Institution: Imperial College London

Unit of Assessment: 8 Chemistry

a. Overview

Imperial College's Chemistry submission of 54.9 FTE represents all of our permanent academic staff bar one (on a part time, non-research contract for family reasons until 2014) as well as 7 Early Career Researchers. Both the College and the department are often independently rated in the top three in the UK, and the top 20 internationally (e.g. www.topuniversities.com), particularly in surveys that emphasise research reputation and environment. We are a young department (mean staff age 46), with an emphasis on new talent and research dynamism; 60% of our research fellows and lecturers started their first academic appointment in the assessment period.

Chemistry Department	RAE08	REF14
Staff Returned (FTE)	53.1	54.9
Total Research Income	£40.8M	£60M
Citations	15,750	27,416
Average Citation per Paper	10.5	15.21
% Collaborative Papers	38%	50%
	Jul-07	**Jul-13**
PDRAs	75	98
PG Student Body	196	246.9
UG Student Body	414	500
Support Staff	37	44

The department is divided into 5 research sections (REF "groups"), namely: Catalysis, Sustainability and Applied Inorganics; Chemical Biology; Chemical Physics; Nanostructured Materials and Devices; Synthesis.

b. Research Strategy

In 2008, the current Head of Department (*Welton*) refocused the departmental strategy on personal development and per capita research performance to build upon the RAE08 panel report that the Department had a "very positive research culture, excellent industrial and outreach activities, and a high international profile", especially given the "early career status" of many staff.

Our mission is to be consistently rated amongst the best Chemistry departments in the world, by emphasising our founding institutional focus on bridging fundamental science and potential application. To produce research at the highest international level across a broad range of chemistry we aim to:

- Foster an intellectually challenging, inspiring, and supportive environment, in order to extend the frontiers of knowledge within and beyond existing research disciplines.
- Combine expertise within and beyond the College to address current and future challenges, particularly in Energy, Healthcare, and the Environment, in line with Imperial College strategy.

We recognise that the Department will succeed only if we recruit the most able and support them to reach their maximum potentials (part c) by providing a collaborative (part e), stable, and professional environment, with excellent facilities (part d). The goals of our **departmental plan**, developed with our Chemistry Advisory Board (CAB, REF3a), Research and Engagement Committee, and in consultation with all staff, have been to:

1) Enable our Research Sections to excel in the key areas identified by our staff: Our research sections provide a flexible and emergent structure which staff can adapt according to their progressing interests and the external environment. This approach allows us to align with and indeed establish areas of national importance, by actively engaging with governmental and other funding bodies (part e and REF3a). Further details on our Research Sections are found below:

Catalysis, Sustainability and Applied Inorganics (submitted 10 FTEs) has made 6 appointments to enhance (i) the synthesis, applicability and sustainability of catalyst systems and reaction environments and (ii) new probes and methodologies for biomedical imaging. New MRes courses in these areas have been developed and a new Imaging CDT has just been funded. The Green Chemistry MRes strengthens the interface with Chemical Engineering, as have 3 GreenCatEng PhD studentships with matched industrial funding, a £1.2M joint grant with Shell, and several joint CASE awards. Areas of growth include:

- The PharmaCat consortium (with Synthesis and Chemical Engineering), for pre-competitive collaboration with industrial partners (REF 3a, £420K from industry) is developing greener, quality-by-design technologies and interdisciplinary training (currently 11 PhDs working).

- Large EPSRC grants (e.g. £2M grant on ionic liquid biorefining of lignocellulose and £5.2M frontier engineering grant) will expand work in sustainability, biorenewables and biocatalysis.

Chemical Biology (submitted 12.3 FTEs) has made 6 appointments to support the development of tools and insights derived from the physical sciences to probe, analyse and manipulate biological systems. The section pioneered the CDT concept (renewal confirmed, part e) and continues to innovate in PhD training (e.g. see "DTC Den", part c). Areas of growth include:

- Plant Chemical Biology supported by a Marie Curie ITN for Next Generation AgriChem (£3.2M).
- New tools for diagnosis and treatment in growing partnership with clinicians through the Laboratory for Translational Molecular Research (LTMR, see below), e.g. human trials of a minimally-invasive, continuous, wireless glucose sensor are underway.

Chemical Physics (submitted 11.6 FTEs) integrates theoretical, computational and experimental researchers within the section and is a partner in CDTs in Theory and Simulation of Materials and Chemical Biology. Areas of growth include:

- Attosecond Electron Dynamics in Molecular and Condensed Phase Systems, building on a £5.5M EPSRC Programme Grant.
- Experimental fuel cell and energy storage, driven by the EPSRC Hydrogen and Fuel Cell Supergen Hub (£5M) and capital funding for GRID scale energy storage (£0.9M chemistry, £14.3M overall), and the Carbon Trust (£3.8M), on new materials, systems and diagnostics.
- Soft matter self-assembly and membrane biophysics, via an inter-institutional EPSRC Programme grant (£5.8M, part e), and a new €1M FP7 project on nanoparticle-lipid mechanics.
- New nanodevices and characterisation will be enabled by a £1.7M EPSRC grant for a unique state-of-the art neon ion microscope, as part the London Centre for Nanotechnology

Nanostructured Materials and Devices (submitted 8.8 FTEs) made 4 appointments in the synthesis, modeling, characterization and application of nanostructured materials, focused on two key, overlapping challenges: (i) printable electronic materials and devices and (ii) energy generation, storage and utilization. Future development will exploit:

- The inter-departmental Centre for Plastic Electronics and associated CDT (part e), with strong government and ~£2M industrial support, and strengths in organic solar cells and transistors.
- Renewable fuel synthesis, through two EPSRC Grand Challenge projects, an ERC Advanced Grant, plus leadership of Imperial's Artificial Leaf Initiative and EPSRC's Solar Fuel Network.
- Hierarchical composite materials, building on a £6M program grant on 'Creativity in Composites' with Aero, Chem. Eng., and Bristol, until 2017, a multifunctional electrical energy storage composite built into a demonstrator for Volvo's concept car, and the development of two new complementary industrially scalable (and licensed) routes to process carbon nanomaterials.

Synthesis (submitted 12.2 FTEs) has made 4 appointments working on core activities on synthesis and collaborative research with, Medicine, Chem. Eng., both at Imperial and internationally; these activities will increase in the future, building on:

- Drug discovery involving the CD^3 Cancer Drug Design and Development Group established with support (£3.1M) from CRUK/EPSRC (part e), and an Advanced ERC award (€2.5m)
- The PharmaCat consortium (see above) and international collaborations e.g. with the Scripps Institute on a unified approach (kinetics, spectroscopy, computation) for the determination of organocatalytic mechanisms.
- The development (with Earth Science and Engineering, Chemical Engineering and Physics) of new microporous/MOF materials and applications, including plastic electronic photonics devices and circularly polarised light responsive organic field-effect phototransistors.

2) Increase the quality and volume of research activity and output, with a balanced portfolio:
Success in this area is evidenced by having one of the highest research expenditures of any UK chemistry department, with a strongly upward trajectory (part d). With active management, the portfolio is well distributed between staff (>95% have been named investigators since 2008) and funders (part d), combining both large grants and individual awards. Since 2008, we have published ~1750 peer-reviewed papers, 22 chapters, and 8 books, with 27,416 citations. The citation rates per paper are ~45% higher than in RAE08, indicating our greatly improved impact. Our papers now appear in journals with a higher average impact factor (IF) of 6.6; using 2013 journal IFs for comparison, the equivalent figure for our 2008 publications was 5.2. We have filed 53 patent families based on 139 patent filings, *via* Imperial Innovations, our technology transfer vehicle and >15 other direct filings with industry (54% increase on RAE08).

3) Provide effective, transparent management for a sustainable department: We have greatly strengthened our financial security (part d), enabling investment in both equipment and staff, by diversifying funding sources (72% RCUK in 2008, 54% now, part d), increasing research volume (>73% increase since 2007), and increasing student numbers. Success in research funding applications has been fostered by the supportive environment (part c), transparent management and specific policies, including mutual peer review of proposals, funds for internal collaborative workshops and an internal "invest for success scheme". We have reconfigured our Advisory Board (REF 3a) to ensure that the on-going departmental plan delivers our strategy. Efficient administration, a collaborative atmosphere, and good communications built by our Academic Opportunities Committee (part c), has also enabled rapid responses to short term opportunities.

4) Provide a stimulating and supportive environment: Imperial benefits from a diverse and international concentration (part c) of scientists and interdisciplinary centres; collaboration is encouraged and facilitated (part e). Joint seminars and other social events abound. There is a culture of interaction extending to other local institutions, e.g. the recent 3rd joint away day with UCL Chemistry. Since 2008, we have held >200 seminars, with international (~40%) and industrial (~10%) speakers, and 180 other events, including distinguished/prize lectures (e.g. *Negishi's* lecture just before his Nobel), industrial collaboration days (e.g. Dow, BASF, Ineos, JM), the RSC Young chemists workshop, and 3 Leverhulme visiting lecture series. We also benefit from seminars at Imperial organised by interdisciplinary centres, such as The Thomas Young Centre (100 seminars), the Centre for Plastic Electronics (36), and the London Centre for Nano Technology (61). To free time for core activities, we have reduced the administrative burden on academic staff, by new appointments including two teaching fellows, a dedicated Director of Undergraduate Studies, an MRes administrator, a Research Operations Manager and a Technical Operations Manager.

5) Collaborate in strategic areas (details in part e): We have focussed on the broad themes identified in RAE08: nanomaterials/soft matter, chemical biology, molecular catalysis for pharmaceuticals/polymers, and sustainable technologies, which play into national priorities on the 'Grand Challenges' of 21st Century: Healthcare, Environment, Security and Energy. To complement our thriving interactions, e.g. the Institute of Chemical Biology (ICB), Pharmacat Consortium and London Centre for Nanotechnology, new collaborations have been established that will drive future research, including Imperial's Climate KIC, Energy Futures Lab (EFL), Centre for Plastic Electronics (CPE), and Manufacturing Futures Lab. Interactions with Imperial's research Hospitals and Academic Health Sciences Research Centre provide opportunities for the new Laboratory for Translational Molecular Research (LTMR), including drug discovery and imaging.

6) Increase PDRA and PG numbers with a stable academic staff size: We have returned 54.9 FTE staff (53.1 category A in RAE08). PDRA numbers have increased to 98 (almost 2 per FTE) from 75 in 2008; PG student numbers have grown, through new MRes courses in Bioimaging Science, Drug Discovery, Green Chemistry, and Plant Chemical Biology, which build on the success of the MRes in Nanomaterials, and especially the seminal Centre for Doctoral Training (CDT) in Chemical Biology (used as a National model, part e). Further MRes courses in Catalysis and Synthesis are planned. The increase in MRes provision reflects a desire to enhance training in areas of specific research interest, whilst also providing opportunities for collaborative projects (all our MRes projects combine two complementary supervisors). We are also strongly represented on the inter-disciplinary CDTs in 'Plastic Electronics', 'Theory and Simulation of Materials', and 'Energy Futures' (part e); we are leading or a major partner in 3 CDTs funded from the current EPSRC call, as well as supporting many others. We changed our Doctoral Training Grant (DTG) distribution system (around 10-12 / year) to support strategic research priorities and the most excellent candidates through a rigorous scholarship selection process, operating at both departmental and College levels. In addition to DTGs, we currently have 9 internally funded scholarships p.a. and we aim to increase the latter allocation in future years.

6) Engage with and define new trends in scientific dissemination: We have pioneered dissemination of chemical research data in an open and semantically rich manner (2012 ACS Skolnik award). Since 2006, a digital repository has archived >50,000 quantum mechanical calculations; 800 of these have been cited via their DOI in 42 publications. In collaboration with Figshare and RSC, we are developing a robust electronic research data collection and archiving system for PhD students; a departmental trial is underway for experimental and computational

data. We use new means of dissemination and research collaboration via social media such as blogs and Wikis; more than 300 scientific blog posts attract a monthly readership of ~6000 from 144 countries. ~10 posts have themselves spawned new research/collaborations and publications. We use new tools such as 3d projection and digital recording, via podcasts and intraweb.

c.i People: Staffing strategy and staff development

Staffing strategy is the cornerstone of our departmental strategy for greater personal development and per capita performance. Our approach relies on well-evidenced corporate leadership methodologies (Goffee/Jones) and has been validated by an Athena SWAN Gold Award. We have recruited young exceptional scientists according to excellence and strategic fit, as illustrated by the following new arrivals: *Fuchter* enhances the Drug Discovery and Laboratory for Translational Molecular Research initiatives; *Heeney* brings industrial skills (Merck) to polymer synthesis as a key component of the Centre for Plastic Electronics and the Energy Futures Lab; *Ashley/Crimmin/Diez-Gonzalez/Wilton-Ely* contribute to various aspects of molecular catalysis, an area that we strengthened before the recent 'grow' determination. The strategically critical interaction with biology has been strengthened by transferring key staff (*Woscholski, Cass*) from elsewhere in the College and *Barter* who has pioneered Plant Chemical Biology. *Kuimova/Bull/Cordier* are examples of young staff who excel in their fields. Our appointment process follows best practice (SWAN Gold). Our ~10% turnover ensures our vitality and we support our staff to achieve their personal ambitions wherever they may take them: e.g., *Gibson* (BP; now Chief Scientific Advisor to the MoD), *Blackmond* (Scripps Institute), *A de Mello* (ETH), *Scheschkewitz* (Krupp-Professur at Universität des Saarlandes), *Leatherbarrow* (Pro VC Liverpool John Moores), *Marshall* (CTO, Plaxica). We aim to provide a supportive environment that builds a fulfilling, productive and happy work place. To this end, we established the Career Academic Opportunities Committee (CAOC) in 2008; CAOC supports and develops good practice, collects and analyses statistics, and promotes aspirational targets, particularly relating to appointments and promotions, career development at all levels, and departmental culture and community. All (academic and support) staff join our open and collaborative decision making processes, through departmental assemblies and Research Sections; committee minutes are published. We actively invite feedback on all departmental processes, e.g. our personalised induction for new staff has been improved by soliciting responses at 3 months. We are also working to improve the physical environment; e.g. by refurbishment of adaptable common spaces, including a new Chemistry café. Increasing levels of sociability and solidarity within the Department encourage collaboration at all levels (part e). In the 2011 Imperial Staff Survey (ISS), 94% of chemists rated their relationships with colleagues 'very highly', the best rating in the Faculty.

Career development support for all stages: The College has implemented fully the Concordat to Support the Career Development of Researchers and has achieved an HR Excellence in Research Badge from the European Commission. Our flexible working policy is applicable to all staff. Annual Personal Review and Development Plans (PRDPs) recognise achievement, provide constructive feedback, and assist with career development; they are collated and reviewed by the HoD. Clear written promotion guidelines are available to all academic staff, and circulated annually, including median, upper, and lower quartile academic metrics to allow self-assessment. Although personal circumstances and academic field have a strong influence, these metrics provide a starting point for promotion discussion and active maintenance of equitable work-loads. Staff are evaluated for promotion/fellowship readiness independently of whether they apply; a plan of support is then agreed. ~10% of academic staff receive a promotion each year. In the ISS, 89% of chemistry staff indicated that they knew "what is expected of me in my role", 80% rated training opportunities "very highly", 81% agreed "I know who I can talk to about anything that concerns me about my work"; the figures are the best in the Faculty. The Learning and Development Centre (LDC) provides management and leadership programmes to all staff, including the Academic Development Centre, the Female Academic Development Centre, and the Senior Academic Leadership Programme. The "In Conversation" Senior Academic Forum is a regular group where the College's academic leaders meet to discuss current challenges and share solutions. Staff are encouraged to engage in a wide range of professional activities (part d), including consultancy, entrepreneurship, outreach, public engagement, governmental advice, and contributions to the scientific community. All staff are encouraged to seek support through mentoring; junior academic arrivals are assigned a mentor. New lecturers and fellows have a minimal teaching and administration workload, and are allocated a studentship on appointment and another in support of their First Grant application.

Early career researchers: From the final stages of PhD study through to early career, Lecturers are supported by the Early Career Development Committee (reporting to CAOC), particularly at key transitions. The Chemistry Post-Doc Team (CPDT) is especially active (annual Symposium, coffee/evening events, mentoring, monitoring, networking, and advice) as highlighted by Nature (February 2011), Royal Society of Chemistry (April 2010), Imperial College Reporter (March 2010). New Post-docs meet the CPDT team and are assigned a 'buddy'. Feedback from the recent (externally-facilitated) Athena SWAN workshop showed that post-docs found our induction and support highly valuable and inclusive. An Early Career Researcher Award of £1000 recognises outstanding contributions to the department. Post-docs are contracted to take 10 days per year of professional development training (College or external). The College's Postdoc Development Centre (PDC) provides skills, career and personal development programmes, two of which are specifically designed for women and black and minority ethnic staff, and individual support. The head of the PDC sits on our CAOC ensuring departmental implementation of the Roberts report. In 2010, the work of the PDC was acknowledged when it was shortlisted for "Outstanding Support for Early Career Researchers" at the Times Higher Education Awards. RAs in Chemistry have made full use of PDC opportunities with 189 attending its courses (2008-2013), 66 receiving 1:1 coaching sessions and 24 taking mock interviews (2009-2013). Of RA leavers reporting a destination, half went overseas, half stayed in the UK; overall half continued in academic research, 41% joined other employment, 9% became students.

Personal research fellowships won in open competition: We continue to work pro-actively to attract and strongly support early career staff, via both external and internal research fellowships. We have a comprehensive fellowships opportunities web-page, actively identify potential candidates, and hold "applying for a fellowship" events and mock interviews. We have hosted 55 personal fellows since 2008, including 1 EPSRC Advanced Fellow, 3 EPSRC Leadership Fellows, 3 ERC Advanced Investigators, 3 Royal Society Industrial Fellows, 6 Royal Society URFs, 2 EPSRC Career Acceleration Fellows, 7 Imperial College Junior Research Fellows (JRFs), 1 EPSRC Postdoctoral Fellow, 15 Marie Curie Research Fellows, 4 Newton Fellows, 2 Ramsay Fellows, and a Wellcome Trust Re-entry Fellow. The College JRF open competition, initiated in 2009, aims to attract the most talented young researchers, providing 3 years funding whilst they establish independent careers. Of the 7 that have come to Chemistry, 4 have already secured permanent positions at Imperial or elsewhere. All fellows benefit from staff support tailored to their level, with duties adjusted according to the scheme. At the mid-point of independent fellowships, fellows are formally reviewed; all candidates are offered further support and career advice.

International staff appointments, recruitment and visiting scholars: Our reputation and London location attracts international overseas (non-UK) research staff/academics (73% non-UK new starters since 2008), long term visitors, and a large number of scientists who 'pass through' the city; since 2008, we have had 96 (55 current, 78% OS) academic visitors, as well as 38 (28 current, 50% OS) honorary appointments.

Supporting equality and diversity: The CAOC team coordinates our *Athena SWAN* work (2 x silver since 2010, gold 2013); our view is that the best practices for a successful department and the best practices for increasing diversity in general, and supporting women in particular, are the same. We have (with Warwick University) created an annual Irene Joliot-Curie conference devoted to promoting women's careers. From 2014, the RSC will take ownership of the conference which will move around the UK. The Head of Department is a member of the steering committee of the Royal Society "Diversity in the Scientific Workforce" programme. The College resources a dedicated Equalities Unit and support networks, including *Imperial as One* (race), *Imperial 600* (LGBT), and *Disability Staff and Student Forums*. Equality-related activities are overseen by committees within the College championed by the Vice Provost (Education). The College's internal leadership programme for black and minority ethnic (BME) staff, iLead, provided the blueprint for Stellar HE, a similar programme across ten HEIs, initially supported by HEFCE. The College has established a leadership programme for disabled staff, *Calibre*, and continues to be a 'Stonewall Diversity Champion'. The College *Elsie Widdowson Fellowship Scheme* provides 50% of the salary costs for 12 months to allow female academics to concentrate fully on research after maternity / adoption leave. This scheme and other department support has been taken up by 2 members of staff twice each, allowing them to submit a full 4 REF papers instead of the allowed reduction.

c.ii People: Research students

The department has a cosmopolitan community of 176 FT PhD students (4.9 PT; July 2013), 20% overseas. An additional and growing cohort are registered for MRes degrees (from 40 in 2008 to 64 in 2012), many as part of CDTs. Currently, the PG student-staff ratio is 4.28:1 for PhDs and 5.7:1 including MRes; 94% of PhD students submit on time (i.e. within 4 years).

Recruitment: Interviews are by research section so candidates meet several relevant academics. All proposed students must be approved by the Director of Post-graduate Study (DPS). Accepted students can apply for both Departmental and newly established Imperial College PhD Scholarships. We promote PG activities widely including through overseas fairs and partnerships (part e) and an annual PG Open Day, as well as by more traditional routes.

Year	PhD (FTE)
2008	182
2009	179.5
2010	177.5
2011	189
2012	192.5

Support mechanisms*:* Our induction programme includes facilities, safety, professional development, talks by the Provost, Head of the Graduate School (GS), HoD, DPS, PG Tutor and Chair of the PG Social committee. The Department, Imperial College Union, International Office, and the Departmental PG Social Committee organize social events. Each student meets the PG Tutor annually and is assigned to one of three experienced academic mentors who are independent of any assessment or disciplinary role. Following an RSC report in 2008, we established a Postdoc/Postgrad Buddy scheme, in which a number of PDRAs are trained (by the PDC) to act as informal mentors to PhD students. Projects led by new academics are assigned an experienced co-supervisor. New Academics must take *Educational Development Unit* (EDU) courses, including "Supervising PhD Students", as a component of the Faculty Learning and Teaching Development Programme, before probation.

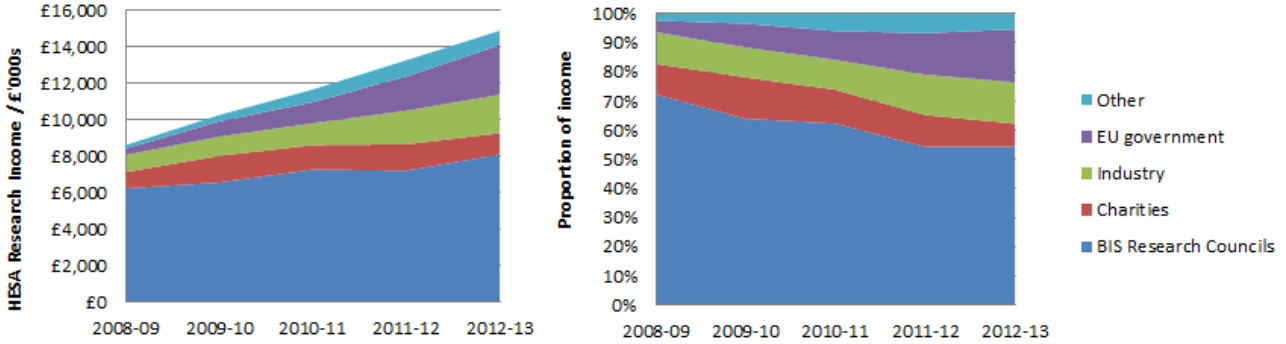
Teaching and Progress monitoring: we have improved student monitoring over recent years. Currently, students submit a study plan within 12 weeks for approval by the supervisor and the DPS. Subsequent assessments occur after 9 months (Early-Stage Assessment), including oral examination, and after 24 months (Late-Stage Review), including presenting at a PG Symposium, before final submission/viva. The purpose of the assessment is to ensure that candidates are of PhD calibre and properly supported. A student who continues to fail any milestone, after feedback, must withdraw. Students attend 3 advanced subject-specific lecture courses, and >10 research seminars in Year 1. CDTs have additional induction, team-building, and taught elements.

Career development*:* The Graduate School (GS) provides professional development for PG students (winning the Times Higher Education Award for Outstanding Support for Early Career Researchers twice during the REF period), through compulsory transferrable skills courses, including a residential course, as well as a series of GS lectures and events, in collaboration with the Careers Service. Of PhD graduates reporting a destination ('09-12 data), 60% continued to a research post (21% Imperial, 9% other UK university, 23% OS university, 8% Research Institute), 34% moved to a company, 8% to other public sector. The most common destinations were Oxbridge, Scripps, ETH and University of California. Within the department, industrial speaker seminars and industrial partner attendance at the annual PG Symposium supplement conference attendance and wider networking opportunities. The department played a strong role in developing cohort-building doctoral training (ICB, part e). One example of innovation in career support is the ICB Dragons' Den style competition (DTC Den) showcasing PhD student entrepreneurship, supported by the Business School and Imperial Innovations. The finalists deliver pitches to a live audience, hosted by Evan Davis (BBC) and Dragons that have included the heads of the RCUK (EPSRC, MRC and BBSRC). The top teams win £20K seed funding (plus TTO support).

d. Income, infrastructure and facilities

Research Income: Our research grant income is currently ~£15M p.a., increasing strongly during the REF period (see Figure below). We remain one of the largest recipients of EPSRC funding, but have strategically diversified our income sources. Industrial income has doubled, and EU income has increased 5-fold since RAE08. The Department has also attracted £2.83M through Imperial-managed strategic funding calls, e.g. EPSRC 'pathways to impact' £529K, KTS (£603K), and PhD Plus/Prize Fellowship (£410K) schemes. Chemistry research is staff intensive, and in future will be enabled through the major strategic initiatives: Laboratory for Translational Molecular Research, Imperial West, and the Molecular Sciences and Engineering Building (see below). Increased industrial funding will be targeted, drawing on our Industrial advisory board (REF3a), industrial

strategic partners (JM, BASF, Dow, Ineos, Shell), and Imperial Business Development. Our continuing culture of collaboration (part e) helps diversify funding by engaging with other funders (AHRC, NERC, MRC, NIH, etc.) and end-users.



Infrastructure and Facilities: The Department occupies 10,907 m^2 in three neighbouring buildings. Research space accounts for 7,385 m^2, with synthesis activities occupying circa 64%, physical measurement laboratories 29% and computational activities 7%. Since 2008, we have improved our built research infrastructure (£3M); refurbishment (£2.2M) of the laboratory space in our oldest building will start in early 2014. To ensure a continued ability to grow research activity, the College is currently progressing a masterplan for its estate in the context of the recent acquisition of its new 22.75 acre Imperial West campus, adjacent to its existing Hammersmith Hospital campus, and its desire to develop further research and teaching activities at its South Kensington campus. A masterplan consultant, together with international architects and master planners, SOM (Skidmore, Owings and Merrill LLP) have been appointed and £6M will be invested over the three years from 2013 to 2016 to establish a comprehensive multi-year strategy for the estate. The complete renewal of Chemistry facilities as part of the Molecular Sciences and Engineering Building (MSEB) project in the timescale of the next REF period is a priority. The project aims to provide facilities for integrated transdisciplinary research across the molecular science-engineering interface, allowing further diversification and expansion of our research, growth of existing collaborations and additional multidisciplinary approaches to global challenges (including a focus on translation via interactions with Chemical Engineering, Materials, and the College's Manufacturing Futures Lab).
From 2015 onwards, 'Imperial West' will host a new £150M Research and Translation Hub, a 42,000m^2 facility providing high-specification, multi-disciplinary research and incubator space for 1,000 engineers, biomedical scientists and physical scientists who will collaborate with global industrial business and higher education partners in an environment that fosters translation and commercialisation. Chemistry's initial focus for this campus will be the:

- Plastic Electronics Translation Hub, part of the Energy and Manufacturing Futures Facilities.
- Laboratory for Translational Molecular Research (LTMR) to strengthen links between clinicians and chemists for the discovery of molecular medicines, molecular diagnostics and the understanding of biological processes. The LTMR will enable novel probes, biomarkers and technologies to move rapidly from 'bench to bedside'.

Instrumentation and Facilities Management*:* We support research activities centrally through two teams; 3 analytical scientists run our core instrumentation (NMR, MS and XRD), whilst 8 technicians provide general chemistry support, including a mechanical workshop technician, electronics expert, instrument tester, chemical waste and inventory coordinator. In addition, technical staff embedded in research groups are funded through research grants. Our technical colleagues are critical to our research and they frequently appear as co-authors on our work, e.g. our X-ray crystallographer, *White* (h-index 66), has co-authored ~150 publications since 2008. Following consultation with all staff, via survey and interview, the department revamped its administrative (2011) and technical (2012) services to ensure more equitable distribution of support; an additional administrator and new Technical Operations Manager were recruited. The department invested £113K in a chemical tracking system (SciQuest) to improve safety, utilisation, and accelerate research. We led implementation within the College and supported uptake with dedicated technicians. Via a Core Capability grant (2013) and internal funding, we invested £1.7M in upgrades specifically targeting higher throughput to meet increasing demand (e.g. new auto-samplers) and improved ease of use. Greater opportunities for open access enhance educational opportunities and free specialist time for the most demanding research problems. In addition to the

core facilities below, we encourage departmental sharing via an equipment register for items in individual groups, and offer maintenance support in exchange for open access:
Mass Spectrometry: >30 research groups analyse over 12,000 samples each year. Current techniques include Electron Ionisation, (Atmospheric Pressure) Chemical Ionisation (positive and negative), Liquid Secondary Ion Ionisation (positive and negative), GC-EI, MALDI-ToF, UPLC Electrospray (low and high resolution) direct infusion and LCMS analyses, Direct Analysis in Real Time Probe (DART), and APCI (Atmospheric Pressure Chemical Ionisation). 150 Da-2 kDa.
NMR Spectroscopy: (ca. 90 000 samples per year). For solution samples, 5 Bruker AVANCE III HD spectrometers, one 500 MHz and four 400 MHz, each with VT -100 to +150 C and a multinuclear probe providing ^{1}H, ^{19}F and ^{31}P to ^{15}N, two with "SmartProbes". A co-located 800 MHz NMR facility is managed by molecular biosciences and biomolecular medicine. For solid samples, VT 200 MHz and 600 MHz spectrometers are available.
X-ray Diffraction: Two single crystal X-ray CCD diffractometers, one Mo-, one Cu-based, are available with cooling to 100K. Six custom designed X-ray beamlines (d-spacing range 2.5-600Å; fully automated control and acquisition; high-throughput: up to 100 samples; custom designed sample environments controlling temperature, pressure, hydration, composition and osmotic stress). These systems are capable of time-resolved SAXS and simultaneous SAXS/rheology, using a rotating anode, BEDE microsource. A hydrostatic X-ray pressure cell is used in conjunction with synchrotron facilities such as ESRF and Diamond (one was commissioned for beamline ID20).
Other instrumentation: there is a wide range of other instruments and equipment available to share on the College-wide equipment sharing register (Chemistry is responsible for 242 items of 903) including: IR, 2D-IR, transient absorption spectrometers, ultrafast photoluminescence spectrometer and UV/VIS/nIR, spectrofluorometry, TGA/DSC thermal analysers, isothermal titration calorimetry, pressure perturbation calorimeter, furnaces, spin coaters, gas chromatography, HPLC equipment including 2D HPLC-CE, GPC, microplate readers, microwave synthesizers, ultrasonic processors, centrifuges, polarimetry, colorimeter, high pressure reactors for hydrogenations etc., thin film coating, microarrayer, laser ablation patterning, potentiostats to 20A, galvanostats, dynamic light scattering (DLS), Langmuir-Blodgett trough, surface profiler, fermentor, peptide synthesizer, sputter coaters, current-voltage-luminance measurement equipment, wide range of lasers. We have two biomechanical force microscopes; Patch clamp/electrophysiology recording instrumentation (high temporal resolution); Raman microscopes, ultrafast high speed imaging (up to 100,000 fps), confocal fluorescence microscopes with two-photon excitation capability, lifetime imaging, and optical trapping, as well as a variety of optical polarizing and fluorescence microscopes. High resolution imaging is provided by AFM, STM (Agilent 5500 AFM/STM) and EM (see below) A range of gloveboxes, and communal access to solvent drying columns are also available. The department maintains a Class 1000 cleanroom.
Computing resource: extensive ICT infrastructure is provided, including a very high bandwidth (4x10Gbits) connection to Janet. The College High Performance Computing service provides computer-intensive architectures, e.g. exclusive access to 104 nodes on a large PC cluster and two nodes on the 5 Tb RAM (384 CPU) SGI Altix UV. Since 2008, the College has invested £5M in HPC; in 2012 alone, Chemistry ran 98,565 jobs over 8,421,630 hours, using the HPC service.
Instrumentation outside the department: One of Imperial's strengths is the range of facilities available within a convenient compact campus, allowing use of a range of open access, technician-managed facilities, e.g., extensive Electron Microscopy (inc. C_S-corrected, monochromated S(TEM), dual beam slice and view etc.); there is excellent cryo equipment for imaging biological, soft, and soft/hard hybrid materials. Additional analytical equipment is available in Chemical Engineering's analytical services (including AES, BET, XRF, PSA, DMTA). Specialist equipment (Hot cells, automated synthesis units, radio HPLC etc.) for the production of radioisotopes for PET imaging, specifically ^{11}C and ^{18}F, is available at the Hammersmith campus. We actively plan with other departments and local research intensive universities (especially UCL) to foster strategically complementary facilities. A new environmental XPS facility, jointly bid with Materials, is being commissioned. Inter-institutional sharing is also established, e.g. via the LCN, giving access to additional lithography cleanrooms, state of the art STMs, and the UK's first neon ion microscope.

Information on consultancies and professional services: Consultancy is encouraged to foster professional development and build contacts with industry. 30 members of our current staff consult with a broad range of organisations, with >115 contracts executed from consumer electronics (Samsung, CDT) to energy (BP, Solar Press), chemicals (BASF, Linde) and pharmaceuticals

(BMS, Sanofi-Aventis, GSK, Pfizer), on topics such as process improvement, research strategy, new materials development. A consultancy with Cardiome led to the development of a cardiovascular drug through clinical trials, approved for sale in 2010. While many consultancies are initiated directly or through College-related service companies, such as Bio Nano Consulting, we also use Imperial Consultants (ICON), a UK leader in academic consultancy services. Since 2007/8, ICON has brokered 45 commercial consulting projects (£707k) between researchers in the Department and 37 clients including private individuals, spin-outs, high-growth start-ups, education authorities, and large multinationals. 10% of ICON revenue returns to the Faculty and is used to support strategic grant applications. A further benefit is relationship development and industrial insight; for example, a technology survey for Toyota, led to a funded PDRA research project, two patent filings, and a 2 year secondment by a Toyota scientist.

e. Collaboration or contribution to the discipline or research base

Information on support for interdisciplinary research collaborations: The culture of collaboration is deeply embedded at Imperial. Chemistry is central to the flexible research environment, and currently has joint projects with almost every department in the College. 40% of all our grants are collaborative, of these 70% are interdepartmental and 30% with fellow chemists. 50% of our publications are collaborations within Imperial (38% in 2008), 21% outside chemistry (up from 15%). ~20% Chemistry-registered PhDs are co-supervised by non-chemists, with a similar number registered elsewhere and co-supervised by chemists. Our strategy is to build on core discipline strength to support direct inter-departmental collaboration, as well as that with multi-disciplinary research Centres and Imperial's four Global Challenge Institutes (energy, climate change, global health and security science). Our Faculty runs 'Creativity Labs' and provides 'Kickstart' funding (£268K, to 15 teams involving Chemistry) for seeding new internal collaborations. Collaboration examples, by type, follow:

Within Imperial, key networks include:

- The Energy Futures Lab (EFL) co-ordinates Imperial's research, training and translation activities in energy research; it has >300 current projects. Chemistry is strongly engaged, particularly on fuel cells, energy storage and solar energy. EFL remains instrumental in securing large scale research collaborative projects led by Imperial, including "New and Renewable Solar Routes to Hydrogen Energy" (£4.1M) and the "Hydrogen and Fuel Cell Supergen Hub" (£5M).
- The Centre for Plastic Electronics (CPE) involves 25 academics (4 ranked in the top 100 materials scientists worldwide by Thomson Reuters) and ~150 research staff/students (~40% based in Chemistry). It has an active CDT and close industrial engagement (14 paying Affiliates and ~£2M direct industrial funding, including Solvay, Samsung, Unilever, Merck and BASF).
- The Institute of Chemical Biology (ICB) is a network of ~90 research groups across the physical-life sciences interface, industrial partners (Astra Zeneca, GSK, Pfizer, Neusentis, Syngenta, P&G, Medimmune, BHF, CRUK) and UK/OS universities. Chaired by chemists, the ICB network is further propagated by the two RC " networks in chemical biology" led by the ICB (PPI-Net and Agri-Net, REF 3a). The ICB CDT, founded in 2003 (£5M) and renewed in 2007 (£4M), 2011 (£1M, 1 year) and 2013 (5M) has accepted >100 PhD students (30% involving industry); 40% come from the QS Rankings top 10 world universities. ICB CDT pioneered bespoke transferable skills courses, now franchised across the UK, and virtual cohort training for UK CDTs (viewed by EPSRC, VITAE and IOP as a model of best practice). Since 2003, the ICB CDT has secured >£60M in follow-on funding for its emerging technologies. In 2014, it will expand further though a £3M Marie Curie ITN in Plant Chemical Biology, a £4.6M Creative Research Landscape award in partnership with RASOR CDT, and the establishment of the Laboratory for Translational Molecular Research (LTMR).

Across London, the department has close ties with other institutions, including through the:

- Thomas Young Centre (TYC) for the Theory and Simulation of Matter, an alliance of ~80 groups at Imperial, King's, Queen Mary and University Colleges. It has high profile industrial projects, e.g. with Unilever, Johnson Matthey, Rio Tinto, British Petroleum, AWE, Rolls Royce. The affiliated CDT funded by a £6.4M EPSRC grant in 2009, has so far admitted 45 students.
- London Centre for Nanotechnology was founded jointly with UCL, involves ~70 academics, with facilities at both Colleges, and is currently co-directed by *Prof Shaffer*. It has stimulated jointly funded, inter-institutional research collaborations in excess of £27M. It provides shared complementary equipment, coordinates appointments, and holds a range of joint events.

- £650M Francis Crick Institute (MRC, CRUK, Wellcome, UCL, King's, Imperial), to open in 2015, as a world-leading centre for biomedical research. We are actively involved in this initiative and will form collaborative projects within the Crick building. As a primer, 2 Imperial Chemistry/Crick PhDs will start in 2014 and the ICB is establishing a Crick/London Chemical Biology Network.

National collaborations are underway via a variety of mechanisms, including:

- Specific topic areas such as catalysis (UCL, Oxford and UK Catalysis Hub) or via specific large programme grants (Creativity in Composites, Bristol; Sculpting Dynamic Amphiphilic Structures, Oxford/Nottingham/Leeds/Cambridge; Next Generation Analytical Tools**,** WestChem).
- The joint appointment of *Prof Harrison* with STFC's Daresbury and RAL, facilitating strong interactions with the STFC Hartree Centre. The STFC team contribute heavily to the development of widely used software, CASTEP and CRYSTAL. The latter is a general purpose electronic structure code for periodic and molecular systems, currently licensed to 315 academic groups and 7 companies worldwide. Since the release of CRYSTAL 95, the code has been cited in 2201 journal articles. Two training workshops are run annually at Imperial and in Turin (MSSC-London and -Torino), each attracting ~60 delegates (10% industrial).
- The UK National Service for Computational Chemistry Software (NSCCS) which has been renewed since 1996 (total EPSRC funding £6.8M) to help the UK remain at the forefront of computational research. Based in chemistry, it has provided access to hardware, software and training to 37 UK HEIs and supported 700 research projects.

EU collaborations are a significant part of our research portfolio (20%). Climate-KIC (Launched 2010) is an example of an EU collaborative framework, one of three knowledge and innovation communities set up by the European Institute of Innovation and Technology to deliver innovative solutions to climate change via a dynamic alliance of European partners drawn from academia, industry and the public sector (currently, >200 partners). Imperial led its establishment, and hosts the CEO, Directors of Education, and the UK co-location centre (directed by a chemist). So far, Climate-KIC in the UK supported 30 UK start-up businesses in the climate mitigation/adaptation field, of which 6 have obtained A-round funded >£1m, and 7 have first sales. It works closely with UK government to support climate change innovation.

International institutional partnerships have been expanded strategically during the REF period, including with Singapore (NTU/NUS/ASTAR), Hong Kong (HKU) and Malaysia (USM, UKM, UTM, UPM), particularly involving shared doctoral training programs. A strategic collaboration (AtlantIC) with ORNL/Georgia Tech./Emory produced a dedicated 'light rail' data connection for remote experimentation, ~20 papers (one in *Science* has >2000 citations), 7 patent applications, and on-going projects particularly in Biofuels/Biomaterials.

Information on how research collaborations with users have informed activities and strategy: Engagement with both funders and end-users of research, particularly industry, is central to our research strategy, as discussed in detail in REF3a. In addition to our own departmental advisory board, several of our extensive collaborations with industry, governments, and charities ranging from individual projects, consultancies (part d), and studentships, to large scale research consortia, have advisory panels. We are engaged in numerous large, agenda-setting, academic-industrial-governmental-pan-EU networks (see examples above and REF 3a).

Exemplars of leadership in the academic community with the REF period

The department has 4 Fellows of the Royal Society (*Barrett, Holmes, Robb, Gibson*), and 17 Fellows of the RSC, along with fellows of a wide range of other international and subject specific institutions. Staff are strongly engaged with the RSC, including as President (2010-2012, *Phillips*), President of Organic Division (2007-2010, *Gibson*), Members of RSC Council (*Welton, Phillips*), as well as members of Division Councils (Faraday: *Templer* and *Seddon*, Materials Chem: *Shaffer,* Chemical Biology: *Cass*, Organic: *McCulloch*). Many staff are involved in Groups and other sub-committees, including as Chair, RSC Research Awards Committee (2007-2010, *Phillips*), (2011-2014, *Gibson*). *Williams* is Macro rep on the SCI Board. Staff contribute to the Royal Society Committees for URFs (*Shaffer, Gibson, Hunt*), Newton Fellowships (*Barter*), Dorothy Hodgkin Award (*Williams*), Scientific Unions (*Seddon*), Diversity (*Welton*) as well as the Hooke Committee (*Haque*). We are represented on Committees for the Ramsay Memorial Trust Fellowship (*Williams*), Royal Institution of Great Britain Nominations, and various international panels. Significant roles at National facilities include: Chair ISIS Facility Board, (2013-, *Templer*); ISIS Spectroscopy Facilities Access Panel (2009-2013, *Bresme*); STFC Daresbury and Rutherford

Appleton Laboratories Head of Energy Programme (2009-2012, *Harrison*); Director CECAM-UK-Hartree node (2012, *Harrison*), UK Catalysis Hub Steering group member - Harwell (2013-, *Williams*), EPSRC H2FC Supergen Management Board (*Kucernak*).

Staff are engaged overseas, for example, as President Elect of The Australian Academy of Science (*Holmes*), Vice President University College Dublin (2006-2011, *Quirke*); Visiting Professor, ITRI, Taiwan (*McCulloch*), Norwegian University of Science and Technology (*Bresme*), Scripps Institute (*Armstrong*), CNRS Scholar, Université Blaise Pascal (*Diez-Gonzalez*); Malaysia Brain Gain Award based at UPM (*Shaffer*); Hans Kupczyk Foundation Professor, University of Ulm (*Holmes*); JSPS Fellowship Japan (2012, *Schesckewitz*); and with overseas learned societies.

Staff have won the following honours: CBE for services to Chemistry (2012, *Phillips*); OBE for services to Chemistry and Science Education (2013, *Gibson*), as well as the following prizes: Novartis Lectureship (2008, *Armstrong*); RSC McBain medal in Colloid and Interface Science (2008, *Bresme*); British Biophysical Society Young Investigator Award (*Kuimova*); RSC Creativity in Industry Prize (2008, *McCulloch*); RSC Boys-Rahman Award (2008, *Robb*); DFG Carl Duisberg-Memorial Prize (2008, *Schesckewitz*); Woehler Prize for Young Investigators (2008, *Schesckewitz*); Aventis Winnacker Fellowship (2008, *Schesckewitz*); RSC Environment Prize (2009, *Durrant*); RSC Award for Service (2009, *Phillips*); RSC Energy, Environment and Sustainability Early Career Award (2009, *Williams*); RSC Charles Rees Award (2010, *Barrett*); Robert Robinson Lecturer, University of Oxford (2010, *Holmes*); Royal Society of Chemistry Interdisciplinary Prize, Medal (2010, *Kornyshev*); Grammaticakis-Neumann Prize (2010, *Kuimova*); Porter Medal from the worldwide Photochemistry Associations (2010, *Phillips*); RSC John B Goodenough Award (*Holmes*); RSC Thomas Graham Lecturer (2011, *Welton*); Bio-Environmental Polymer Society (BEPS) Outstanding Young Scientist Award (2011, *Williams*); RSC Chemical landmark Award (2012, *Cass*); RSC Tilden Prize (2012, *Durrant*); RSC Corday-Morgan (*Heeney,* 2012); The Royal Society, The Royal Medal (2012, *Holmes*); RSC Harrison-Meldola Prize (2012, *Kuimova*); DFG Paul Walden Lecturer (2012, *Welton*); ESF JSP Burgenstock Award (*Fuchter*, 2013); Chem Comm Emerging Lecturer (2013, *Kuimova*); RSC Medimmune Protein and Peptide Science Award (2013, *Tate*). A THE 2011 citation survey ranked *McCulloch* and *Durrant* in the top 100 materials scientists globally (35th & 41st, or 2nd & 3rd in the UK).

UK Governmental roles include Sustainable Technologies Advisory Board of the Chemistry Innovation KTN and SusChem UK (*Welton*); Home Office/MOD Blackett Review on Biosecurity, Chaired by Sir John Beddington, (2011-2013, *Phillips*); Roundtable adviser to David Willets on EU funding for innovation (2012, *Templer*); DECC collaboration to create a global carbon calculator (2013-2014, *Templer*); Evidence to the House of Commons Environmental Audit Committee, the European Parliament, and various parts of the EC (DG CLIMA, DG ENER, DG RTD) (*Templer*); UK Chemicals Stakeholder Forum, DEFRA (2013, *Phillips*); 'Educators for Reform', Reform think tank (2010-, *Spivey*), as well as various international advisory roles. Contributions to funding bodies include: UK Government TSB Project Monitoring Officer (2009-, *McCulloch*); TSB Assessment Panels (*Cass*); Wellcome Trust, UK, Advisor (2010-, *Edel*); Physical Sciences Strategic Advisory Team, EPSRC (2008 - 2011, *Templer*); EPSRC Review of Discipline of Chemistry (2009, *Holmes*); many staff contribute to RC peer review panels in various forms.

28 of our staff are on the editorial boards of 46 journals, including Chem. Rev., Chem. Sci., Sci. Rep., and Chem. Eur. J.; in addition, they are editor in chief of Journal of Organic Semiconductors, International Journal Molecular Simulation, and Journal of Chemical Biology. *Phillips* is Chair, Imperial College Press Editorial Advisory Board; *Ces* and *Long* serve on the Chemistry sub-committee. Collectively, since 2008, we have completed 296 External PhD examinations, and served as external examiners for Master's courses in Cambridge, Glasgow, and Hong Kong, and undergrad Chemistry in UCL, Glasgow, Birmingham, York, Oxford, Leeds, Cardiff and Reading. *Lickiss* serves on RSC Qualifications and Professional Practice Board, QAA Institutional Reviewer Panel (2011-) and on the RSC Committee for Accreditation and Validation, member, 2009-2012.

Since 2008, the department has employed a staff member in the Outreach Office to run events for prospective students and assist academics with public engagement; > 4500 prospective students have participated. We run taster days, summer schools, lectures and competitions, often working with other institutions including Salters' Institute and the RSC. We also engage with the South Kensington academic arts community (Victoria and Albert Museum, Royal College of Art) and specific artists, e.g. advising Hiorns on his Turner Prize nominated work Seizure (2009).