Institution:
Kings College London

Unit of Assessment:
UoA 3: Dentistry

a. Overview

King's College London (KCL), a multi-faculty research-led institution, ranks among the world's top 25 universities, educating more than 24,000 students including about 10,000 postgraduates. KCL is the academic partner of **King's Health Partners (KHP)**, one of five Academic Health Sciences Centres in the UK accredited by the Department of Health, which joins KCL's world-class research with three successful NHS Foundation Trusts: Guy's and St Thomas', King's College Hospital, and South London and Maudsley. KHP integrates research, education and clinical services into 21 Clinical Academic Groups (CAGs), of which Dentistry is an example. KHP's extensive research portfolio includes three Biomedical Research Centres (BRCs) attracting a total of £113 million of NIHR funding.

Within this environment is the **Dental Institute (DI**) with 85 academic staff, the largest Dental School in the UK and one of the largest in Europe. Its overarching aim is to maximise impact on health and wellbeing by **integrating excellence across four areas: world-class science, clinical approaches, patient care and education,** to provide scientifically informed solutions to clinical problems. To achieve this goal, basic scientists are juxtaposed to clinicians, physicists and tissue engineers focusing on diseases of world-wide importance, while health practitioners, social and behavioural scientists provide translation of science into practice and policy. The DI's strategy is from "*Basic Discovery to Clinical Implementation and Commercialisation*". To deliver this vision the DI is organised into four Divisions: *Craniofacial Development & Stem Cell Biology* with a strong basic science focus, *Mucosal & Salivary Research* and *Biomaterials, Biomimetics & Biophotonics* with a focus on basic and translational research and *Population and Patient Health* concentrating on policy and implementation. This structure is designed to achieve our overall vision to **understand disease and restore function** in order to **enhance health**.

In the current REF period the DI has recruited 10 new research active academics, produced over 1300 manuscripts, obtained over £23 million in new research grants (1/3 of which are RCUK), awarded 94 doctoral degrees, invested £1.5m of core funding in research infrastructure, and translated discoveries into significant improvements in health and healthcare for patients and populations.

b. Research strategy

Strategic objectives outlined in the RAE 2008 were, and remain:

1. to develop and expand our existing strengths in basic research to remain at the forefront of internationally leading science;
2. to invest in translational infrastructure to help identify opportunities arising from basic research and accelerate translation;
3. to ensure our research remains relevant to health improvement.

***Overall research strategy to meet these objectives**:*

Essential elements for success and research productivity include a critical mass of researchers with a shared focus on establishing impact from discoveries through to translation, supporting cores for shared services, and technical, administrative and financial support, along with strategic investments from the Institute and College.

With their unique focus on strategic topics, the four Divisions each provide a critical mass of multi-disciplinary researchers with broad expertise, including scientists and dual-trained academic clinicians. Basic science at world-class level not only contributes to greater understanding of biological processes and the basis of disease, but also provides research standards of the highest level of rigour. The breadth of expertise in each Division, along with cross-cutting activities, enables progression from discovery through translation and implementation, and engenders clinical questions informing discovery research. Development and expansion of strong basic research (*strategic objective 1*) is described in detail below and includes investments in new staff, particularly in mucosal biology and craniofacial biology, with plans for further investments. To ensure critical mass, the DI condensed its previous 6-group structure presented in the 2008 RAE

into 4 divisions. This structure is complemented by theme leads (discovery, translation and implementation) championing cross-cutting initiatives.

The DI's investment in translational research (*strategic objective 2*) is most apparent through its creation of the Dental Innovation and Translation Centre, recruiting a director and co-director in January 2013. Working closely with all 4 divisions, this Centre translates research into impact for clinical practice, public health policy, and fosters development of new technologies and products. In parallel, a core Oral Clinical Research Unit was created to facilitate introduction of new approaches and products into clinical practice.

Embedding clinical academics into all of the research divisions promotes the dialogue between basic and clinical scientists, and ensures that research remains relevant to the concept of health improvement (*strategic objective 3*). The Oral Clinical Research Unit, collaborating with supporting infrastructure across the KCL Health Schools and the Trusts, creates an environment where *clinical research is the easiest thing a clinician does*, adding evidence-base to clinical care.

Since 2008, through matching grant funding and direct investments, the DI has invested £1.5m of core funding in new research equipment and laboratory upgrades, £242K/year to support PhD studentships and £15,700/year to fund international travel, facilitating sabbaticals and participation in professional organisations. Intramural research funding is also available from the DI, KCL, and KHP pump-prime research projects, increasing probability of successfully obtaining extramural funding.

Our ambition, and the incentive for the DI's investments, is to leverage strong discovery science and foster research programmes in directions that together improve oral health and change the way in which dental treatment is delivered in the future. The existing dynamic, vibrant and multidisciplinary research environment promotes cross-disciplinary working between clinical and basic scientists and the active identification and exploitation of translational research opportunities to influence practice, policy, and products.

Research divisions – achievements and future plans.

Craniofacial Development and Stem Cell Biology Division. As one of the top centres for craniofacial biology world-wide, this division uses *molecular approaches to understand the regulation of tissue and organ development, homeostasis and regeneration in the craniofacial complex*. Its research is internationally recognised, routinely publishing in high profile journals including Nature, Science, Cell Press, Nature Genetics and PNAS. Among the recent major discoveries are: the finding that the mammalian ear arises from different embryonic tissues with major implications for ear infections and ear evolution (**Tucker; Science**), the identification of the signals controlling regenerative capacity of muscle stem cells during ageing (**Basson; Nature**), elucidation of the molecular control of tooth shape (**Ohazama, Sharpe; PNAS**), discovery of a new link between ciliopathies and FGF-related human syndromes (**Liu; Dev. Cell**), novel interactions between cranial embryonic cells as a paradigm for cancer cell behaviour (**Streit; Nature Cell Biol.**), a Turing-type mechanism that patterns palatal rugae (**Green, Cobourne; Nature Gen.**) and the dual origin of mesenchymal stem cells in the tooth with wider implications for stem cell research (**Sharpe; PNAS**). Advances with direct **clinical relevance** include a cell-based tissue engineered approach (BioTooth), pioneered by **Sharpe,** to create fully developed teeth with periodontal ligament in small animals, entirely from human epithelial and mesenchymal cells.

Since the 2008 RAE, this group has expanded from craniofacial developmental biology to include stem cell biology and tissue engineering. It now consists of 16 PIs managing a research team of over 80. The interest in development remains strong, but now also embraces cutting-edge approaches including genome and epigenome analysis (**Basson, Cobourne, Sharpe, Streit**), systems biology (**Streit**), small molecule screens (**Liu**), and work on human embryonic and induced pluripotent stem cells (**Grigoriadis**), regulation of organ size (**Francis-West**), stem cells and evolution (**Tucker**) and cell shape regulation and patterning **(Green)**.

The expansion was achieved through specific targeted recruitment of junior PIs, which has now created an excellent balance across the spectrum of junior to senior investigators, with implications for staff development and group sustainability. Among those recruited are (1) **Knight** from the MRC Centre for Developmental Neurobiology leading a team on muscle stem cells; (2) **Miletich**, an RCUK Fellow and now KCL lecturer with a focus on salivary gland stem cells; (3**) Ohazama,** also an RCUK Fellow and now lecturer with main research in primary cilia and dental epithelial

stem cells, (4) **Gentleman** from Molly Stevens's group at Imperial College, focusing on novel biomaterials, tissue engineering, and stem cells, (5) **Ghuman** a trained periodontist, now lecturer, focusing on mesenchymal stem cells and periodontal regeneration and (6) 2013-recruited **Andoniadou** as lecturer in stem cell biology with specific interest in pituitary stem cell homeostasis and disease. Stem cell research exemplifies how close association between strong basic science and clinicians **(Hughes)** promotes clinically research on reconstructing the periodontal ligament**.**

The Division has strong interactions with others. Recruitment of Fiona Watt FRS, KCL's Director of the Centre for Stem Cells and Regenerative Medicine, provides a cohesive link between the DI and the KCL stem cell community. Watt's close proximity to the Craniofacial Development and Stem Cell Division facilitates cross-fertilization of ideas, leverages expertise and equipment use. Recruitment of **Gentleman** into the Division has strengthened the link to ongoing stem cell and biomaterials research in the *Biomaterials, Biomimetics, and Biophotonics Division* (described below) with bioactive materials, especially nano-scaffolds, created by **Di Silvio** and **Deb** providing an important platform to study stem cell behaviour. Outcome characterisation, including cell-mediated mineral formation, capitalise on the biophotonics-based imaging skills and equipment of **Festy** of the Biomaterials, Biomimetics, and Biophotonics Division. Thus, advances in tissue engineering exemplify translation of discovery science through collaborations between groups and divisions, drawing on the expertise available in Craniofacial Development and Stem Cell Division, Watt's laboratory, and in the Biomaterials, Biomimetics, and Biophotonics Division.

In the future, the Division will continue its emphasis on using molecular approaches to understand development, growth and repair of tissue and organs in the craniofacial complex, including the use of animal models to study human disease. It will continue to attract bright, well-trained new investigators to keep it vibrant, and will embed more clinician-scientists into the group, supported by clinical training fellowships. The use of whole genome and epigenome analysis together with the application of systems biology approaches to understanding cell signalling and transcriptional networks will be major targets for future expansion. The group will continue to produce cutting-edge research supported by external peer-reviewed funding, to publish in high impact journals, and increasingly to apply discoveries to address clinical challenges.

Mucosal and Salivary Research Division. The major strength of this Division stems from **strong basic science** underpinning **translational research** and **clinical approaches**. It investigates *health and disease at mucosal surfaces* and its research is published in internationally recognised journals including Cell Press, AIDS, Europ. J. Immunology, Int. J. Epidemiol., Cancer Res and J. Infect. Disease. Among its many achievements are a major breakthrough in understanding the mechanisms that discriminate between commensal and pathogenic states of Candida albicans (**Naglik, Challacombe, Thavaraj; Cell Host & Microbe, F1000 recommended**), discovery of a novel apoptin pathway with potential application in autologous transplantation (**Tavassoli; Cancer Research**), demonstration of the diagnostic potential of 120,000 salivas collected by UKBiobank (**Proctor; Int. J. Epidemiology**), discovery of mTor activation in atrophic salivary glands (**Carpenter, Proctor; Cell Death & Disease**) and identification of novel inhibitors of Helicobacter adhesion to gastric epithelium (**Kelly; J. Infect. Disease**). International recognition is exemplified by its leadership role in large multi-centre projects supported by the EU (**Kelly, Lehner**) and the Gates Foundation (**Lehner**).

A strong focus on **collaboration between basic and clinical** researchers is enabled by the high percentage of clinically qualified staff, including both dentist/dental specialists and physicians, including a dual appointment between the DI and Dermatology. The overall mission of the Division is to translate basic research to clinical application of techniques for diagnosis and treatment of disease, including oral cancer. To achieve this goal research is grouped into three main themes *Infection & Immunity*, *Salivary Research* and *Head & Neck Cancer*.

In *Infection & Immunity*, discovery research explores host-pathogen interactions at mucosal surfaces and immune regulation. Studies of the mechanisms leading to candidiasis identified a molecular basis for discrimination by mucosal epithelia of commensal and pathogenic states of *Candida albicans* **(Naglik),** while studies of HIV-1 infection at mucosal surfaces have explored novel HIV-1 vaccination approaches **(Lehner**). International activities on Sjögren's syndrome are NIH funded (**Challacombe**), and the Division leads on large international collaborative projects on the development of novel microbicides and microbicide formulations against HIV (**Kelly**).

The *Salivary Research* theme explores the role of human salivary components in maintenance of oral health and has begun to exploit the enormous potential of saliva as a diagnostic fluid and source for biomarkers (**Proctor, Carpenter**). Salivary gland function in disease is studied in humans and animal disease models (**Proctor, Carpenter**), including regenerative and stem cell approaches in collaboration with the Craniofacial Development and Stem Cell Division (**Tucker, Miletich**). Using basic science findings, minimally invasive diagnosis and treatment of salivary gland disease have been developed (**Escudier**, **McGurk**).

The *Head & Neck Cancer* group (**Odell, Warnakulasuriya, Tavassoli**) is closely integrated within the broader KHP Cancer CAG and Integrated Cancer Centre**,** providing a platform for sharing ideas and discoveries. The overarching aim is to use strong basic science approaches to understand the molecular pathogenesis of head and neck cancers and to develop strategies for early diagnosis (**impact case study C**), prediction of the response to treatment and the evaluation of novel therapeutics to improve the outcome for patients with head and neck cancer. Endoscopic imaging of tumour margins (**Festy, Cook, McGurk**) is an example of excellent collaboration with the Biomaterials, Biomimetics, and Biophotonics Division.

At the **patient care** end, the Division has made strong impact in establishing the severity of disease reliably and objectively, which underpins assessing and developing new treatments for oral disease (**impact case study A**). The Oral Disease Severity Scoring System (**Challacombe, Setterfield, Escudier**) translates clinical signs into an easy-to-use system to monitor severity and progression of diseases and patient response to treatment. Application of this scoring system facilitated **implementation** of a dietary treatment, replacing drug therapy for orofacial granulomatosis (**Escudier, Challacombe**) and providing patient cohorts for additional studies on immunobullous diseases (**Setterfield, Challacombe**).

Overall, the three themes are clearly aligned with the DI's mission "*Basic Discovery to Clinical Implementation and Commercialisation"* through collaborations within the Division, across the DI and KCL and at international level.

In the future, the Division will consolidate its research in an effort to strengthen two successful areas. (i) The newly emerging Centre for Host-Microbiome Interactions, currently recruiting a director, will not only broaden the scope of the Division including a theme on the "Oral Microbiome in Health and Disease", but also leverage expertise from other KCL Schools and KHP CAGs. (ii) The Division has a strong record in oral, head & neck cancer from pathology to molecular cancer biology; it will seek to recruit high-profile junior researchers in the field from top international groups. It will further exploit close links with the Integrated Cancer Centre; our large patient resource and tissue bank provide fertile ground for collaborations with the Crick Institute (when it opens in 2015). The Division will continue its pursuit of high quality competitive funding resulting in excellent publications and translation into clinical practice.

Biomaterials, Biomimetics, Biophotonics Division. This division has strength from its critical interface between **basic** and **applied biology** with **clinical translation;** using biomaterials and stem cell technology to create viable grafts and dental materials - with the potential of turning laboratory innovations into **clinical solutions for patients and commercial products**. The overarching goal of this Division is to *develop novel strategies to repair, regenerate and image damaged or diseased tissue*. Intrinsically multidisciplinary, the Division combines experts from cellular and molecular biology (**Di Silvio**) and materials science (**Deb**) with imaging (**Festy, Watson, Cook**) and medicine. Its multidisciplinary expertise has been significantly strengthened (joint students, funding, clinical-academic research mentoring) by successful links with clinical colleagues (dental, maxillo-facial, orthopaedics and medical imaging) over the last 5 years, thus addressing more specific clinical questions right through to **clinical implementation**. This is illustrated by the inclusion of the Division in the £11.2M Wellcome/EPSRC Medical Engineering Centre at KCL. Among the many achievements of the Division are the development of bone grafts (**Di Silvio, Deb; J. Periodontology**) now being explored in clinical trials, its success in spinning out a company 'OSspray' (**impact Case study E**), and its strong record in commercialisation and IP generation, with over **11 current inventions and international patents** held by PIs. The Division's publications appear primarily in dental and biomaterials journals, many of highest impact in the field, including J Dental Res., J Materials Sci. and Materials in Medicine, Dental Materials and Caries Research.

Differentiating active from inactive caries has major implications in treatment approaches yet, to

date, no reliable system exists and the decision remains largely based on clinicians' judgement. One team (**Pitts, V. Thompson, Watson, Cook, Festy, Banerjee**) investigates non- or minimally-invasive technologies to ascertain caries activity. Other groups explore tissue-selective minimally invasive materials and approaches for tooth restoration (**Watson, I. Thompson**), advanced imaging techniques to detect and identify bacteria at the apex of endodontically treated teeth (**Mannocci, Foschi, Festy**), high resolution characterisation of tooth wear to establish causative mechanisms and management (**Bartlett, Moazzez, Austin, Festy, Watson**) and novel approaches to adhesive bonding**,** capitalising on the DI's reputation as the UK's leading centre in adhesive dentistry (**Watson, V. Thompson, Banerjee, Mannocci**).

Regeneration of damaged and diseased tissue often requires innovative scaffolds to direct healing. Working with maxillofacial and orthopaedic groups, **DiSilvio** and **Deb** develop and test novel porous, injectable, acellular and cellular scaffolds from an array of materials. Cross-divisional links with Craniofacial Development and Stem Cells (**Gentleman, Grigoriadis, Sharpe**) and with Watt's Centre for Stem Cells and Regenerative Medicine serve to push regenerative approaches forward more rapidly. More clinically applied research is the development of novel surgical techniques (e.g. **impact case study D**; **Renton**).

Imaging approaches are a crucial component for many of the above studies; application of biophotonics (**Festy**) serves as a basis for high resolution imaging including both single- and multi-photon fluorescence to identify cell and cell-matrix components in tissue engineering constructs as well as novel non-invasive opto-diagnostic approaches to visualise vasculature and blood flow in vivo without ionising radiation.

The Division fully embraces the DI's guiding principle "*Basic Discovery to Clinical Implementation and Commercialisation"* through multidisciplinary collaborations within and across divisions, as well as across KCL as a whole. The Biomaterials, Biomimetics and Biophotonics Division has close ties with manufacturers and dental suppliers who fund many of their studies, support PhD students and enable translation of discoveries into practice and products, e.g. Septodont (Paris), 3M ESPE (MN, USA) and GC (Tokyo). The clinical relevance and research quality is also highlighted by international lecturing commitments of many PIs, especially to dental professionals.

In the future this Division will increase the **translation of new products and innovations to clinical practice**, capitalising on close industrial and cross College collaborations; it will seek to recruit high-profile junior biomaterials scientists from top laboratories. The Division will introduce new techniques and innovation in the practice of restorative dentistry that will improve the quality of **patient care** by simplifying diagnostic and operative procedures. It will remain a fertile training environment for young clinician-scientists supported by clinical training fellowships. It will continue to address the fundamental concepts that underlie the biology, engineering and manufacture of tissues concerning the human face and their replacement, either by using tissue engineering, new biomaterials/prosthetic and imaging approaches.

Population and Patient Health Division. The overarching focus of this Division is *designing and implementing health service level approaches to tackling oral and dental health problems* and as such provides the DI's mechanism for **implementation and policy** change. This multidisciplinary group of PIs integrates the expertise of social and clinical epidemiologists, social and behavioural scientists, and public health practitioners. It develops theory-based interventions for the direct benefit of patient populations, including early recognition of oral cancer (**Scott**) and implementing primary care based interventions for screening diabetes (**Asimakopoulou**), diet and alcohol, as well as fear of dentistry (**Newton**). Notably, this Division is the academic home of the statistical support core for the entire DI. Recruitment of new staff (2011: **Bernabe**; 2013: **Sabbah**) has considerably strengthened the group bringing in new expertise in global health to complement existing strength.

Using both analytical and descriptive epidemiology, this group, with the strategically recruited **Bernabe** and **Sabbah,** explores the social determinants of oral health and the interface of oral and general health conditions in collaboration with both national and international partners. **Bernabe** is part of the Global Burden of Disease Project that summarises epidemiological and other evidence from the 1980's to 2010, globally. The DI is now part of the 2013 Child Dental Health Survey of England, Wales and Northern Ireland Consortium; working with the Office of National Statistics and the Universities of Birmingham, Cardiff, Newcastle and UCL, to establish a comprehensive profile

of the oral health and attitudes of children and young people on behalf of the Departments of Health and the NHS Information Centre. This Division plays an important role in NHS Dental Epidemiology working across both the British Association for Community Dentistry (which provides quality standards for the NHS at a UK level) and for the new Dental Public Health structures within Public Health England (**Pitts**). In collaboration with the recently formed *Kings Improvement Science* (KIS), the group is investigating new approaches to better health by improving health services. This work will be developed under the umbrella of the recently announced South London "CLAHRC" a joint NHS – University Collaborations For Leadership In Applied Health Research Centre.

Modelling the dental workforce, in particular career patterns and intention of the dental teams (**Gallagher, Newton**) has led to key roles in advising government on the dental workforce, including membership of advisory bodies and presentations to parliamentary committees.

In the future, this Division will continue to move forward toward the aspiration of the DI and the KHP Dental CAG that all patients contribute to research activity (the DI staff and students see 300,000 patients each year). In addition the Division is seeking governance approval for routine tissue banking to include saliva, blood and discarded tissues to enhance research into genetic and biomarker studies. Options to build a range of formal and informal networks to facilitate research in primary dental care are being explored. The Population and Patient Health Division is also finding ways to assure consistent public health messages across all of KHP's clinical academic groups. The Division will continue to invest in strong researchers, e.g. by exploring joint appointments with divisions in the Institute of Psychiatry, and actively engage in translation of science to policy and practice.

c. People, including:

i. Staffing strategy and staff development.

Overall Strategy: Since the 2008 RAE, the DI's policy to maintain research strength has primarily concentrated on recruiting, then developing, high quality young investigators capable of establishing independent research programmes that complement existing research. Our junior academic staff recruited since 2008 are often supported by fellowships: two had RCUK training fellowships (**Ohazama, Miletich**), one had an MRC clinical training award (**Ghuman**) another a European Training Fellowship (**Bernabe**) and three were recruited from internationally leading labs (**Andoniadou, Gentleman, Sabbah**). All are making significant contributions to research and are thriving. Once appointed, each junior staff member receives start-up funds for consumables and equipment as well as travel funds from an endowment to participate in high-profile conferences. Complementing this approach are three senior appointments (**Hughes, V. Thompson, Pitts**), recruited for targeted areas of strategic emphasis, with a brief to develop successors in their discipline.

KCL appointed **Rekow** as DI Dean in 2012. Dual-trained in engineering and dentistry, she has had continuous extramural funding for over 20 years (just under $10M in direct costs). Her enthusiasm for research was recognized by her election as President of the International Association for Dental Research, a post she held when she joined the DI. Her appointment to the DI has expanded research emphasis, leveraging discovery research while emphasising translation into practice, policy, and product development.

Staff Development*:*

Mentoring and Personal development: Mentoring and personal development is important and extends from MSc and PhD students, to post-doctoral researchers and academics at all levels.

Early career mentoring: The DI adheres strongly to the principles outlined in the Concordat for the Career Development of Research Staff. All PIs are strongly encouraged to mentor the careers of postdoctoral researchers, e.g. through developing independent areas of research, building up collaborations, and involvement in teaching, management and decision-making. This is achieved by partnering our early career researchers with a senior academic mentor, actively informing and encouraging them to take advantage of training and funding opportunities that exist both internally and externally, providing training and promoting excellence in supervision, research and academic leadership. Senior academics in the DI have entered a training programme for mentors. There is a

strong emphasis on feedback from both mentors and mentees to evolve and improve the programme over the coming years.

Equality and Diversity: In the DI, we promote equality of opportunity in all areas of work and ensure that all KCL members and prospective members are treated solely on the basis of merit, ability and potential without discrimination. We promote a positive working, learning, and social environment free from prejudice, harassment or bullying. Recruitment and other panels are chosen to reflect diversity in experience and expertise. Schemes such as the B-MEntor scheme, the Career Break Fund, the Women's Network and the Springboard Women's Development Programme are strongly encouraged. The DI has also put in place a number of initiatives including flexible working hours and lunchtime (rather than evening) seminars and meetings to support staff with outside commitments. Building on these initiatives, we are in the process of developing a Silver Athena Swan application. We believe that visible female role models are very important in inspiring and guiding younger female scientists, with nearly 50% of senior leadership positions now held by women.

Personal Development: This is promoted through comprehensive KCL-wide as well as DI-specific programmes. The Graduate School-based Researcher Development Unit (RDU) provides training, development and career advice for post-doctoral staff, postgraduate students and PhD supervisors. Over 300 workshops are available to all researchers to attend (http://www.kcl.ac.uk/study/pg/school/training/RDPTrainingBrochure.aspx). These include training in leadership, becoming a PI, teaching, equality and diversity, conflict resolution, language and IT skills, mentorship, and 1-to-1 coaching. The RDU leads College strategy on personal, professional and career development for researchers and implementing the Research Concordat. It also hosts the Vitae London Hub (http://www.vitae.ac.uk), providing input into national policy on researcher development.

Junior academic clinical lecturers are fully integrated into research groups by engaging them in ongoing projects in well-established, world-leading laboratories. This exposes them to the rigorous standards of evidence based science and allows them, under the watchful eye of established investigators, to develop progressively and establish their own research interests in an active research environment. In collaboration with senior staff, junior clinical academics co-supervise PhD students, ensuring that the research project and supervision activities receive the proper emphasis and are not overshadowed by training and clinical demands.

A key aspect of staff development is exposure to new ideas. Extensive sets of seminars are available both within and beyond the DI. Within the DI, each term a research forum highlights selected research topics, discusses current trends and emerging techniques, and wrestles with research issues, creating an excellent strategic resource for identifying potential collaborators. Special effort is made to assure cross-cutting research themes and junior PIs are showcased. A weekly lunchtime seminar brings eminent researchers from outside the DI, potentially seeding new ideas within the DI. These complement the division-specific seminars and College-wide lecture series.

Appraisal: To ensure we offer the best opportunities to our team and to enable them to contribute to the full, we engage in an annual appraisal for all academic staff. Appraisal, reflecting on the previous years performance, focuses on individual needs to ensure a tailored training and support programme is provided. In addition, it allows any concerns to be raised in a more formal setting and ensures these are addressed at the appropriate level. Our business planning process, conducted after the appraisal, allows each academic and their Head of Division to plan grant, publishing, teaching and other activities for the coming year.

Promotions: In preparation for College promotion decisions, an internal DI committee reviews applications. This internal review precedes the submission to the KCL committee by a few months, giving feedback to the candidate when needed to strengthen their submission. In the two years since this scheme was implemented, all candidates submitted were promoted.

Research Management. The Associate Dean for Research (now **Streit,** formerly **Watson** over the REF period**)** aims to enhance the quality, visibility, and impact of research within the DI with a post that also carries significant management and leadership demands. The Associate Dean reports to the Dean and represents the DI at the KCL College Research Committee

The DI Research Committee, (chaired by the Associate Dean for Research) is made up of directors of the research divisions, director of the Centre for Innovation & Translation, the lead for

the Oral Clinical Research Unit, the director of postgraduate education, and the research lead from the KHP Clinical Academic Group. The committee's responsibility is to advise on strategic directions, grant opportunities, research appointments, space usage and research capital investments. The committee meets monthly; minutes are kept, published, and shared with the KCL research committee and Health Schools Management Group.

Each research Division has a Director who reports to the Associate Dean for Research. The primary role of the director is to leverage the strengths and expertise within their group, which includes clinical academics as well as basic researchers, to realise the vision and strategic direction of the DI and KCL. The Director provides academic leadership in their research area, mentors staff, and exercises sound fiscal responsibility. They contribute to articulating and achieving the DI's strategy, as well as championing the Division within the DI, KCL, KHP, and internationally.

ii. Research students

The DI *undergraduate* curriculum is research inspired to nurture rigorous evidence-based decision-making, and exposes students to new biological therapies. Some undergraduates engage in laboratory-based research during the academic year. Summer studentship laboratory placements are available, encouraged, and DI funded by scholarships of £1000. An additional year added to the 5-year BDS programme, usually between years 3 and 4, permits students to earn a BSc. Within this intercalated programme, three courses offer research opportunities, including the BSc in Regenerative Medicine & Innovative Technology, focused industrial translation of scientific discoveries, and the BSc in Oral and Craniofacial Biology, focused on developmental mechanisms, human disease and scientific rigour of project design.

Postgraduate students can choose from a number of MSc programmes (239 students have completed studies over this REF period) all of which involve a research project. The first non-clinical MSc course, in Regenerative Dentistry, has just been launched and was oversubscribed in its first offering, reflecting the growing demand by dental graduates to understand modern biological advances relevant to dental treatment.

PhD-centred research is fundamental to a world-class organisation. KCL has excellent PhD completion rates (91.6%; HEFCE 2013) and graduate employment rates (94%; HESA 2011/12). The DI has made 94 doctoral awards over the REF period. Students have the opportunity to attend taught training modules, including project design & development to foster critical evaluation of their own and others' research, as well as preparing them to write fellowship proposals. In 2009, the DI launched a major initiative to improve the quality of PhD education and experience, also associated with a near doubling of the number of PhD students. Projects are aligned with active research programmes within the Divisions, with active mentorship from staff and supporting core courses. Arising from this initiative, an average of nine new students per annum have received full funding through KCL-funded studentships, charities, RCUK funding or BRC studentships and fellowships. A DI endowment provides top-up funding to support student projects when required, with requests for funding competitively reviewed.

Postgraduate research is celebrated in a research day with prizes for the best presentations. The DI provides travel bursaries to support students presenting their results at high profile international and national conferences such as the IADR annual session, Gordon Research Conference, and Keystone Conferences. DI research students engage in many activities. In 2011, PhD students organised a Young Embryologist Network meeting (http://www.youngembryologist.org/), drawing over 100 participants from the UK and EU. Nobel Laureate Sir John Gurdon gave the Keynote presentation. DI students participate in European Dental Student Association-organised internet conferences. Engaging in "A Pint of Science" (http://www.pintofscience.com), students share their enthusiasm – and discoveries – with the general public.

An important priority for any research institution is *recruiting the next generation of investigators*. DI PIs visit schools to discuss their science and, through Nuffield Foundation and local organisations, host sixth form students in DI laboratories during the summer. Classes from local schools visit and are introduced to research opportunities (and realities).

Summary: Our dynamic, multidisciplinary research environment promotes collaboration between clinical and basic scientists - at all levels - underpinning active identification and exploitation of

translational research opportunities to influence practice, policy, and products.

d. Income, infrastructure and facilities

Income. Since RAE2008, the DI has attracted around £20M research income from multiple sources. Collaborative grants are listed in section E. New awards have increased significantly in the last year of the REF period with £5.3m awarded in 2012-13, a 79% increase on the previous year. This includes nearly £2M from the BBSRC in six grants and £1.8M from the MRC in three grants, representing 73% of new grants. RCUK funding has therefore accounted for around 25-30% of total research income over the REF period, rising to 37% in the final REF year.

Infrastructure. Within the DI, research has been highly valued for decades; the DI has strategically recruited and invested in research over this REF period. Its re-organisation into four divisions in 2013, with cross-cutting themes of discovery, translation and implementation strengthens research focus. This infrastructure fosters collaborative research, exchange of ideas and resources. Importantly, academic clinicians are embedded in each division; clinical disciplines retain their continuity, but responsibility for management and leadership of clinical academics lies within each division. This infrastructure offers many important advantages, including increased emphasis on research in broadening knowledge base, as well as underpinning evidence-based teaching and clinical practice. It creates a platform for clinical challenges informing discovery research, with scientific excellence and rigour infiltrating all levels.

Establishing the Oral Clinical Research Unit, engaged in both research administration and nurse support broadens the DI's capacity and agility to deliver high quality clinical research, including corporate-based and NIHR CLRN portfolio studies. The Dental Innovation and Translation Centre further reinforces the ethos of translation of discoveries into clinical practice, policy, and products.

This infrastructure is supported by financial investment by the DI, KCL and KHP, including DI seed funds for new collaborations with matching funds from other Schools introduced in 2013. Internal DI funds are available for grant matching and bridging funds and research studentships, complemented by multiple intra-mural funding mechanisms within KCL and KHP. Among these is the KHP Challenge Grant, funded by Guy's and St Thomas' Charity, supporting high-risk projects (1 year, $\leq$£100K) and preliminary studies intended for future competitive grant proposals. Together, KCL and KHP provide extensive research support infrastructure to facilitate grant applications as well as research governance training and implementation, including Public and Patient support development. KHP's Joint Clinical Trials Office, responsible for commercial grants and contracts, supports processing of applications for ethical approval and contract negotiation and management.

Facilities. Excellent physical infrastructure is available to support research reflecting the DI's long-term research strategy, critical mass of investigators, high quality modern KCL-wide facilities and continuing strong relations with our partner NHS trusts within KHP. Within the DI, continuous investment assures that research is adequately supported, including full-time support of especially skilled technicians throughout. In addition, through a combination of long-term strategic investment in capital equipment, successful applications for grant funded capital equipment and open access to College and BRC core facilities, and the Francis Crick Institute (when it opens in 2015). DI researchers have access to a very wide range of state of the art research facilities.

KCL's Library Services allow access to over 25,000 electronic journals and 600 databases. The library also contains over 1.25 million books, as well as historical collections of dental journals. KCL hosts a Centre for Ultrastructural Imaging, incorporating advanced, high resolution, electron microscopes. BRC core facilities include a flow cytometry and cell sorting facility, a genomics centre with facilities for pyro sequencing, exon sequencing, SNP genotyping, RNA sequencing and Affymetrix microarrays together with bioinformatics support. A proteomic facility with extensive mass spectrometry equipment and supporting technical expertise supports the DI's salivary biomarker studies. An extensive clinical trials unit provides dedicated space and associated expertise, complementing and expanding the DI's Oral Clinical Research Unit team.

Since RAE 2008, KCL has emerged as a major biophotonics research centre, internationally recognised by the establishment of the Nikon Imaging Centre, one of only eight in the world. Merging interests from physics, biomedical engineering, and the Randall Institute, the DI contributes substantially to the Biophotonics Research Group, with DI laboratories housing 6 confocal microscopes, high-resolution Raman imaging, single- and multi-photon microscope capable of fluorescence lifetime measurements (FLIM), Förster resonance energy transfer (FRET),

second harmonic generation (SHG) imaging, and endoscopic imaging which includes Optical Coherence Tomography (OCT) capability. New £550k Wellcome funding has been awarded to create a dual beam multi-photon microscope and imaging workstation for live imaging of cellular dynamics in large specimens. These facilities were primarily created and associated activities supported through funding from EPSRC, Wellcome, and the Wolfson/Royal Society. Facilities supporting tissue engineering initiatives include x-ray micro-tomography, laser capture microscopy and a Bose Bioreactor. The Tissue Imaging Core supports all of KCL and includes micro CT imaging, Faxitron x-ray imaging, and optical projection tomography microscopy (OPT).

Summary and future plans: KCL Dental Institute has superb state of the art infrastructure and facilities. Future strategy will develop and expand this, as well as investing in translational research support to ensure research remains relevant to the concept of health improvement.

e. Collaboration and contribution to the discipline or research base

Integral to modern, cutting-edge research is an active network of external collaborations. As a leading research institute, the DI engages in many collaborations, spanning from provision of key materials and resources to specific jointly funded projects. A dedicated fund supports short, medium and long-term visits, including sabbaticals. A newly established seed fund, generated by dental alumni contributions, and matched by participating KCL schools, encourages collaboration across schools. Over the last year, the DI began hosting a series of workshops, 'Catalytic Conversations at King's' to promote interaction across a wide range of stakeholders. The first addressed innovations in materials science and was co-sponsored by IADR, WHO, UN Environmental Protection Programme, and the Word Dental Federation helping to inform the Minamata Convention on mercury usage (http://www.unep.org/hazardoussubstances/MinamataConvention/ tabid/106191/Default.aspx). The second engaged 75 stakeholders from 11 countries to agree a framework for implementation of the International Caries Classification and Management System. The next will engage NHS and other stakeholders around how patient records in dental primary care can best be used to unlock quality improvements in services as well as to monitor oral health.

*KCL and KHP strongly encourage collaboration, sometimes stimulated with funding. One such example is KCL's Policy Institute's support for investigations to facilitate policy change. Such funds were awarded to support international research and implementation collaborations relating to an international caries detection and assessment system (ICDAS) with the Universities of Copenhagen, Indiana, Michigan, and Temple (**Pitts, Banerjee**; see **Impact case study F**).*

*Many Joint Investigator Project Grants involve PIs from the DI: there are four NIH RO1 grants with George Washington School of Medicine and CalTech (**Streit**), Georgia Tech (**Sharpe**) and the Univ. of Colorado (**Watson**). The DI is also coordinator of EU Framework collaborative grants such as: CHAARM, MOTIF, EMPRO (**Kelly**) and ALLOMICROVAC (**Lehner**), each of which is a network of 10 countries. Dental Institute PIs contribute to MUVAPRED (**Lehner**), Disc Regeneration (**Di Silvio**), EHRI, and ADITEC programmes (**Lehner**) and EUROPRISE (**Kelly, Lehner**). **Francis-West** received a Marie Curie Training grant for THE HEAD and has BBSRC projects with Rutgers Univ. and the Royal Vet School. **Streit** shares a BBSRC project with UCL. A large joint project examining tooth wear with a significant lead from **Bartlett** combines the European Organisation for Caries Research, European Dental Education Association, Univ. of Manchester and Colgate Palmolive company.*

***Examples of trials grants** collaborating with other Institutions include being the UK site for the UCSF NIH-sponsored Sjögren's International Collaborative Clinical Alliance (SICCA) (**Challacombe**), while **Newton** has NIHR-funding to collaborate with UCL on modelling social determinants of oral health and the University of Sheffield on analyzing the cognitive behaviour of dental patients. Further major UK-wide NIHR funded primary dental care grants (INTERVAL and FiCTION) have arisen through the Collaboration for Improving Dentistry (**Pitts**). Within KCL, the Institute of Psychiatry has NIHR-funding collaborating with the DI to investigate the effect of periodontal inflammation control in dementia.*

***Examples of Joint Projects** and **Studentships** include joint supervision of PhD students with FAPESP and USP (Brazil)-funded with the University of Sao Paulo. A BBSRC India Strategic Partnership for KCL-Bangalore projects; National Science Council of Taiwan funding with the University of Taiwan and Biologists/Friends of Israel Academic Study Group supporting linkages*

with Israel's Weizmann Institute.

Exchange Programmes: *Specific formal research agreements exist between the DI and the University of Malta, Chonnam National University South Korea, Umm-Alqura University, Makkah, Saudi Arabia, Tohoku University, Osaka Dental University, Tokyo Medical and Dental University, Peking University School of Stomatology, Brunei Darassalam and MTEC Thailand. In addition, the DI is a partner in general KCL memoranda of understanding with Johns Hopkins, UCSF, UNC, University of Sao Paulo, University of Hong Kong and the National University of Singapore.*

Fellowships*: During the assessment period, 8 fellowships were awarded: three from the Well-come Trust, two from the European Orthodontics Society, and one each from the MRC, ESRC, and the Federation of European Microbiology Societies.*

Contributions through Professional Organisations*: Only major leadership roles are reported:*

Grants Panels/Research Councils*: Tertiary Education Assessment panel, Health Sciences, New Zealand* ***(Challacombe)****; Research for Patient Benefit Panel, NIHR (****Newton****); Swedish Research Council (Vettenskapsradet) (****Pitts****); NIDCR* ***(Rekow)****; MRC Regenerative Medicine Research Committee, Finnish Academy of Sciences and NIH (****Sharpe****); BBSRC Panel Committee A & C (****Streit****); European Research Commission Advanced Grants* ***(Watson)****.*

Professional Societies: *(2012) President UK Society for Biomaterials (****Deb****); President of World Biomaterials Conference 2020 (Glasgow), (2008-12) UK Society of Biomaterials, 'Ordine della Stella d'Italia' (The Order of the Star of Italy) June 2012 - bestowed by the President of the Italian Republic "to recognise those expatriates who have made an outstanding contribution to the preservation and promotion of national prestige abroad" (****Di Silvio****); (2011) Co-organiser of a European Science Foundation Exploratory Workshop on Bacteria and Cancer (****Grigoriadis****); (2007-9) President IADR Pan European Federation and (2009-10) President British Society of Periodontology (****Hughes****); (2008-9) President European Federation of Periodontology, (2009-12) Scientific Chairman Europerio 7 Conference (****Palmer****); Chair: European Association for Dental Public Health: Caries Epidemiology and Prevention Special Interest Working Group, International Caries Detection and Assessment System (ICDAS) Charitable Foundation, Alliance for a Cavity Free Future Charity (****Pitts****); (2011-12) President International Association for Dental Research (IADR) (****Rekow****); (2008) Director European Research Group for Oral Biology (****Sharpe****); (2013-14) Chair of Gordon Research Meeting on Craniofacial Morphogenesis and Tissue Regeneration; Elected Fellow of the Society of Biology (****Streit****); (2011-13) President IADR Network for Practice Based Research (****V Thompson****) (2011-13) President: IADR Dental Materials Group, British Society for Oral and Dental Research, (2013-16) IADR Pan European Regional Board Member (****Watson****).*

Editors: *BMC Public Health (****Bernabe****); J of Orthodontics (****Cobourne****); J Biomaterial Application & Intl J of Biomaterials (****Deb****); Int Endodontic J (****Mannocci****); Archives of Oral Biology (****Proctor****); J Clinical Periodontology (****Sharpe****); Royal Microscopical Society (****Watson****);* ***Associate Editor****, Developmental Dynamics (****Francis-West****).*

Editorial Boards: *There is DI staff representation on the Editorial boards of over 30 journals.*

Companies and Commercial Innovation*: Contributions to the discipline are also made through commercialization of research discoveries and innovation. OSspray, established to commercialize IP and research based on bioactive glass air abrasion for minimal cavity preparation, launched its first product in 2008 and spun out in 2013 to S&C polymer with products now sold worldwide (see* ***impact case study E****). The Dental Innovation and Translation Centre, working with KHP's Commercialisation Office and Edinburgh-based Calcivis, recently obtained funding to develop further the commercialization of an innovative caries-activity assessing device. Negotiations are on going with a major commercial endoscope manufacturer to license a DI-designed vascular imaging device for detecting tumour lesion margins.*

Summary: The quality of our research catalyses extensive international collaborations, many specifically focused on training and professional development, and is the foundation for new product development. Through our wide-ranging engagement in professional activities, we influence future research funding directions, stimulate advances in clinical care and inform national and international policy.