses high-end 3D Printers to build parts for turbines. Many of these systems are used for rapid prototyping, before mass production methods are employed. Higher education has proven to be a major buyer of desktop and professional 3D printers which industry experts generally view as a positive indicator. Libraries around the world have also become locations to house smaller 3D printers for educational and community access. Several projects and companies are making efforts to develop affordable 3D printers for home desktop use. Much of this work has been driven by and targeted at DIY/Maker/enthusiast/early adopter communities, with additional ties to the academic and hacker communities.
- Computed axial lithography is a method for 3D printing based on computerised tomography scans to create prints in photo-curable resin. It was developed by a collaboration between the University of California, Berkeley with Lawrence Livermore National Laboratory. Unlike other methods of 3D printing it does not build models through depositing layers of material like fused deposition modelling and stereolithography, instead it creates objects using a series of 2D images projected onto a cylinder of resin. It is notable for its ability to build an object much more quickly than other methods using resins and the ability to embed objects within the prints.
- Liquid additive manufacturing (LAM) is a 3D printing technique which deposits a liquid or high viscose material (e.g. Liquid Silicone Rubber) onto a build surface to create an object which then is vulcanised using heat to harden the object. The process was originally created by Adrian Bowyer and was then built upon by German RepRap

Medical Applications for 3D printing:

3D printing has been applied in medicine since the early 2000s, when the technology was first used to make dental implants and custom prosthetics. Since then, the medical applications for 3D printing have evolved considerably. Recently published reviews describe the use of 3D printing to produce bones, ears, exoskeletons, windpipes, a jaw bone, eyeglasses, cell cultures, stem cells, blood vessels, vascular networks, tissues, and organs, as well as novel dosage forms and drug delivery devices. The current medical uses of 3D printing can be organized into several broad categories: tissue and organ fabrication; creating prosthetics, implants, and anatomical models; and pharmaceutical research concerning drug discovery, delivery, and dosage forms. A discussion of these medical applications follows:

Bio printing Tissues and Organs:

Tissue or organ failure due to aging, diseases, accidents, and birth defects is a critical medical problem. Current treatment for organ failure relies mostly on organ transplants from living or deceased donors. However, there is a chronic shortage of human organs available for transplant. In 2009, 154,324 patients in the U.S. were waiting for an organ. Only 27,996 of them (18%) received an organ transplant, and 8,863 (25 per day) died while on the waiting list.As of early 2014, approximately 120,000 people in the U.S. were awaiting an organ transplant. Organ transplant surgery and follow-up is also expensive, costing more than $300 billion in 2012. An additional problem is that organ transplantation involves the often difficult task of finding a donor who is a tissue match.[1] This problem could likely be eliminated by using cells taken from the organ transplant patient's own body to build a replacement organ. This would minimize the risk of tissue rejection, as well as the need to take lifelong immunosuppressants.

Therapies based on tissue engineering and regenerative medicine are being pursued as a potential solution for the organ donor shortage. The traditional tissue engineering strategy is to isolate stem cells from small tissue samples, mix them with growth factors, multiply them in the laboratory, and seed the cells onto scaffolds that direct cell proliferation and differentiation into functioning tissues. Although still in its infancy, 3D bioprinting offers additional important advantages beyond this traditional regenerative method (which essentially provides scaffold support alone), such as: highly precise cell placement and high digital control of speed, resolution, cell concentration, drop volume, and diameter of printed cells. Organ printing takes advantage of 3D printing technology to produce cells, biomaterials, and cell-laden biomaterials individually or in tandem, layer by layer, directly creating 3D tissue-like structures. Various materials are available to build the scaffolds, depending on the desired strength, porosity, and type of tissue, with hydrogels usually considered to be most suitable for producing soft tissues.

Although 3D bioprinting systems can be laser-based, inkjet-based, or extrusion-based, inkjet-based bioprinting is most common. This method deposits "bioink," droplets of living cells or biomaterials, onto a substrate according to digital instructions to reproduce human tissues or organs. Multiple printheads can be used to deposit different cell types (organ-specific, blood vessel, muscle cells), a necessary feature for fabricating whole heterocellular tissues and organs. A process for bioprinting organs has emerged: 1) create a blueprint of an organ with its vascular architecture; 2) generate a bioprinting process plan; 3) isolate stem cells; 4) differentiate the stem cells into organ-specific cells; 5) prepare bioink reservoirs with organ-specific cells, blood vessel cells, and support medium and load them into the printer; 6) bioprint; and 7) place the bioprinted organ in a bioreactor prior to transplantation. Laser printers have also been employed in the cell printing process, in which laser energy is used to excite the cells in a particular pattern, providing spatial control of the cellular environment.

Although tissue and organ bioprinting is still in its infancy, many studies have provided proof of concept. Researchers have used 3D printers to create a knee meniscus, heart valve, spinal disk, other types of cartilage and bone, and an artificial ear. Cui and colleagues applied inkjet 3D printing technology to repair human articular cartilage. Wang et al used 3D bioprinting technology to deposit different cells within various biocompatible hydrogels to produce an artificial liver. Doctors at the University of Michigan published a case study in the *New England Journal of Medicine* reporting that use of a 3D printer and CT images of a patient's airway enabled them to fabricate a precisely modeled, bioresorbable tracheal splint that was surgically implanted in a baby with tracheobronchomalacia. The baby recovered, and full resorption of the splint is expected to occur within three years.

A number of biotech companies have focused on creating tissues and organs for medical research. It may be possible to rapidly screen new potential therapeutic drugs on patient tissue, greatly cutting research costs and time. Scientists at Organovo are developing strips of printed liver tissue for this purpose; soon, they expect the material will be advanced enough to use in screening new drug treatments. Other researchers are working on techniques to grow complete human organs that can be used for screening purposes during drug discovery. An organ created from a patient's own stem cells could also be used to screen treatments to determine if a drug will be effective for that individual.

Challenges in Building 3D Vascularised Organs:

Proof-of-concept studies regarding bioprinting have been performed successfully, but the organs that have been produced are miniature and relatively simple. They are also often avascular, aneural, alymphatic, thin, or hollow, and are nourished by the diffusion from host vasculature. However, when the thickness of the engineered tissue exceeds 150–200 micro meters, it surpasses the limitation for oxygen diffusion between host and transplanted tissue. As a result, bioprinting complex 3D organs will require building precise multicellular structures with vascular network integration, which has not yet been done.

Most organs needed for transplantation are thick and complex, such as the kidney, liver, and heart.[11] Cells in these large organ structures cannot maintain their metabolic functions without vascularization, which is normally provided by blood vessels. Therefore, functional vasculature must be bioprinted into fabricated organs to supply the cells with oxygen/gas exchange, nutrients, growth factors, and waste-product removal—all of which are needed for maturation during perfusion. Although the conventional tissue engineering approach is not now capable of creating complex vascularized organs, bioprinting shows promise in resolving this critical limitation. The precise placement of multiple cell types is required to fabricate thick and complex organs, and for the simultaneous construction of the integrated vascular or microvascular system that is critical for these organs to function.

TIJ printers are considered to be the most promising for this use. However, various 3D printing techniques and materials have been applied successfully to create vasculature as simple as a single channel, as well as more complex geometries, such as bifurcated or branched channels. Recently, collaborators from a network of academic institutions, including the University of Sydney, Harvard University, Stanford University, and the Massachusetts Institute of Technology, announced that they had bioprinted a functional and perfusable network of capillaries, an achievement that represents a significant stride toward overcoming this problem.

Customized Implants and Prostheses:

Implants and prostheses can be made in nearly any imaginable geometry through the translation of x-ray, MRI, or CT scans into digital .stl 3D print files. In this way, 3D printing has been used successfully in the health care sector to make both standard and complex customized prosthetic limbs and surgical implants, sometimes within 24 hours. This approach has been used to fabricate dental, spinal, and hip implants. Previously, before implants could be used clinically, they had to be validated, which is very time-consuming.

The ability to quickly produce custom implants and prostheses solves a clear and persistent problem in orthopedics, where standard implants are often not sufficient for some patients, particularly in complex cases. Previously, surgeons had to perform bone graft surgeries or use scalpels and drills to modify implants by shaving pieces of metal and plastic to a desired shape, size, and fit. This is also true in neurosurgery: Skulls have irregular shapes, so it is hard to standardize a cranial implant. In victims of head injury, where bone is removed to give the brain room to swell, the cranial plate that is later fitted must be perfect. Although some plates are milled, more and more are created using 3D printers, which makes it much easier to customize the fit and design.

There have been many other commercial and clinical successes regarding the 3D printing of prostheses and implants. A research team at the BIOMED Research Institute in Belgium successfully implanted the first 3D-printed titanium mandibular prosthesis. The implant was made by using a laser to successively melt thin layers of titanium powders. In 2013, Oxford Performance Materials received FDA approval for a 3D-printed polyetherketoneketone (PEKK) skull implant, which was first successfully implanted that year. Another company, LayerWise, manufactures 3D-printed titanium orthopedic, maxillofacial, spinal, and dental implants. An anatomically correct 3D-printed prosthetic ear capable of detecting electromagnetic frequencies has been fabricated using silicon, chondrocytes, and silver nanoparticles. There is a growing trend toward making 3D-printed implants out of a variety of metals and polymers, and more recently implants have even been printed with live cells.

3D printing has already had a transformative effect on hearing aid manufacturing. Today, 99% of hearing aids that fit into the ear are custom-made using 3D printing. Everyone’s ear canal is shaped differently, and the use of 3D printing allows custom-shaped devices to be produced efficiently and cost-effectively. The introduction of customized 3D-printed hearing aids to the market was facilitated by the fact that class I medical devices for external use are subject to fewer regulatory restrictions. Invisalign braces are another successful commercial use of 3D printing, with 50,000 printed every day. These clear, removable, 3D-printed orthodontic braces are custom-made and unique to each user. This product provides a good example of how 3D printing can be used efficiently and profitably to make single, customized, complex items.

Anatomical Models for Surgical Preparation:

The individual variances and complexities of the human body make the use of 3D-printed models ideal for surgical preparation. Having a tangible model of a patient’s anatomy available for a physician to study or use to simulate surgery is preferable to relying solely on MRI or CT scans, which aren’t as instructive since they are viewed in 2D on a flat screen. The use of 3D-printed models for surgical training is also preferable to training on cadavers, which present problems with respect to availability and cost. Cadavers also often lack the appropriate pathology, so they provide more of a lesson in anatomy than a representation of a surgical patient.

Figure 4 Researchers at the National Library of Medicine generate digital files from clinical data, such as CT scans, that are used to make custom 3D-printed surgical and medical models.[12]

3D-printed neuroanatomical models can be particularly helpful to neurosurgeons by providing a representation of some of the most complicated structures in the human body .The intricate, sometimes obscured relationships between cranial nerves, vessels, cerebral structures, and skull architecture can be difficult to interpret based solely on radiographic 2D images. Even a small error in navigating this complex anatomy can have potentially devastating consequences. A realistic 3D model reflecting the relationship between a lesion and normal brain structures can be helpful in determining the safest surgical corridor and can also be useful for the neurosurgeon to rehearse challenging cases. Complex spinal deformities can also be studied better through the use of a 3D model. High-quality 3D anatomical models with the right pathology for training doctors in performing colonoscopies are also vital, since colorectal cancer is the second leading cause of cancer-related deaths in the U.S.

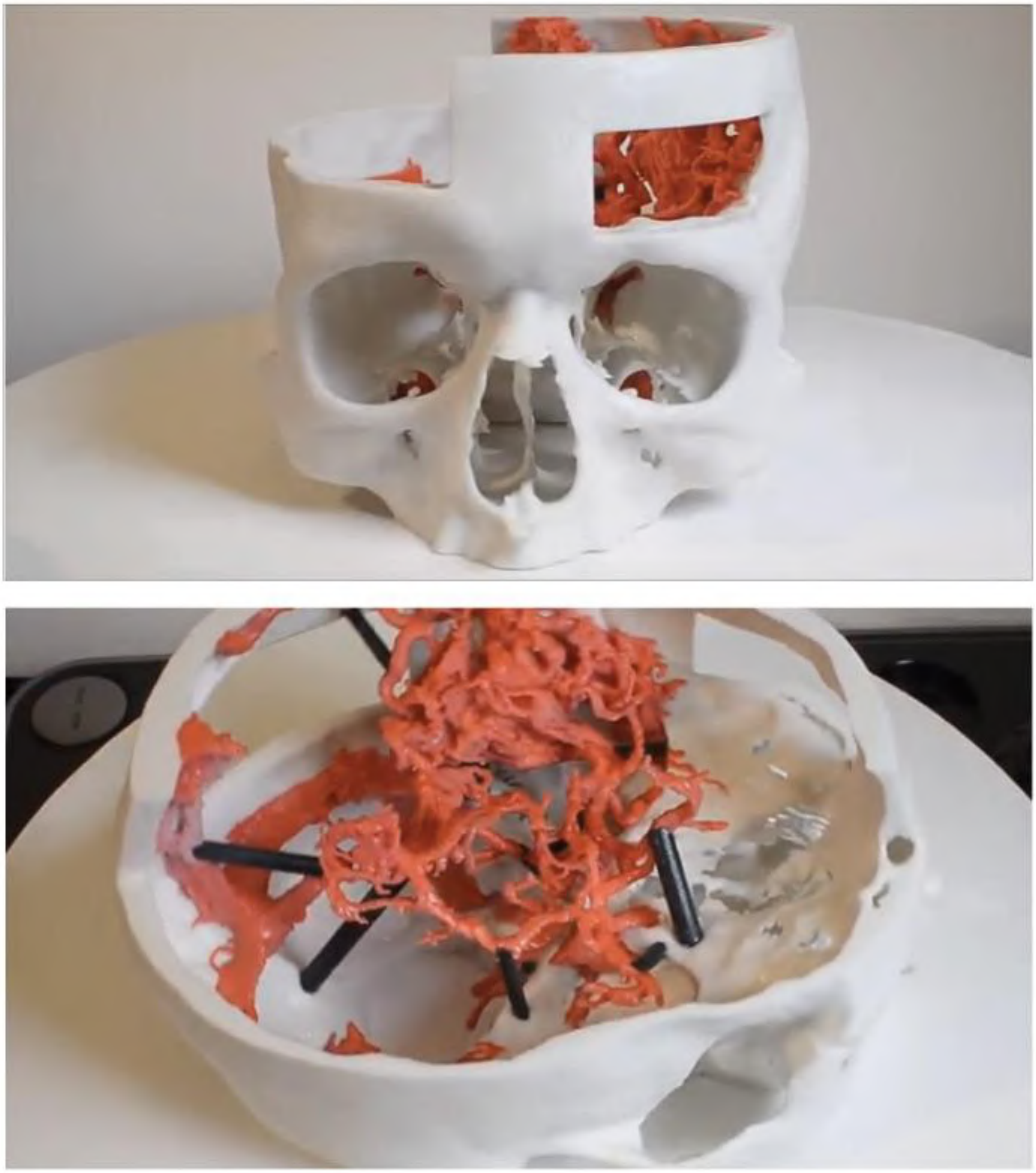


Figure 5 A 3D model used for surgical planning by neurosurgeons at the Walter Reed National Military Medical Center.[12]

3D-printed models can be useful beyond surgical planning. Recently, a polypeptide chain model was 3D printed in such a way that it could fold into secondary structures because of the inclusion of bond rotational barriers and degrees of freedom considerations. Similar models could be utilized to aid the understanding of other types of biological or biochemical structures. Pre- and post-comprehension study results have shown that students are better able to conceptualize molecular structures when such 3D models are used.

Health & Safety:

Emissions from fused filament printers can include a large number of ultrafine particles and volatile organic compounds (VOCs). The toxicity from emissions varies by source material due to differences in size, chemical properties, and quantity of emitted particles. Excessive exposure to VOCs can lead to irritation of the eyes, nose, and throat, headache, loss of coordination, and nausea and some of the chemical emissions of fused filament printers have also been linked to asthma. Based on animal studies, carbon nanotubes and carbon nanofibers sometimes used in fused filament printing can cause pulmonary effects including inflammation, granulomas, and pulmonary fibrosis when at the nanoparticle size. A National Institute for Occupational Safety and Health (NIOSH) study noted particle emissions from a fused filament peaked a few minutes after printing started and returned to baseline levels 100 minutes after printing ended. Workers may also inadvertently transport materials outside the workplace on their shoes, garments, and body, which may pose hazards for other members of the public.

Laser sintering and laser beam melting systems for additive manufacturing have become more important recently. The Institute for Occupational Safety and Health (IFA) together with German social accident insurance institutions conducted a measurement programme on inhalation exposure to hazardous substances during laser deposition welding and laser beam melting with alloyed steels and nickel-, aluminium- and titanium-based alloys.
No chromium(VI) compounds were detected in the workplace air during the process when materials containing chromium were processed, and the assessment criteria were complied with during processes with the other metal powders. One reason for this is that the machines are usually operated with encapsulation or dust extraction in order to achieve the required product quality. Since many work steps before and after the process including the handling of powder or powdered parts are performed manually or semi-automatically, there are huge effects on the degree of inhalation exposure and the measured values vary broadly. It is therefore difficult to derive tailored measures for these processes.
Carbon nanoparticle emissions and processes using powder metals are highly combustible and raise the risk of dust explosions. At least one case of severe injury was noted from an explosion involved in metal powders used for fused filament printing.

Hazard controls include using manufacturer-supplied covers and full enclosures, using proper ventilation, keeping workers away from the printer, using respirators, turning off the printer if it jammed, and using lower emission printers and filaments. Personal protective equipment has been found to be the least desirable control method with a recommendation that it only be used to add further protection in combination with approved emissions protection.

Future of 3D Printing:

4D printing:

4D printing has the potential to find new applications and uses for materials (plastics, composites, metals, etc.) and will create new alloys and composites that were not viable before. The versatility of this technology and materials can lead to advances in multiple fields of industry, including space, commercial and the medical field. The repeatability, precision, and material range for 4D printing must increase to allow the process to become more practical throughout these industries.

To become a viable industrial production option, there are a couple of challenges that 4D printing must overcome. The challenges of 4D printing include the fact that the microstructures of these printed smart materials must be close to or better than the parts obtained through traditional machining processes. New and customizable materials need to be developed that have the ability to consistently respond to varying external stimuli and change to their desired shape. There is also a need to design new software for the various technique types of 4D printing. The 4D printing software will need to take into consideration the base smart material, printing technique, and structural and geometric requirements of the design.

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Annexure II

VALUE ADDED COURSE

3D printing in Anatomy Education & its applications (code - AN100)

List of students Enrolled – September 2018

Sl. No.	Registration Number	Name of the Student	Signature
1	U18MB251	AASHLESHA DHARKAR	[signature]
2	U18MB252	ABINAYAVARTHINI N	[signature]
3	U18MB253	ADARSH KUMAR	[signature]
4	U18MB254	AISWARYA PREMRAJ	[signature]
5	U18MB255	AKSHAYA .R	[signature]
6	U18MB256	ALOK PANDA	[signature]
7	U18MB257	AMULYA N GOWDA	[signature]
8	U18MB258	ANINDA CHAKRABORTY	[signature]
9	U18MB259	ANJALI SADHWANI	[signature]
10	U18MB260	ANKU KUMAR	[signature]
11	U18MB261	ANNIE WELLY	[signature]
12	U18MB262	ANTONY ROHAN	[signature]
13	U18MB263	ANUPAMA	[signature]
14	U18MB264	AQSA QURESHI	[signature]
15	U18MB265	ARSHAD AMIN	[signature]
16	U18MB266	ASHIQUE RIFANA	[signature]
17	U18MB267	ASHWIN R	[signature]
18	U18MB268	ASHWINI.N	[signature]
19	U18MB269	ASMIT KESHAV	[signature]
20	U18MB270	AVIRAL TYAGI	[signature]

RESOURCE PERSONS

1. [signature]
2. [signature]
3. [signature]

COORDINATOR

[signature]

PROF & HOD OF ANATOMY
SRI LAKSHMI NARAYANA INSTITUTE OF MEDICAL SCIENCES
Usudu Agaram Village, Pondicherry-605 502

Annexure III

SRI LAKSHMI NARAYANA INSTITUE OF HIGHER EDUCATON AND RESEARCH

VALUE ADDED COURSES

3D PRINTING IN ANATOMY EDUCATION & ITS APPLICATIONS

Course Code: AN100

I. ANSWER ALL THE QUESTIONS (2 x 5 = 10 marks) **Duration – 30 minutes**

1. What is 3D printing
2. Mention the basic principles in 3d printing
3. List any 4 common material used in 3d printing
4. Name the types of 3d printers with is uses
5. Lists the applications of 3d anatomical models in medicine

1.10.2018. Value added Course – 3D Printing Aashlesha
U18MB251

8½/10
2/10/2018

1. What is 3D Printing?

Also called as additive Manufacturing. It is a process of making 3 dimensional solid objects from a digital file. Here an object is created by laying down successive layers of materials until the entire object is created.

2

2. Mention the basic Principles in 3d Printings?

The basic principles in 3d Printings are:

a) Modeling – 3D Printable models may be created with CAD package (or) other computer softwares.

b) Printing – 3D model is Printed from an STL file. Errors like holes, noise shells should be rectified before doing printing. The G-Code file can be printed with 3D printing client software.

1½

c) finishing – a slightly oversized version of object is achieved & then removing material using a higher resolution subtractive process.

3. List any 4 common materials used in 3D printing?

Nylon, polymethylmethacrylate,
ABS, polyester

2

1.10.2018 VALUE ADDED COURSE – 3D PRINTING. Asmit Keshav.
U18MB269.

9/10

2/10/2018

1. WHAT IS 3D PRINTING?

It is a process of making three dimensional objects (solid) from a digital file. This process is achieved by using additive processes. Here an object is created by laying down successive layers of materials until the whole object is created.

2

2. Mention the basic principles in 3d printing?

Basic Principles involved in 3d Printing are:

a) modeling b) printing c) Finishing.

1

3. List any 4 common materials used in 3D printing?

ABS, ceramics, polycarbonate, Aluminium.

2

4. Name the type of 3D printers & its uses?

a) Stereolithography (SLA) – models produced are with high levels of details, smooth surface & tight tolerances.

b) poly Jet – Here models are produced with multiple properties like colors & materials.

c) Selective Laser Sintering (SLS) – models are made from real thermoplastic material, they are durable, suitable for functional testing, and can support living hinges & snap-fits.

2

Annexure 5

Student Feedback Form

Course Name: 3D printing in Anatomy Education & its applications

Subject Code: AN100

Name of Student: Adarsh kumar **Roll No.:** U18MB253

We are constantly looking to improve our classes and deliver the best training to you.

Your evaluations, comments and suggestions will help us to improve our performance:

Sl. No.	Particulars	1	2	3	4	5
1	Objective of the course is clear					✓
2	Course contents met with your expectations					✓
3	Lecturer sequence was well planned					✓
4	Lectures were clear and easy to understand					✓
5	Teaching aids were effective					✓
6	Instructors encourage interaction and were helpful					✓
7	The level of the course					✓
8	Overall rating of the course	1	2	3	4	5 ✓

** Rating: 5 – Outstanding; 4 - Excellent; 3 – Good; 2– Satisfactory; 1 - Not-Satisfactory*

Suggestions if any:

Very informative session. Looking forward for new such courses.

Signature of Student

Date: 29.9.2018

Annexure 5

Student Feedback Form

Course Name: 3D printing in Anatomy Education & its applications

Subject Code: AN100

Name of Student: Anupama **Roll No.:** U18MB263

We are constantly looking to improve our classes and deliver the best training to you.

Your evaluations, comments and suggestions will help us to improve our performance:

Sl. No.	Particulars	1	2	3	4	5
1	Objective of the course is clear					✓
2	Course contents met with your expectations					✓
3	Lecturer sequence was well planned					✓
4	Lectures were clear and easy to understand					✓
5	Teaching aids were effective					✓
6	Instructors encourage interaction and were helpful					✓
7	The level of the course					✓
8	Overall rating of the course	1	2	3	4	5 ✓

** Rating: 5 – Outstanding; 4 - Excellent; 3 – Good; 2– Satisfactory; 1 - Not-Satisfactory*

Suggestions if any:

–

Anupama
Signature of Student
Date: 29.9.2018

Date: 03-10-2018

From

Dr. Somasekar I Tolanur
Professor and Head,
Department of Anatomy,
Sri Lakshmi Narayana Institute of Medical Sciences,
(BIHER University),
Puducherry - 2.

To

The Dean,
Sri Lakshmi Narayana Institute of Medical Sciences,
(BIHER University),
Puducherry - 2.

Sub: Completion of value-added course: 3D Printing in Anatomy Education & its Applications – Reg.

Dear Sir,

With reference to the subject mentioned above, the Department of Anatomy has conducted the value-added course on **3D printing in Anatomy Education & its Applications** during September 2018 for 1st year MBBS Students (2018-2019 Batch). We solicit your kind action to send certificates for the participants whose list is attached with this letter. Also I am attaching the photographs captured during the conduct of the course.

Kind Regards,

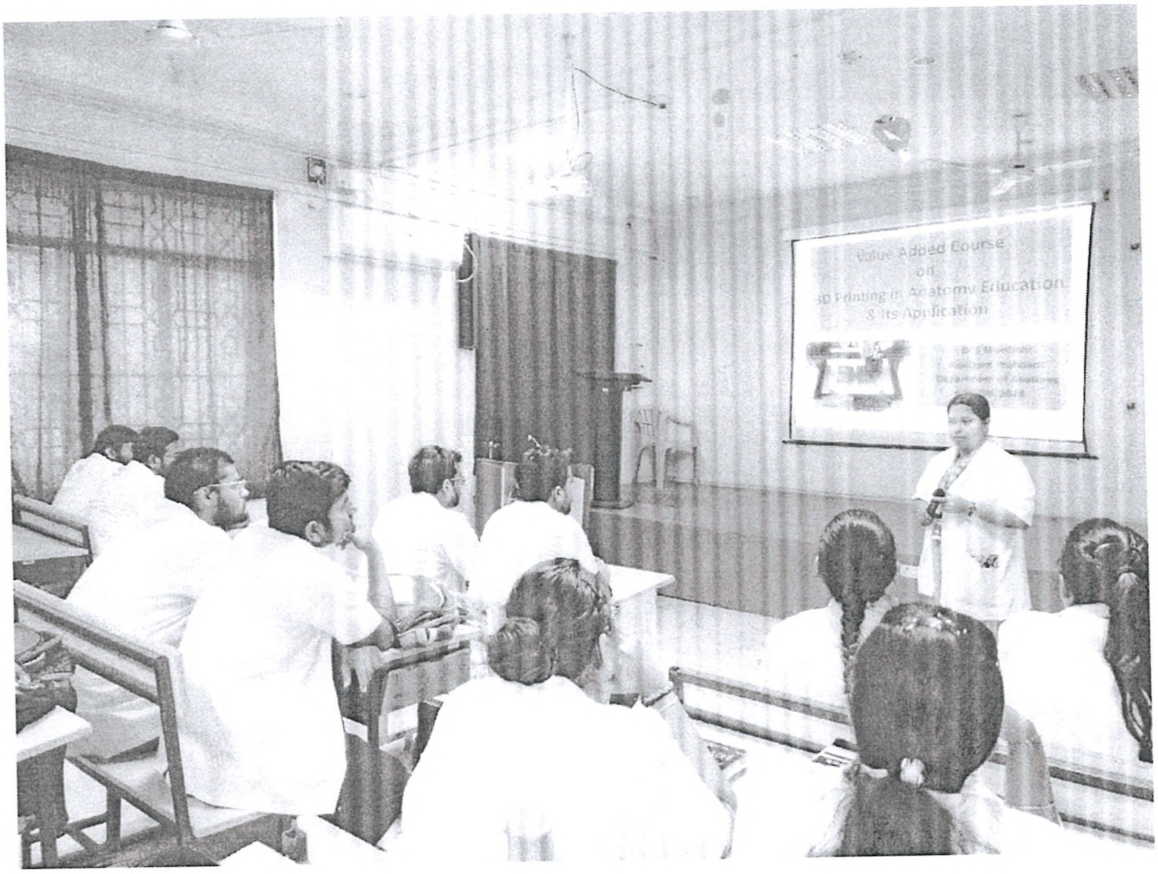
PROF & HOD OF ANATOMY
SRI LAKSHMI NARAYANA INSTITUTE OF
MEDICAL SCIENCES
Osudu Agaram Village, Pondicherry-605 502

Encl: Participants List

Photograph

LIST OF PARTICIPANTS

Sl. No.	Registration Number	Name of the Student
1	U18MB251	AASHLESHA DHARKAR
2	U18MB252	ABINAYAVARTHINI N
3	U18MB253	ADARSH KUMAR
4	U18MB254	AISWARYA PREMRAJ
5	U18MB255	AKSHAYA .R
6	U18MB256	ALOK PANDA
7	U18MB257	AMULYA N GOWDA
8	U18MB258	ANINDA CHAKRABORTY
9	U18MB259	ANJALI SADHWANI
10	U18MB260	ANKU KUMAR
11	U18MB261	ANNIE WELLY
12	U18MB262	ANTONY ROHAN
13	U18MB263	ANUPAMA
14	U18MB264	AQSA QURESHI
15	U18MB265	ARSHAD AMIN
16	U18MB266	ASHIQUE RIFANA
17	U18MB267	ASHWIN R
18	U18MB268	ASHWINI.N
19	U18MB269	ASMIT KESHAV
20	U18MB270	AVIRAL TYAGI


Value Added Course
on
3D Printing in Anatomy Education
& its Application

Sri Lakshmi Narayana Institute of Medical Sciences

Affiliated to Bharath Institute of Higher Education & Research
(Deemed to be University under section 3 of the UGC Act 1956)

CERTIFICATE OF MERIT

This is to certify that ABINAYAVARTHINI N has actively participated in the Value Added Course on **3D Printing in Anatomy Education & its Applications** held during September 2018 Organized by Department of Anatomy, Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry- 605 502, India.

Dr. S Shanthini Resource person	Dr. B Anitha Resource person	Dr. B Rajesh Resource person	Dr. Somasekar I Tolanur Co-ordinator	Dr. G Jayalakshmi Dean
			PROF & HOD OF ANATOMY SRI LAKSHMI NARAYANA INSTITUTE OF MEDICAL SCIENCES Osudu Agaram Village, Pondicherry-605 502	Dr. G. JAYALAKSHMI, BSc., MBBS., DTCD., M.D., DEAN Sri Lakshmi Narayana Institute of Medical Sciences Osudu, Agaram, Kudapakkam Post, Villianur Commune, Puducherry-605502.

Sri Lakshmi Narayana Institute of Medical Sciences

Affiliated to Bharath Institute of Higher Education & Research
(Deemed to be University under section 3 of the UGC Act 1956)

CERTIFICATE OF MERIT

This is to certify that ANTONY ROHAN has actively participated in the Value Added Course on **3D Printing in Anatomy Education & its Applications** held during September 2018 Organized by Department of Anatomy, Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry- 605 502, India.

Dr. S Shanthini Resource person	Dr. B Anitha Resource person	Dr. B Rajesh Resource person	Dr. Somasekar I Tolanur Co-ordinator	Dr. G Jayalakshmi Dean

PROF & HOD OF ANATOMY
SRI LAKSHMI NARAYANA INSTITUTE OF MEDICAL SCIENCES
Osudu Agaram Village, Pondicherry-605 502

Dr. G. JAYALAKSHMI, BSC., MBBS., DTCD., M.D.,
DEAN
Sri Lakshmi Narayana Institute of Medical Sciences
Osudu, Agaram, Kudapakkam Post,
Villianur Commune, Puducherry-605502.