EMERGENCE OF SYNTHETIC BIOLOGY: EXPECTATIONS, RESISTANCE AND LEGITIMATION

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by

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Dedicated to

Savitribai Phule, Mahatma Jyotiba Phule, Chhatrapati Shahu Maharaj,

and Dr. B. R. Ambedkar

CERTIFICATE

This is to certify that the thesis entitled "**Emergence of Synthetic Biology: Expectations, Resistance and Legitimation"** being submitted by **Mr. Mahendra D. Shahare** to the Department of Humanities and Social Sciences, Indian Institute of Technology Delhi, for the award of **Doctor of Philosophy,** is a record of the bonafide work carried by him under my supervision. In my opinion, the thesis has reached the standards of fulfilling the requirements for submission relating to the degree.

The contents of the thesis have not been submitted in part or full, to any other university or institute for the award of any degree or diploma.

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Abstract

Synthetic biology (SB) has mobilised the interest of a heterogeneous set of actors and has grown from a nascent-undertaking into a new research field. Its proponents espouse the vision to design and construct new and existing biological systems using multiple approaches for engineering biology at the molecular level. The sociology of expectations emphasises that S&T changes do not substantively pre-exist themselves but are rather constituted by the imaginings, expectations and visions. Herein I investigate the ways through which the dynamics of expectations contributed to the 'conditions of possibility' for the emergence of synthetic biology.

Employing a multi-methods, multi-sited research approach that draws and builds on STS scholarship, I examine three spaces of SB. First, I analyse the public-funded research institutions space of SB, through four different sites working on the development of biofuels, production of isoprenoids, treatment for Kala-azar, and a drug delivery mechanism for cancer therapeutics respectively. I thereby underscore how scientists sought to create *protected spaces* (viz. laboratory) for SB through *interlocking stories*, and the ways in which material practices within the laboratory contributed to *legitimation* of the new research field. Second, I analyse the corporate space of SB, through four different sites engaged in attempts at producing industrial bulk chemicals, biofuels, flavours and fragrances for the food industry, and GM mosquitoes for dengue control respectively. I thereby bring into sharp focus the enabling rhetoric of *bioeconomy*, specify how in practice resistance can foreclose or legitimise certain pathways over a period of time, as also denote the ways in which expectations evolve and become concretised around pathways that succeed in practice. Third, I analyse the amateur space of SB, through engagement with two sites – an iGEM team, and a Do-It-Yourself biology (DIY-bio) group. I thereby exhibit how SB practitioners, through their material practices, legitimised both promises and concerns about SB.

In analysing different spaces of SB, I situate SB between imagination and embodiment, discursivity and materiality. I suggest that synthetic biology is characterised by the *synthesis of alternative bio-materiality*. Furthermore, I suggest that the emergence of synthetic biology as a new research field has been shaped and legitimated by the dynamics of expectations through a triad of collective expectations, resistance, and bio-materiality. Moreover, through this study, I also extend the framework of sociology of expectations.

Keywords: Synthetic biology, sociology of expectations, science and technology studies (STS), policy studies, sociotechnical imaginaries, technoscientific futures.

सार

सिंथेटिक बायोलॉजी (एसबी) या कृत्रिम जीवविज्ञान ने विभिन्न लोगों के दिलचस्पी को कार्यप्रवृत्त किया है, और अब एक नवजात-उपक्रम से एक नए शोध क्षेत्र में विकसित हो चूका है। इसके प्रस्तावक एक नई दृष्टि का समर्थन करते हैं जो आणविक स्तर पर जीव अभियांत्रिकी के कई नवीनतम दृष्टिकोणों का उपयोग करके नए और मौजूदा जैविक प्रणालियों की रचना और निर्माण को बढ़ावा देता हैं। अपेक्षाओं का समाजशास्त्र इस बात पर जोर देता है कि वैज्ञानिक और तकनीकी परिवर्तन स्वयं पहले से मौजूद नहीं होता, बल्कि कल्पनाओं, अपेक्षाओं और दृष्टियों द्वारा गठित किए जाते हैं। इस शोध प्रबंध में, मैं उन तरीकों की जांच करता हूं जिनके माध्यम से अपेक्षाओं की गतिशीलता ने सिंथेटिक बायोलॉजी के उद्भव के लिए 'संभावना की स्थितियों' को बनाने में योगदान दिया।

एक बहु-विधियों, बहु-स्थलीय अनुसंधान दृष्टिकोण का इस्तेमाल करके, जो विज्ञान और प्रौद्योगिकी अध्ययन (एसटीएस) विद्वत्ता का आधार लेता हैं, मैं सिंथेटिक बायोलॉजी के तीन स्थानों की जांच करता हूं। सबसे पहले, मैं सिंथेटिक बायोलॉजी के सार्वजनिक वित्त पोषित अनुसंधान संस्थानों के स्थान का विश्लेषण क्रमशः चार विभिन्न स्थलों - जो जैव-ईंधन का विकास, आइसोप्रेनॉइड्स का उत्पादन, काला-अजार के लिए उपचार, और कैंसर चिकित्सा विज्ञान के लिए एक दवा वितरण तंत्र के विकास में जुटे हैं - के माध्यम से करता हूं। इस प्रकार से मैं इस बात को रेखांकित करता हूं कि कैसे वैज्ञानिकों ने अन्तर्ग्रथन (इंटरलॉकिंग) कहानियों के माध्यम से सिंथेटिक बायोलॉजी के लिए संरक्षित स्थान (अर्थात प्रयोगशाला) बनाने की कोशिश की, और किस तरह से प्रयोगशाला के भीतर की सामग्री तरीकों ने नए अनुसंधान क्षेत्र को वैध बनाने में योगदान दिया। दूसरा, मैं सिंथेटिक बायोलॉजी के कॉर्पोरेट स्थान का विश्लेषण क्रमशः चार विभिन्न स्थलों – जो औद्योगिक थोक रसायन, जैव ईंधन, खाद्य उद्योग के लिए स्वाद और सुगंध, और डेंगू नियंत्रण के लिए आनुवंशिक रूप से संशोधित (जीएम) मच्छरों के उत्पादन लिए के प्रयासरत हैं - के माध्यम से करता हूं। इस प्रकार मैं जैव अर्थव्यवस्था (बायोइकॉनॉमी) का शब्दाडंबरपूर्ण समर्थीकरण केंद्र-बिंदु में लाता हूं, निर्दिष्ट करता हूं कि कैसे व्यवहार में प्रतिरोध समय के साथ कुछ पथ प्रतिबंधित या वैध बना सकता हैं, और साथ ही किस तरह से अपेक्षाएं उत्क्रांत होकर व्यवहार में सफल पथ के इर्द गिर्द ठोस रूप लेती हैं इसको सूचित करता हूँ। तीसरा, मैं सिंथेटिक बायोलॉजी के शौकिया स्थान का विश्लेषण दो स्थलों - एक आईजीईएम टीम, और एक घरेलू (डू-इट-योरसेल्फ) बायोलॉजी समूह - के माध्यम से करता हूं। इस प्रकार मैं दिखाता हूँ कि कैसे सिंथेटिक बायोलॉजी अभ्यासियों ने अपनी सामग्री तरीकों से सिंथेटिक बायोलॉजी के वादों और चिंताओं दोनों को वैधता दी।

सिंथेटिक बायोलॉजी के विभिन्न स्थानों का विश्लेषण करके, मैं सिंथेटिक बायोलॉजी को कल्पना और मूर्त रूप, तार्किक और भौतिकता के बीच स्थापित करता हूं। मेरा सुझाव है कि *वैकल्पिक जैव-भौतिकता की कृत्रिम रचना* सिंथेटिक बायोलॉजी का वर्णन विशेष करता है। इसके अलावा, मेरा सुझाव है कि सिंथेटिक बायोलॉजी के एक नए अनुसंधान क्षेत्र के रूप में उद्भव को आकार और वैधता अपेक्षाओं की गतिशीलता ने दी हैं जिसमे सामूहिक अपेक्षाओं, प्रतिरोध, और जैव-भौतिकता की त्रय की भूमिका है। इसके अलावा, इस अध्ययन के माध्यम से, मैं अपेक्षाओं का समाजशास्त्र के ढांचे का भी विस्तार करता हूं।

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BIRAC	Biotechnology Industry Research Assistance Council
CSIR	Council of Scientific and Industrial Research
DBT	Department of Biotechnology
DIY-Bio	Do-It-Yourself Biology
DNA	Deoxyribonucleic Acid
ETC	Action Group on Erosion, Technology and Concentration
ELSI	Ethical, Legal, Social Implications
GM	Genetically Modified
HGP	Human Genome Project
ICGEB	International Centre for Genetic Engineering and Biotechnology
iGEM	International Genetically Engineered Machine Competition
IIT	Indian Institute of Technology
IISc	Indian Institute of Science Bangalore
IISER	Indian Institute of Science Education and Research
JNU	Jawaharlal Nehru University
KBBE	Knowledge-based Bio-economy
MIT	Massachusetts Institute of Technology
NCBS	National Centre for Biological Sciences Bengaluru
NCCS	National Centre for Cell Science Pune
NEST	New and Emerging Science and Technology
NVBDCP	National Vector Borne Disease Control Programme
OECD	Organization for Economic Cooperation and Development
RRI	Responsible Research and Innovation
SB	Synthetic Biology
SINP	Saha Institute of Nuclear Physics Kolkata