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Top 10 Keywords by Degree Centrality:

[(' engineered living materials', 0.35220125786163525), (' Engineered living materials', 0.17138364779874216), (' synthetic biology', 0.12578616352201258), ('3D printing', 0.09905660377358491), (' Synthetic biology', 0.059748427672955975), ('engineered living materials', 0.05660377358490566), (' living materials', 0.05188679245283019), (' Engineered living material', 0.04716981132075472), (' Biomaterials', 0.04245283018867925), ('additive manufacturing', 0.04088050314465409)]

Top 10 Keywords by Closeness Centrality:

[(' engineered living materials', 0.4292806320980951), ('3D printing', 0.4169083518716871), ('3D bioprinting', 0.3803665839785512), (' synthetic biology', 0.3800637443416256), ('Bioprinting', 0.3655130650023597), (' Saccharomyces cerevisiae', 0.35677134745372324), (' Engineered living materials', 0.35465086396217066), (' bacterial cellulose', 0.3486925222009363), (' optogenetics', 0.3426848979849833), (' sustainability', 0.3409714734950584)]

Top 10 Keywords by Betweenness Centrality:

[(' engineered living materials', 0.39839950981422084), (' Engineered living materials', 0.2475319028067859), ('3D printing', 0.22002536003716167), (' synthetic biology', 0.11390620405183463), ('3D bioprinting', 0.08042063593303439), ('engineered living materials', 0.05489986038381514), ('Bioprinting', 0.05127145349317797), (' Synthetic biology', 0.04991149038824103), (' Engineered living material', 0.046407726670540723), (' Saccharomyces cerevisiae', 0.040998047937533574)]

Cluster 0: ['biomanufacturing', ' biomass', ' bread waste', ' degradable polymers', ' shape change']

Cluster 1: [' engineered living materials', 'bacteria', ' growth', ' materials', ' nonlinear dynamics', ' synthetic biology', ' living materials', '3D bioprinting', 'engineered living materials', ' materials science', ' biofilms', ' cellulose', ' curli fibers', ' disinfectant resistance', 'bioengineering', ' cell engineering', 'bacterial cellulose', ' curli nanofibers', 'DLP printing', ' printed living materials', ' volumetric printing', ' hybrid living materials', ' taxonomy', 'biofilms', ' extracellular electron transfer', ' genetic circuits', ' living electronic sensor', 'engineered living hydrogels', ' microbe-material interactions', ' real-world applications', 'anisotropicity', ' bacterial cellulose', ' structural hierarchy', ' three-dimensional patterning', ' functional application', 'genetic engineering', ' protein', ' self-assembly', 'biodiagnostic', ' biotherapeutics', ' multiplex diseases', ' synthetic live therapy', 'antibacterial materials', ' metabolism', ' photodynamic therapy', ' wound healing', ' biosensors', 'biomaterial', ' Caulobacter', ' quantum dots', ' RsaA', 'biomaterials', ' smart materials', 'amyloid proteins', ' bacterial biofilms', ' living cellular glues', ' MAP4: Demonstrate', ' underwater adhesives', ' growth instability', ' living matter', ' morphogenesis', 'bioactive derivatives', ' disease therapy', ' mammalian cells', ' microorganisms', ' mycelium', ' soft material', ' viscoelastic hydrogel', ' wrinkling', 'bioinspired coating system', ' bioreceptivity of building materials', ' early fungal colonisers', '4D printing', ' microbial synthesis', ' responsive polymers', 'additive manufacturing', ' bioaugmentation', ' engineering living materials', ' mass transfer', ' water purification', 'bioremediation', ' cyanobacteria', ' heavy metals', ' metal chelators', ' mechanical stresses', ' microfluidics', ' porous materials', ' MAP 3: Understanding', ' prediction', ' synthetic adhesin', ' tuning', 'disgust', ' social acceptance of materials', ' yuck factor', ' functional materials', 'adaptive materials', ' programmable materials', ' direct ink writing', ' living sensors', ' biomimetic', ' bone', ' biocomposites', ' microbial biosynthesis', 'composites', ' mechanical properties', ' structural ELMs', ' structural materials', 'biohybrid materials', ' carbon', ' smart', 'elastin-like polypeptide (ELP)', ' microstructure', ' protein matrix', ' rheological properties', ' bioreactor', ' bioelectric signaling', ' bioinspired materials', ' mycelium-based composites', ' magnetic actuator', ' biotic–abiotic interfaces', ' exoelectrogens', ' living bioelectrodes', ' redox-active materials', ' regenerative Medicine', ' thermal control', ' bioink', ' fungi', ' living hybrid materials', ' biomaterial', ' Komagataeibacter', 'bioglass', ' photonic nanojets', ' silicatein', ' ethics', 'division of labor', ' microbial consortia', ' synthetic biology toolkits', ' graphene-based nanostructures', ' living graphene hydrogels', ' smart living materials', 'alginate', ' lactobacillus', ' secretion', ' ethical principles', ' societal aspects', ' living biosensors', ' multiplexed detection', ' smartphone-based detection device', 'bio-sensing', ' scaffolds', 'Bacillus subtilis', ' bacterial spore', 'biomineralization', ' fungal mycelium', ' microbially induced calcium carbonate precipitation', ' medicine', ' tissue engineering', 'amidase', 'BES', ' DNA materials', ' S. oneidensis']

Cluster 10: ['Engineered living materials (ELMs)', ' Living composites', ' Multicellular consortia', ' Responsive materials', ' Synthetic biology', ' Protein engineering', ' Engineered living materials', ' Biopolymers', ' Bacteria', ' Scaffold', '3D-bioprinting', ' Bioink', ' Pluronic F-127', 'Biomaterials', ' Construction', ' Energy', ' Engineering', ' Materials science', ' Nanotechnology', 'Bioprinting', ' Biosensors', ' Engineered bacteria', 'Bacteria', ' Cell delivery', ' Hydrogels', ' Shape change', 'Bioinspired material', ' Mechanical property', ' Molecular engineering', ' Protein self-assembly', ' Bone', ' Electron microscopy', ' Tissue scaffolds', 'Cell encapsulation', ' Interactive materials', ' Metabolic engineering', ' Nanomaterials', ' Smart materials', ' Stimulus-responsive materials', 'Biofilms', ' SpyCatcher', ' SpyTag', ' Systems chemistry', ' Gene circuit', ' Living functional materials', 'Combinatorial pathway design', ' Metagenome', ' Transformation', '3D Bioprinting', ' Algae', ' Biotechnology', ' Microenvironmental analysis', ' Microorganisms', ' Plant cells', ' Real-time monitoring', ' Living therapeutics', 'Additive manufacturing', ' Biologically inspired materials', ' Sustainable composite materials', 'CRISPR gene Activation (CRISPRa)', ' ELM bioproduction', ' Input-responsive engineered living materials (ELMs)', ' Programmable bioproduction', 'Bacterial carrier', ' Bio-concrete', ' CaCO<sub>3</sub> precipitation', ' Microcrack healing', 'Biomineralization', ' Living building materials', ' Microbial-induced calcium carbonate precipitation', ' Self-healing', ' Calcium phosphate', ' Osteogenesis', 'Antibacterial', ' Photothermal bacteria', ' Protein hydrogel patch', ' Wound healing', ' Drug delivery', ' Targeted therapy', ' Carbon sequestration', ' Cyanobacteria', ' Sustainability', 'Agarose', ' Blue light', ' E. coli', 'Co-culture', 'Capillary microfluidics', ' LCD-SLA 3D printing', ' Stereolithography', 'Biodevices', ' Electrochemical manipulation', ' Insulin secretion', ' Membrane potential', ' PEDOT:PSS', 'Angiogenesis', ' Anti-inflammation', ' Nitric oxide', 'Bacterial cellulose', ' Bioreactor', ' Engineered living fabricator', ' Intermittent feeding', ' Komagataeibacter xylinus', ' Static culture', 'Biocompatibility', ' In vitro culture', ' Ceramics processing', ' Coagulation', ' Particles']

Cluster 3: ['controlled release', ' deoxyviolacein', ' metabolic engineering', ' biomaterials', 'bioproduction', ' hydrogels', ' lyophilization', ' shelf stability', ' trehalose', 'cell nanoencapsulation', ' enzymes', ' metal–organic complexes', ' nanofilms', ' supramolecular self-assembly', 'actuating', ' bioinks', ' bioprinting', ' bioreactors', ' double networks', ' polyNIPAM', ' shape changing', ' thermosensitive']

Cluster 4: [' optogenetics', 'Architecture', ' Biomaterials', ' Ceramics', ' DNA hydrogels', '3D printing', ' biofilm', ' electrospinning', ' ELMs', ' skin patches', ' Hydrogel', ' Microbially-induced calcium carbonate precipitation', ' Microgel', ' Mineralization', ' Additive manufacturing', ' Bio-ink', ' Bioprinting', ' Computer-aided design (CAD)', ' Computer-aided manufacturing (CAM)', ' Direct-write', ' Fused deposition modeling', ' Laser printing', ' Multiphoton lithography', ' Tissue engineering', ' chemical patterning', ' computer-aided design (CAD)', ' engineered living material (ELM)', 'Biohybrid constructs', ' Biomedicine', ' Cell engineering', ' Living materials', ' Tissue Engineering', ' actuation', ' sensing', ' stimuli-responsive', ' biophotonics', ' degradable waveguides', ' optical waveguides', 'Allergy', ' Biocompatibility', ' Biological performance', ' Dental materials', ' Toxicity', ' Agar', ' Mycelium', ' Sustainable development goals', ' Waste', ' Generalized model', ' Manufacturing theory', ' Self-assembly', ' Direct ink writing', ' Foraging behavior', ' Bioengineering', ' Polymers', ' Engineered Living Materials', ' Memristive Digital Twin', ' Memristor Oscillator', ' Biomedical application', ' Organic functional substance', 'angiogenesis', ' bacteria', ' growth factor', '3D Printing', ' Additive Manufacturing', ' Bioinks', ' Extrusion', ' Microbial Inks']

Cluster 5: ['Artificial extracellular matrix', ' Bioactive protein network', ' Protein hydrogel', ' Protein network', ' Biofilm', 'Caulobacter crescentus', ' Engineered living material', ' Extracellular matrix', ' Protein secretion', ' Surface layer protein', ' Surface structures', ' Type i secretion', 'Bacteria-materials interactions', ' Bacterial hydrogel', ' Biocontainment', ' Biosensor', 'B. subtilis biofilm', ' Green remediation', ' Heavy metal ions pollution', ' In-situ sensing', 'Aspergillus niger', ' Filamentous fungus', ' Genetic circuit', ' Melanin', 'Aureobasidium', ' Coating', ' Fungus', ' Wood protection', 'Bayesian optimization', ' Individual-based modeling', ' Metamaterials', ' Porous media']

Cluster 6: [' Saccharomyces cerevisiae', 'biofabrication', ' biohybrid materials', ' biological biofabrication', ' bioprogrammable materials', ' functionally graded biomaterials', ' manufacture of biological systems', 'biobased coatings', ' biocatalysis', ' catalase', ' cellular agriculture', ' cultured meat', ' engineered-living materials', ' organ-on-a-chip', ' regenerative medicine', 'bioprinting', ' drug delivery', ' supramolecular materials']

Cluster 7: [' biomineralization', 'biocement', ' living building materials', ' MICP', ' microbially induced carbonate precipitation', ' Synechococcus sp', ' three-dimensional printing']

Cluster 8: ['bacterial hydrogel', ' living material', ' protein release', 'curli fibers', ' hydrogel', ' mucoadhesive protein nanofibers', ' self-regenerating material', ' bacterial–materials interactions', ' cell encapsulation', ' dynamic hydrogel', ' engineered living material', 'block copolymer', ' dynamic covalent chemistry', ' engineered B. subtilis', 'bacterial growth', ' physical properties of hydrogel', ' polymeric film', ' CO<sub>2</sub> consumption', ' functional living surface', ' microalgae', ' spatial organization', 'blood−brain barrier', ' CCR4', ' CXCR4', ' glioblastoma', ' natural killer cell']

Cluster 9: ['bioinspiration', ' biomimicking', ' building materials', ' climate adaptations', ' sustainable architecture']

Cluster 11: ['Biofactories', ' Cellulose', ' Chitin', ' Collagen', ' Cross-linking', ' Decellularization', ' Electrospinning', ' Polyethylene', 'Bacteria encapsulation', ' Biomineralization', ' Calcium carbonate']

Cluster 12: ['Algae building technology', ' Biocementation', ' Engineered living materials (ELMs)', ' Living building materials (LBMs)', ' Living façades', ' Mycotecture', ' Self-healing materials', ' Soil stabilization']

Cluster 13: ['Biodesign', ' Biofabrication', ' Characterization', ' Engineered Living Materials (ELMs)', ' Engineered Plant Root Materials (EPRMs)', ' Growing Design', ' Natural Fiber Composites', ' Plant Roots', 'Adsorption', ' Heavy metal (loid)s', ' Nanohybrids', ' Phosphorylation', ' Surface display', ' Yeast cells']

Cluster 14: ['Ag43 autotransporter', ' engineering signal peptides', ' error-prone PCR', ' protein surface display', ' single-cell screening', 'disulfide engineering', ' self-healing materials', ' tunable mechanical properties']

Cluster 15: [' self-healing', 'adaptable', ' bioelectronics', ' biosensing', ' memory', ' programmable', ' self-powering', ' stimuli responsive', ' training', 'chlamydospores', ' mycelium materials', ' regeneration']

Cluster 16: ['E. coli Nissle 1917', ' engineered-living-materials (ELMs)', ' enzyme catalysis', ' flavonoid', ' pinocembrin', ' probiotic', ' PVA hydrogel']

Cluster 17: ['Engineered living materials', ' Glucose', ' Photosynthesis', ' Polymer network model', ' Self-strengthening', ' Near infrared stimulation', ' Photothermal nanocomposite', ' Surface plasmon resonance', ' Thermogenetics']

Cluster 18: ['cobalamin', ' material sciences', ' photoreceptor', ' protein engineering', ' protein modifications']

Cluster 19: ['artistry', ' interdisciplinary education', ' mycelium construction materials', ' sustainability', 'bioinspired materials', ' biomimetics', ' bio-augmentation', ' biocomposite', ' biodegradable', ' biomanufacturing', ' bioplastic', ' genetic programming', ' inducible bioproduction', ' MAP 6: Development']

Cluster 20: ['Engineered Living Materials', ' Microbial Bioengineering', ' Protein Biomaterials', ' Secretion', ' Silk Fibers', ' Interaction design', ' Living Artefacts', ' Softness']

Cluster 21: ['Cellular Automata', ' FPGA', ' Mycelium-based ELMs', ' Reaction-Diffusion', ' Reconfigurable Hardware', '2D and 3D Modeling', ' Cellular Automata']

Cluster 22: ['Bio-composites', ' Engineered', ' Fungi', ' Living', ' Material', ' Responsive', ' Self-repair']

Cluster 23: ['Bacillus', ' calcium carbonate', ' coatings', ' paint']

Cluster 24: ['drugs', ' imaging', ' microswimmers', ' Nanoparticles', ' targeting', ' theranostics']

Cluster 25: [' coaxial extrusion', ' direct ink printing', ' functional inks', ' perfusion', ' stimulus-responsive polymers']

Cluster 26: ['beating rate control', ' cardiomyocytes', ' Fuzzy logic', ' simulation environment', ' temperature']

Cluster 27: ['alternative life forms', ' future', ' multi-species', ' technological practices']

Cluster 28: ['ABU', ' ABU 83972', ' ELM', ' UPEC', ' uropathogens', ' UTI']

Cluster 29: ['Agriculture', ' Applications', ' Fermentation', ' Health', ' Industry', ' SCOBY']

Cluster 30: ['Bacillus subtilis biofilm', ' H1N1', ' H5N1', ' SARS-CoV-2', ' virus disinfection']

Cluster 31: ['abiotic/biotic interface', ' bioelectrochemical systems', ' conductive polymer hydrogels', ' electroactive bacteria', ' extracellular polymeric substances', ' gene expression']

Cluster 32: ['bacterial behavior control', ' bacterial migration', ' bacterial motility modulation', ' bacterial motility patterns', ' enhancing bacterial metabolites', ' EPS production']

Cluster 33: ['color-changing hydrogels', ' MAP 4: Demonstrate', ' pH-responsive hydrogels', ' proton flux', ' shape-changing hydrogels']

Cluster 34: ['bio-phosphor', ' hybrid light-emitting diodes', ' photon management', ' spheroplast']

Cluster 35: [' Ethical', ' Legal and societal implications', ' Living and non-living matter', ' Smart materials and structures']

Cluster 36: ['bio-energy device', ' engineered living energy materials', ' materials synthetic biology', ' miniaturized and portable bio-battery', ' nerve stimulation']

Cluster 2: [' genetic modification', ' living hydrogel', ' Microalgae', ' photosynthesis', ' stress responses']