WP9. National Graduate School and Beyond: A Cross-Disciplinary Training Platform for Breakthrough Technologies for Health

Program Description

The graduate school of the Breakthrough Technologies for Health excellence cluster represents a fundamentally new model for doctoral and professional training in life science and precision medicine. Rather than functioning as a traditional, discipline-bound PhD program, it is conceived as a cross-disciplinary training platform whose ambition is to form a vibrant, integrated community of researchers, clinicians, innovators, and technology developers around the shared mission of accelerating breakthrough technologies into patient benefit. Realizing this mission demands a new generation of professionals who are fluent across disciplinary, sectoral, and national boundaries: scientists who understand both molecular mechanisms and clinical workflows, data analysts who grasp regulatory pathways, and clinician-researchers who can harness AI-enabled tools critically. No single university or research group can provide this breadth. The graduate school does, through a nationally coordinated, infrastructure-anchored program that is unique in Europe.

Overall Vision and Three-Pillar Architecture

The training platform is organized around three mutually reinforcing pillars that together constitute a coherent ecosystem of education:

1. **Doctoral excellence in breakthrough technologies.** A rigorous, interdisciplinary PhD-level curriculum that trains the next generation of researchers at the interface of synchrotron-based X-ray imaging, spatial multi-omics, AI-driven data science, and clinical translation. Doctoral students conduct research in internationally leading environments at host universities of SciLifeLab and MAX IV, undertake cross-sector secondments, and are exposed to the full translational value chain from technique development through clinical validation to healthcare implementation.

2. **Technology and AI literacy for clinical researchers.** A dedicated educational track providing clinical researchers, healthcare professionals, and research engineers with practical competence in breakthrough molecular technologies, advanced imaging, and AI/ML-based analytics. As precision medicine technologies enter clinical workflows at accelerating pace, Sweden's capacity for adoption and equitable implementation depends critically on a clinically trained workforce that understands both the potential and the limitations of these tools. Intensive short courses, workshops, and a structured expert lecture series will serve this audience on an ongoing basis.

3. **Innovation and translation education for all.** A suite of training activities focused on entrepreneurship, intellectual property strategy, regulatory science, health technology assessment, and implementation research. These offerings are open to PhD students, postdoctoral researchers, clinical investigators, and industry partners linked to the cluster, reflecting the conviction that translation is a team sport requiring shared language and shared competencies across all participants. This pillar directly embeds the Innovation Plan's ambition to transform Sweden's fragmented discovery pipeline into a nationally coordinated, parallel-track innovation ecosystem.

The three pillars are united by a commitment to open access: all courses, summer schools, and lecture series developed within the program will be made available to participants beyond the formally enrolled doctoral students, extending the cluster's educational impact across the Swedish and Nordic research and healthcare communities. This community of learners, extending from enrolled PhD students to postdoctoral researchers, clinical investigators, research engineers, and industry scientists, constitutes the vibrant professional network that the graduate school is designed to cultivate.

Planned Educational Activities

The program's educational activities span five interconnected formats, each designed to address distinct learning objectives (Table 1):

Annual Cluster Meetings (obligatory): Annual meetings will serve as the primary forum for community building, scientific exchange, and student visibility. Each meeting will include dedicated doctoral student sessions with oral presentations, poster discussions, and workshops led by PhD students and postdoctoral researchers alongside senior scientists, clinician-researchers, and industry representatives. These events reinforce the cluster's culture of interdisciplinary collaboration and provide students with repeated opportunities to communicate complex research across disciplinary audiences. PhD students should attend at least three of five annual meetings.

PhD Summer Schools (obligatory): Four thematic summer schools, whereof three are mandatory, each spanning approximately one week, will deliver intensive interdisciplinary training organized around the cluster's core scientific and translational themes. Themes will be drawn from areas including multiscale X-ray imaging and tissue characterization, spatial multi-omics and AI-driven disease modelling, clinical implementation and regulatory science, and AI literacy for life science and healthcare. Each summer school will combine lectures by national and international experts, hands-on methodological sessions, team-based scientific challenges, site visits to MAX IV and SciLifeLab facilities, and structured activities supporting transferable skills including scientific communication, leadership, and entrepreneurial thinking. A direct model for these events is the InfraLife Integrated Structural Biology course, which has demonstrated the strong and sustained demand for immersive, infrastructure-linked interdisciplinary training, combining Cryo-EM, NMR, structural proteomics, crystallography, SAXS/SANS, biophysical characterisation, and computational methods including AlphaFold, now running for a third consecutive edition.

Educational Activity	Format	Obligatory?	Open to Non-PhD Participants
Annual Cluster Meeting	yearly, 2–3 days	Yes, all students	Postdocs, industry
PhD Summer School (min. 3)	34x program, 5–7 days	Yes, (min 3) doctoral students	Postdocs, clinical researchers
Overview Courses (min. 3)	Block weeks, ~5 ECTS each	Yes (min. 3 courses)	All registered participants
Specialized Courses (min. 4)	Modules, 2–3 ECTS each	Yes (min. 6 ECTS)	All registered participants
Innovation Courses (min. 2)	Modules, 2–3 ECTS each	Yes (min. 4 ECTS)	All: industry, clinicians, postdocs
Expert Lecture Series	Rolling, ≥10 per year	Yes (10 lectures)	Open access, remote
Secondment	Min. 2 weeks, partner org.	Yes (1 minimum)	Postdocs (encouraged)
Peer Mentoring Program	Ongoing, yr 3–4 as mentors	Encouraged	N/A

Table 1. *Educational activities of the Breakthrough Technologies for Health Graduate School.*

PhD Courses (obligatory, minimum 15 ECTS): Students will complete a minimum of 15 ECTS in designated graduate school courses, comprising at least three interdisciplinary overview courses and a set of specialized and innovation-focused courses. Overview courses will survey breakthrough technologies (imaging, multi-omics, spatial biology, AI/ML, clinical data science) and their integration, providing students with a common conceptual map regardless of their disciplinary entry point. Specialized courses will enable deep practical training in specific technologies or methodological areas: examples include advanced phase-contrast X-ray imaging and data processing, cryo-EM data analysis and AI-based structure prediction, single-cell and spatial transcriptomics pipelines, GDPR and data governance in healthcare research, and regulatory pathways for in vitro diagnostic devices. Innovation-directed courses will cover IP strategy, health economics and HTA, clinical trial design, medical device regulation, and the commercialization of precision medicine technologies. All courses will be co-developed with the relevant SciLifeLab platforms, MAX IV beamline scientists, university hospitals, and industry partners to ensure currency, practical orientation, and career-relevant competency development.

Secondments (obligatory, minimum two weeks): The doctoral student will complete at least one secondment of at least two weeks at a partner organization outside their home institution: at a MAX IV beamline, a SciLifeLab platform facility, a university hospital partner or at an industry partner. Secondments provide hands-on access to technologies and working cultures that are otherwise unavailable within a single research environment and are expected to be formative experiences for the students' understanding of translational workflows and sector-specific needs.

Expert Lecture Series (ten lectures obligatory): A rolling lecture series featuring national and international speakers from research, healthcare, and industry will be hosted across participating

universities, research infrastructures, and hospitals, with remote access ensuring broad participation throughout Sweden's geographically distributed research environments. The series will regularly feature early-career researchers alongside established experts, deliberately modelling a culture in which emerging scientists contribute to the intellectual life of the field.

Recruitment Basis and Participant Community

The 24 doctoral students directly funded through the Research Plan will form the program's core cohort; they will be joined by all PhD students affiliated with the demonstrator projects teams (estimated 15–20 additional students) and by doctoral students from research groups associated with the cluster's work packages WP1–WP7. The total enrolled doctoral cohort is expected to reach approximately 50 students at steady state, with a deliberate maximum set to preserve the quality and interactivity of shared activities. Beyond the formally enrolled doctoral cohort, postdoctoral researchers, research engineers, clinical investigators, and industry-affiliated scientists linked to the cluster will be able to participate in the technology and AI literacy track and in the innovation education offerings. This community-building dimension, reaching well beyond doctoral students, is central to the program's mission and reflects the Innovation Plan's emphasis on systemic transformation of the translational ecosystem.

Organisation

Governance and Leadership: The graduate school operates under a dual governance structure with a coordination team from MAX IV and SciLifeLAB balancing operational agility with strategic oversight.

Coordination Team: The Graduate School will be coordinated by a dedicated Research School Coordinator, Marjolein Thunnissen, senior lecturer at MAX IV Laboratory, Lund University, who brings extensive experience in structural biology research and graduate education including leadership of the PRISMAS MSCA COFUND doctoral program. The coordinator is supported by an administrative team that includes an education and training coordinator at MAX IV and designated personnel from SciLifeLab. Together, the team manages course administration, logistics for summer schools and annual meetings, secondment coordination, communications, web presence, and engagement with external partners. The team serves as the primary point of contact for enrolled students, course organizers, partner institutions, and industrial collaborators.

Study Committee: Strategic governance of the graduate school is vested in a Study Committee composed of in total 7-8 representatives spanning the full breadth of the cluster's scientific and sectoral communities: faculty from partner universities covering WP1 (imaging technologies) and WP2 (spatial multi-omics and AI), and rotating representatives from the demonstrator projects, the SUHA university hospitals, industrial partners and the enrolled doctoral students. The Study Committee meets at minimum twice per year to review the course portfolio, evaluate secondment arrangements, assess student progress and wellbeing at the program level, and ensure that the educational offering remains aligned with emerging scientific, technological, and societal needs. The Study Committee reports to the cluster's Strategic Steering Board (WP10), integrating educational strategy into the cluster's broader innovation and implementation priorities.

Course Offerings, Development, and Quality Assurance: Courses will be selected through competitive open calls, in which academic staff, infrastructure scientists, and clinician-researchers affiliated with partner organizations are invited to propose and lead course modules. The open-call mechanism ensures that course content reflects the most current scientific and technological advances and actively engages the wider community of cluster-affiliated researchers. The coordination team provides administrative and logistical support for approved courses, while academic leadership and full responsibility for scientific content and pedagogical quality rest with the proposing course organizers. Courses are reviewed after each edition by a course evaluation sub-committee drawn from the Study Committee, and content is updated on a regular cycle to maintain relevance to the evolving precision medicine and AI landscape.

A formal program-wide evaluation process, including student feedback surveys, mid-program review meetings, and an annual report to the Study Committee, will provide continuous quality data. The Study Committee uses this data to adjust the portfolio, retire outdated offerings, and commission

new courses in emerging areas such as AI-enabled clinical decision support, multi-modal foundation models, and regulatory frameworks for software as a medical device.

Supervision, Examiner Roles, and Study Follow-Up: All enrolled doctoral students remain formally registered within the doctoral programs of their home universities, in full accordance with the Swedish Higher Education Ordinance (Högskoleförordningen). Each student has a principal supervisor and co-supervisors appointed through home institution procedures, and individual study plans (ISPs) are prepared and reviewed in accordance with local regulations. The graduate school complements but does not replace home university supervisory and examination structures.

The graduate school coordinator and the Study Committee maintain a program-level view of student progress, tracking participation in obligatory activities and facilitating support where needed. Students who fall behind in mandatory requirements are offered structured remedial plans before any formal institutional consequences are considered. Communication between the graduate school coordination team and home institution supervisors is maintained through standardized reporting templates and regular check-in calls, ensuring that graduate school monitoring is integrated with, not duplicated from, local institutional oversight.

An internal peer mentoring program, in which third- and fourth-year doctoral students serve as mentors for incoming cohorts, will support student integration, wellbeing, and navigation of the early PhD phase. This approach, well evidenced in interdisciplinary doctoral programs, accelerates the development of collaborative working relationships across cohorts and builds the culture of mutual support that is central to the graduate school's community-building mission.

Dimensioning and Bias-Free Recruitment: The enrolled doctoral cohort will be maintained between approximately 40 - 50 students at steady state, with a maximum of 50 to preserve the quality and interactivity of shared educational activities. PhD students are recruited through their respective employing universities and research groups, following each institution's established procedures, which under Swedish law already mandate equal-opportunity and non-discrimination principles under the Discrimination Act (Diskrimineringslagen) and the Higher Education Act (1). The graduate school will additionally require that all participating research groups publish positions internationally, use structured interview processes with diverse selection panels, and document recruitment decisions transparently.

The Study Committee will monitor gender balance, international composition, and disciplinary diversity across the enrolled cohort annually, flagging departures from targets to the Strategic Steering Board. A minimum target of 40 percent representation for any single gender within the enrolled cohort will be established, with active promotion of recruitment from underrepresented backgrounds across both STEM and medical disciplines. International candidates will be actively encouraged through promotion via EMBL, LEAPS, and MSCA networks, and all position announcements will be published in English through relevant European and global channels.

Significance

Building the Next Generation of Excellent Researchers and Innovators: Sweden's ability to maintain international leadership in precision medicine and life science innovation depends fundamentally on sustained investment in competence building and the training of future researchers and innovators. The graduate school of the Breakthrough Technologies for Health cluster directly addresses this need by training a new generation of professionals who are not merely technically proficient within a single discipline but are capable of operating at the interface of multiple fields and of driving the translation of scientific discoveries into clinical and commercial impact. This dual mandate, scientific excellence and translational competence, defines the program's distinctive national significance.

1. Creating a New Competence Profile for Life Science Leadership

The researchers and innovators who will define precision medicine in 2035 must command competencies that currently have no single academic home: for instance, they must understand synchrotron physics and histopathology; design AI models and interpret their outputs to clinical standards; or navigate regulatory approval pathways and health-economic evaluation while sustaining scientific rigor. The graduate school is explicitly designed to produce this competence

profile through its integration of technology, AI literacy, and innovation education within a shared doctoral training framework.

The program builds on Sweden's unique position as the host of both SciLifeLab and MAX IV, research infrastructures that are globally unmatched in their combination of molecular technologies, advanced X-ray capabilities, and data science infrastructure. By embedding doctoral training within these environments and connecting students directly to cutting-edge instrumentation, clinical collaborators, and industry partners, the graduate school provides an educational context that is not replicable elsewhere. This infrastructure-anchored training model, proven effective in the InfraLife Integrated Structural Biology course (2) the MAX IV-hosted PRISMAS MSCA COFUND doctoral program (3), as well as in the SciLifeLab-hosted PULSE MSCA COFUND postdoc program (4) ensures that students and postdocs acquire not just theoretical knowledge but genuine experimental fluency and cross-sector professional awareness.

2. Addressing the Translational Competence Gap in Swedish Healthcare

A critical bottleneck in Sweden's precision medicine ecosystem is the limited capacity of clinical researchers and healthcare professionals to evaluate, implement, and scale breakthrough technologies. Technologies emerging from SciLifeLab and MAX IV require clinical champions who understand their technical foundations well enough to design appropriate validation studies, interpret AI-generated outputs critically, and engage productively with regulatory requirements. The graduate school's dedicated technology and AI literacy track directly targets this gap by providing structured, practically oriented training for clinical researchers and healthcare professionals affiliated with SUHA university hospitals. This contribution to clinical research capacity accelerates the uptake of validated innovations into healthcare practice and reduces the risk of suboptimal or inequitable implementation across Sweden's geographically distributed healthcare system.

3. Catalysing Innovation Culture and Entrepreneurial Capacity

The Innovation Plan of the Breakthrough Technologies for Health cluster explicitly aims to transform Sweden's fragmented, sequential innovation pathway into a coordinated ecosystem in which development, validation, and commercialization proceed simultaneously. Achieving this transformation requires professionals at all career stages who understand innovation as an integral part of their professional identity and practice. The graduate school's innovation education pillar, covering IP strategy, regulatory science, health technology assessment, venture development, and implementation research, instils this culture from the earliest stages of doctoral training and extends it to clinical and industry-affiliated participants. The program will actively connect students with SciLifeLab's entrepreneurship activities, the cluster's National Innovation Accelerator (WP6), and established innovation support structures such as the BioInnovation Institute (BII), creating direct pathways from training to translational action and commercial venture creation.

4. Strengthening Sweden's National Research and Innovation Ecosystem

Through its community-building functions, annual meetings, summer schools, peer mentoring, and an open expert lecture series, the graduate school functions as a platform that actively integrates researchers, clinicians, and innovators from across Sweden into a cohesive professional network. The long-term value of these networks, which persist and strengthen throughout participants' careers, is one of the most robust and durable contributions a national graduate school can make to the research and innovation ecosystem. Graduates of the program will occupy leadership positions in academia, industry, regulatory agencies, and healthcare systems, positions from which they will continue to collaborate across the boundaries that currently slow translation, because they share a common professional formation and common relationships forged within the graduate school community.

The program's national significance is further enhanced by its commitment to open access: all courses and educational materials developed within the graduate school will be made available to the broader Swedish and Nordic research community, amplifying the investment in course development and contributing to a national elevation of competence in breakthrough technologies, AI, and translational science. The program aligns fully with the strategic ambitions of VR and Vinnova to build Sweden's research and innovation capacity and responds directly to the national priorities

articulated in the Life Science Strategy of 2023 (4) and the Digital Transformation Strategy for health and social care (5).

National Coordination

The graduate school is positioned as a nationally coordinated training platform, connecting all of Sweden's major research-intensive universities with the national research infrastructures SciLifeLab and MAX IV, and with the Swedish University Hospital Alliance. This breadth of national engagement reflects the cluster's ambition to transform the Swedish precision medicine ecosystem, an ambition that can only be realized through genuinely shared ownership and committed contribution from institutions across the country.

Coordinating Institutions: MAX IV and SciLifeLab: MAX IV Laboratory, hosted by Lund University, is the world's first fourth-generation synchrotron radiation facility (6) and serves as the coordinating institution for the graduate school, providing the Research School Coordinator and core administrative infrastructure. MAX IV's internationally recognized beamlines — spanning phase-contrast X-ray imaging, micro-CT, protein crystallography, SAXS/SANS, and spectro-imaging — give doctoral students direct access to instrumentation at the global forefront of structural and biomedical research. MAX IV hosts the PRISMAS MSCA COFUND doctoral program (3), involving eight Swedish universities, providing a robust institutional foundation for national graduate school coordination of this ambition and complexity.

SciLifeLab is the national research infrastructure for molecular life sciences, with nodes at all major Swedish universities and technology platforms spanning genomics, proteomics, metabolomics, structural biology, imaging, bioinformatics, and drug discovery. SciLifeLab contributes course development, expert lecturers, secondment opportunities across its platforms, and integration with the SciLifeLab Data Centre's data science training resources. The SciLifeLab and Wallenberg National Program for Data-Driven Life Science (DDLS) (7), funded by the Knut and Alice Wallenberg Foundation, provides an established research school framework for AI and data science training with which the graduate school coordinate activities to maximize complementarity and avoid duplication.

Partner Universities and Their Specific Contributions: Ten Swedish universities participate in the graduate school through their affiliation with SciLifeLab and their direct participation in the cluster's research work packages and demonstrator projects. Each contributes specific competencies that enrich the educational offering (Table 2):

University	Key Competencies Contributed to Graduate School
Lund University (host, MAX IV)	Synchrotron X-ray imaging, structural biology, materials characterisation, course coordination infrastructure, PRISMAS network, LINXS thematic initiatives
Karolinska Institutet	Clinical and translational medicine, precision oncology, spatial biology, AI in clinical diagnostics, regulatory medicine
Uppsala University	Structural biology, drug development and discovery, genomics, SciLifeLab platform expertise, bioinformatics, DDLS program host
Stockholm University	Computational biology, bioinformatics, data-driven life science, structural biochemistry
Royal Institute of Technology (KTH)	Data science, AI/ML engineering, computational imaging, digital health systems, signal processing
Chalmers University of Technology	Bioinformatics, AI for image analysis, imaging physics, health technology assessment, biomedical engineering
University of Gothenburg	Clinical research, health economics, implementation science, biomarker validation, SUHA partnership
Linköping University	Medical imaging, AI in diagnostics, clinical decision support, biomedical engineering, spatial biology
Umeå University	Epidemiology, clinical genomics, population health, data governance, infection and cancer biology
Örebro University	Clinical microbiology, translational infection research, hospital-based and implementation research

Table 2. *Partner universities and key competencies contributed to the graduate school.*

The Swedish University Hospital Alliance (SUHA), encompassing all major Swedish university hospitals, contributes the clinical dimension essential to the program's translational mission. SUHA partners host secondments in clinical research units, provide clinical researchers for the technology and AI literacy educational track, contribute patient and clinical data expertise to case-based educational activities, and ensure that regulatory, ethical, and implementation dimensions of precision medicine are embedded in the *curriculum*. Clinical researchers and healthcare professionals from SUHA hospitals are primary target beneficiaries of the technology and AI literacy track, and SUHA is represented on the Study Committee.

National Division of Responsibilities

Coordination of the graduate school is centralized at MAX IV/Lund University to ensure operational coherence and consistency of quality. Scientific course leadership is distributed across partner universities and infrastructures, reflecting the genuine expertise residing at each institution. The DDLS Research School, will serve as a complementary national partner for AI and data science course offerings, with reciprocal participation agreements ensuring that students in each program can access relevant offerings from the other. The Study Committee ensures that this distributed structure functions as a coordinated whole.

International and Other National Collaborations

A central feature of the Breakthrough Technologies for Health graduate school is its deliberate integration into a rich network of national and international doctoral training initiatives, research infrastructures, and innovation communities. These collaborations extend the educational opportunities available to enrolled students well beyond what the cluster can provide on its own, expose students to international working cultures and scientific networks, and ensure that the program remains at the international forefront of training in breakthrough technologies and precision medicine.

National and International Doctoral Training Networks: Several established national doctoral training programs provide complementary expertise and will be engaged through formal coordination agreements (7,8,9):

The graduate school will leverage and coordinate with existing national and international training initiatives to provide students with access to complementary expertise, infrastructures, and professional networks. Key partners include the DDLS Research School, providing advanced training in AI, machine learning, and data science; the National Research School in Clinical and Translational Cancer Research (NatiON), contributing expertise in biomarker development, clinical trials, and regulatory science; and the XANADU PhD School, offering training in X-ray and neutron-based methods linked to MAX IV and ESS.

Students will also benefit from interdisciplinary activities within LINXS, particularly the AIDA and SHINE initiatives, which integrate AI, imaging, and life science research. Internationally, collaborations with EMBL, Euro-BioImaging, INSTRUCT-ERIC, and EMBL-EBI will provide access to world-leading training environments in molecular biology, imaging, structural biology, bioinformatics, data stewardship, and AI. Through joint courses, workshops, summer schools, researcher exchanges, and secondments, these partnerships will ensure that students receive broad interdisciplinary training while connecting the graduate school to leading European research infrastructures and networks.

Industry and Healthcare Collaboration: Industrial partners affiliated with the cluster, spanning medtech, pharmaceutical, and health IT companies, as well as early-stage start-ups, will contribute to the graduate school as course co-designers, secondment hosts, expert lecturers, and case study providers. The cluster's National Innovation Accelerator (WP6), developed in partnership with the BioInnovation Institute (BII), will serve as an organizational bridge between the educational platform and the innovation ecosystem, ensuring that students in the innovation education pillar engage with real industrial challenges and that industry partners benefit from access to the talent pipeline emerging from the graduate school. University hospitals within SUHA function as both research partners and educational actors, hosting clinical research training, providing patient-centred case studies, and employing the clinician-researchers who constitute the primary audience for the technology and AI literacy educational track.

The combined network of national and international collaborations positions the Breakthrough Technologies for Health graduate school as a genuinely European-scale training platform with deep national roots. Enrolled students gain unmatched access to expertise, infrastructure, and professional communities, while Sweden's own research and innovation ecosystem benefits directly from the competencies and relationships that students develop across this network. Together, these collaborations ensure that the graduate school fulfils its founding ambition: to form the vibrant, cross-disciplinary community of professionals that will drive Sweden's transformation into a global leader in precision medicine and AI-enabled health innovation.

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