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Three-Dimensional Printing of Complex Structures by Freeform Reversible Embedding of Suspended Hydrogels (FRESH)[1]

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We demonstrate the additive manufacturing of complex three-dimensional (3D) structures using soft protein and polysaccharide hydrogels that are challenging or impossible to create using traditional fabrication approaches. These structures are built by embedding the printed hydrogel within a secondary hydrogel that serves as a temporary, thermoreversible, and biocompatible support. This process, termed freeform reversible embedding of suspended hydrogels (FRESH), enables 3D printing of hydrated materials with an elastic modulus less than 500 kPa including alginate, collagen, hyaluronic acid and fibrin. A range of crosslinking mechanisms can be used depending on the polymer being printed, including ionic, enzymatic, pH, thermal and light based approaches. CAD models of 3D optical, computed tomography, and magnetic resonance imaging data can be 3D printed at a resolution of 100 μm and at low cost by leveraging open-source hardware and software tools. Proof-of-concept structures based on femurs, branched coronary arteries, trabeculated embryonic hearts, and human brains are mechanically robust and recreate complex 3D internal and external anatomical architectures. Recent advances have improved the resolution and broadened the range of materials that can be FRESH 3D printed.

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