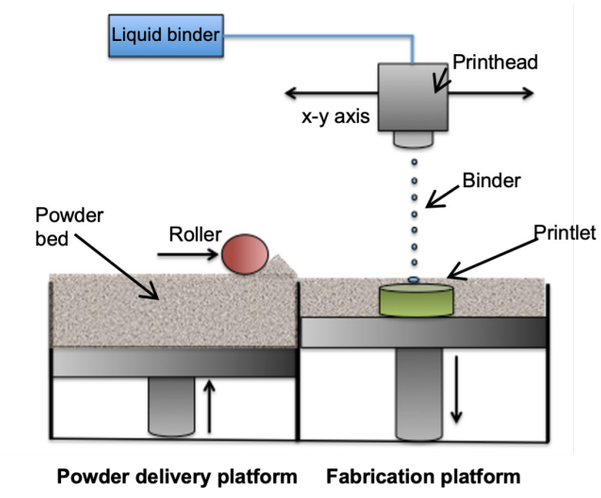
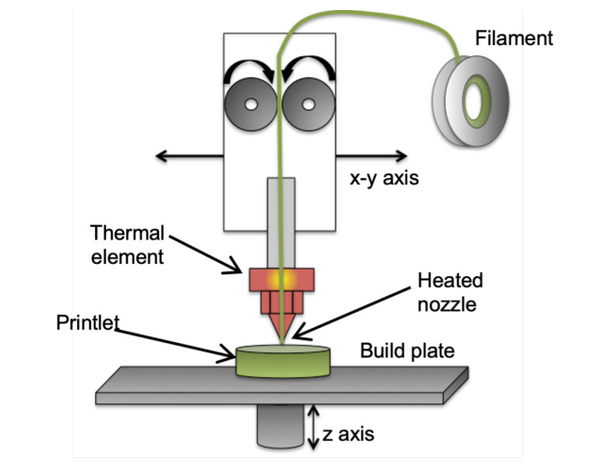
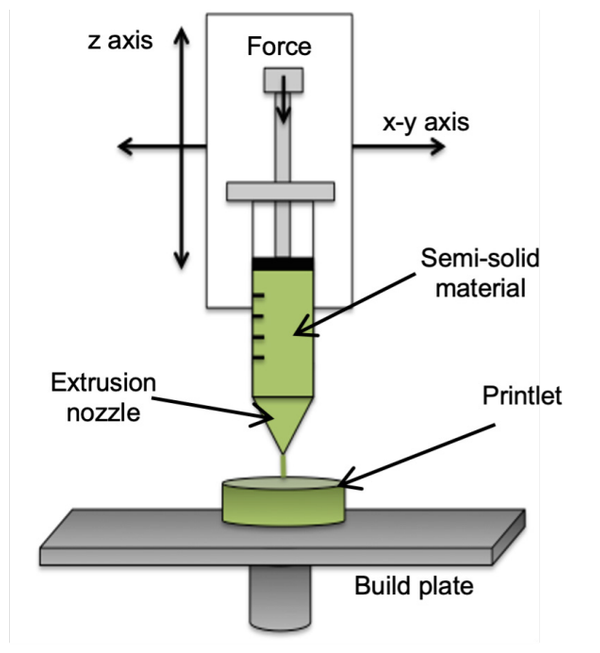
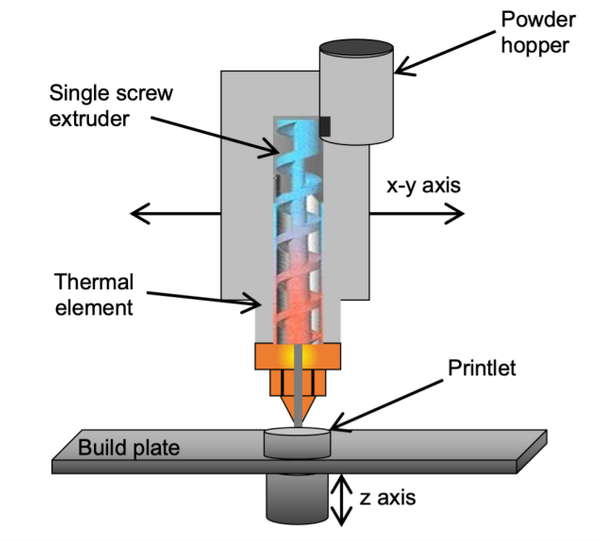
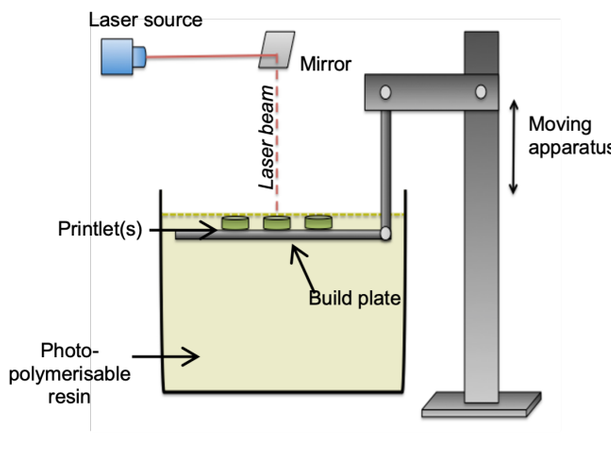
3D printer	Mode of action	Advantages	Disadvantages	Schematic
Binder jet printing	A nozzle containing a binder liquid moves along an x–y axis depositing the liquid onto a flat powder surface. The liquid binds the powder particles together, causing layer solidification. The fabrication build plate is then moved down along the vertical z–axis. A thin powder layer is distributed on top and the process is repeated sequentially to fabricate a 3D–printed medicine	• Capable of producing delayed release and zero order release (a drug released at a constant rate) formulations; • Used to develop the world's first US Food and Drug Administration (FDA)–approved 3D printed medicine; • Capable of producing immediate– and sustained–release formulations; • High resolution enables the formation of complex geometries.	• Expensive process; • Lack of portable equipment.	
Fused deposition modelling	A drug–loaded filament is extruded through a heated nozzle. The printer head is moved along the x–y axis to release the molten extrudate, which solidifies at room temperature onto a build plate. The build plate is sequentially lowered along the vertical z–axis to enable a layer–by–layer fabrication of a 3D–printed medicine	• Capable of producing immediate and sustained–release formulations; • Can improve solubility of poorly soluble drugs (by producing amorphous solid dispersions); • Ability for multi–nozzle printing (production of multi–drug combinations); • Cheap system; • Portable, compact and user friendly.	• May be unsuitable for thermosensitive drugs; • Can be challenging to formulate the initial filament feedstock; • Challenging to scale up; • Low drug loading.	
Semi–solid extrusion	A drug–loaded semi–solid material (e.g. gel or paste) is extruded using a syringe–based tool head. The printer head is moved along the x–y–z axis to release the extrudate, which solidifies at room temperature onto a build plate	• Suitable for production of chewable and palatable formulations; • Capable of producing a range of formulation types, including immediate–release and controlled–release dosage forms, polypills and oral films.	• Low resolution compared to other 3D printing technologies; • Only suitable for drugs that can be formulated as a semi–solid; • Low throughput.	
Direct powder extrusion	An extrusion–based process, a drug–loaded formulation blend is inserted into a powder hopper. The hopper feeds into a heated single screw extruder in the print head, creating a molten extrudate, which solidifies at room temperature onto a build plate. The build plate is sequentially lowered along the vertical z–axis to enable a layer–by–layer fabrication of a 3D–printed medicine	• Capable of producing immediate– and sustained–release formulations • Can improve solubility of poorly soluble drugs (by producing amorphous solid dispersions); • Capable for scale up (demonstrated by Triastek, which developed a FDA investigational new drug application clearance for a formulation prepared using a similar technology).	• May be unsuitable for thermosensitive drugs; • Relatively new 3D printing technology in pharmaceuticals.	
Stereo–lithography	The process involves exposing a photopolymerisable resin to high–energy light (e.g. UV light) to induce polymerisation and solidification of the material. Each time, the resin is solidified to a defined depth, the platform is moved down vertically along the z–axis and the built layer is recoated with resin. The process is repeated to create a 3D–printed medicine	• Widely explored for the production of sustained–release drug products and medical devices; • High resolution and accuracy (superior to other 3D printing technologies) enabling the production of complex geometries; • Can improve solubility of poorly soluble drugs; • Suitable for the production of multi–layered polypills.	• May be unsuitable for photosensitive drugs; • Potential issues around material toxicity.	
Selective laser sintering	This process employs a laser that is directed to draw a specific pattern on the powder bed, causing selective partial or full melting to bind powder particles. Once the layer is sintered, a roller distributes a fresh layer of powder on top of the sintered material. The process is repeated layer–by–layer to fabricate a 3D–printed medicine	• Capable of forming highly porous dosage forms (rapidly dissolving); • Capable of producing a range of formulation types, including immediate–release through to controlled–release dosage forms and medical devices; • High resolution process enabling the production of complex geometries; • Suitable for the production of polypills.	• May be unsuitable for photosensitive and thermosensitive drugs; • Requires precise control over powder flow characteristics; • Post–processing required.