2010–2011

学科发展报告综合卷

COMPREHENSIVE REPORT ON ADVANCES IN SCIENCES

中国科学技术协会　主编

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2010－2011
学科发展报告综合卷
COMPREHENSIVE REPORT ON ADVANCES IN SCIENCES

序

当前，诸多学科发展迅速，学科分化、交叉和融合愈加明显，新的学科不断涌现。开展学科发展研究，探索和总结学科发展规律，明确学科发展方向，有利于促进学科内部、学科之间的交叉和融合，汇聚优势学术资源，推动学科交叉创新平台的建立。

开拓和持续推进学科发展研究，促进学术发展，是中国科协作为科学共同体的优势所在。中国科协自2006年开始启动学科发展研究及发布活动，至今已经编辑出版“学科发展研究系列报告”108卷，并且每年定期发布。从初创到形成规模和特色，“学科发展研究系列报告”逐渐显现出重要的社会影响力，越来越受到科技界、学术团体和政府部门的重视以及国外主要学术机构和团体的关注。

2010年，中国科协继续组织了中国化学会等22个全国学会分别对化学、心理学、机械工程、农业工程、制冷及低温工程、控制科学与工程、航空科学技术、兵器科学技术、纺织科学与技术、制浆造纸科学技术、食品科学技术、粮油科学与技术、照明科学与技术、动力机械工程、农业科学、土壤学、植物保护、药学、生理学、药理学、麻风病学、毒理学22个学科进行学科发展研究，完成了近800万字、22卷学科发展研究系列报告以及《2010－2011学科发展报告综合卷》。

本次出版的学科发展研究系列报告，汇集了有关学科最新的重要研究成果、发展动态，包括基础理论方面的新观点、新学说，应用技术方面的新创造、新突破，科技成果产业化转移的新实践、新推进等。一些学科发展报告还提出了学科建设的对策和建议。从这些学科发展报告中可以看出，近年来，学科研究课题更加重视服务国家战略，更加重视与民生关系密切的社会需求，更加重视成果的产业化转移；学科间的交叉融合更加明显，理论创新与技术突破的联系结合更加紧密。

参与本次学科发展研究和报告编写的专家学者有1000余人。他们认真探索，深入研究，披沙拣金，凝练文字，在较短的时间里完成了研究课题。这些工作亦是对学科建设不可忽略的贡献。

在本次“学科发展研究系列报告”付梓之际，我由衷地希望中国科协及其所属全国学会不断创新思路，坚持不懈地推进学科建设和学术交流，以学科发展研究以及相应的发布活动带动各个学科整体水平的提升，在增强国家自主创新能力中发挥强有力的作用，以推进我国经济持续增长和加快转变经济发展方式。

2011年3月

前　言

当前，学科发展正呈现重大的分化和组合趋势，深入开展学科研究，汇聚各学科优势学术资源，推动学科交叉创新平台的建立，促进学科内部以及各个学科之间的交叉、汇聚与融合，培育学科生长点，对提升原始创新能力、加速经济发展方式转变具有重要意义。

2006 年，中国科学技术协会（以下简称中国科协）启动学科发展研究及学术建设发布项目，逐渐显现出良好的社会影响力。2010 年组织中国化学会等 22 个全国学会，分别就化学、心理学、机械工程（成形制造）等 22 个学科的发展状况进行了系统的研究，编辑出版了中国科协学科发展研究系列报告（2010—2011）。为更好地梳理、分析 22 个学科的发展概貌，受中国科协学会学术部委托，中国科协学会服务中心组织有关专家在上述 22 个学科发展报告的基础上，编写完成《2010—2011 学科发展报告综合卷》（以下简称《综合卷》）。组织成立了《综合卷》专家组与编写组，专家组由中国科协学会与学术工作专门委员会委员组成，编写组由中国化学会等 22 个全国学会选派的专家学者等组成。

项目启动后，开始了文献调研工作。2011 年 1 月中旬，对各相关学科提交的材料进行认真研究、分析与总结，先后召开了 3 次撰写及审稿会议，对《综合卷》大纲及初稿进行了深入而广泛的研讨，并对《综合卷》内容进行了多次修改与完善。《综合卷》分 4 个部分：第一部分，分析梳理了本年度 22 个学科近年来的发展概貌，对 22 个学科发展进行了综述与分析。第二部分简要介绍了 22 个学科发展研究报告的主要内容，分别介绍了各学科最新研究进展、国内外发展水平比较以及各学科的发展趋势与对策建议等；第三部分为 22 个学科发展报告主要内容的英文介绍；第四部分为我国 2010 年度与学科进展有关的主要科技成果资料的介绍。

对于《综合卷》的完成，各学科专家投入了很大的精力和热情，汇聚了集体智慧，希望能较准确、科学地反映 22 个学科的发展趋势和特点，力求具备较强的学术性、横向性与前瞻性。

需要说明的是，《综合卷》是在《2010—2011 化学学科发展报告》等 22 个

学科发展报告的基础上综合而成，只能概括部分学科的进展情况和综合发展态势，不能反映我国自然科学与技术学科发展的全貌。《综合卷》学科排序根据所属全国学会在中国科协代码顺序排列。鉴于各学科分报告均列出了所引用的参考文献，《综合卷》不再重复列出所引用的参考文献。

受中国科协学会学术部委托，中国科协学会服务中心承担了《综合卷》相关资料的收集整理、相应文稿的汇总修订以及组织协调等工作；中国科学技术出版社为《综合卷》的出版付出了辛勤的劳动。在此，谨向上述部门、单位以及胡光华研究员、王宏章研究员等所有为《综合卷》付出辛勤劳动的同志表示诚挚的谢意！

由于《综合卷》涉及的学科面广，编写时间仓促，很多问题的分析难以深化，以及学科发展调研自身难度所限，虽经多方努力，仍难免存在问题或遗憾，敬请读者指正。

《2010－2011 学科发展报告综合卷》编写组

2011 年 3 月

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第一章

学科发展综述

学科是科学技术体系形成与发展的重要标志。中国科协自2006年开始启动学科发展研究工作，先后组织85个全国学会开展了85个相关学科的发展研究，连续4年完成了学科发展研究系列报告编辑出版工作。通过深入开展学科发展研究，努力探索学科发展规律，对于明晰学科发展方向，促进各学科之间的交叉、汇聚与融合并以此孕育衍生新兴学科，促进科学技术的发展和产业结构的调整以及经济发展方式的转变，发挥了积极作用。

2010年中国科协又组织中国化学会等22个全国学会，分别对化学、心理学、机械工程、农业工程、制冷及低温工程、控制科学与工程、航空科学技术、兵器科学技术、纺织科学技术、制浆造纸科学技术、食品科学技术、粮油科学与技术、照明科学与技术、动力机械工程、农业科学、土壤学、植物保护学、药学、生理学、药理学、麻风病学、毒理学22个学科进行梳理、分析、研究与总结，较为全面地勾勒了近年来我国在这些学科领域的主要成果和发展趋势，为相关学科领域制订“十二五”发展规划创造条件、奠定基础。

一、服务国家发展战略需要，推动战略新兴产业发展

党的十七届五中全会提出，“坚持把经济结构调整作为加快转变经济发展方式的主攻方向”，并把“培育发展战略性新兴产业”作为发展现代产业体系、培育产业核心竞争力的重要任务。近年来，我国在航空、兵器和能源等战略性科技领域取得了一系列重大研究成果，相应产业快速发展，相关学科水平得以提高。

2010年，我国大飞机研制工作取得重要进展。C919是我国自主研制的150座级大型客机，具备安全、经济、舒适、环保等特点；其基本型全经济级布局为168座，混合级布局为156座，设计经济寿命为90000飞行小时/30个日历年，标准航程型设计航程4075km，增大航程型设计航程为5555km。科研人员全面按照国际民航规章和适航标准对C919开展设计研制并进行适航审定，保证了飞机的安全性；采用新一代发动机，降低了燃油消耗，其座千米直接使用成本比现有同类飞机低，具有较好的经济性；通过加大客舱和座椅宽度、配备新的机载设备等措施，改善了乘机的舒适性；选用低噪声、低污染物排放发动机，提高了飞机的环保性能。这一年，C919完成了技术经济可行性研究，确定了总体技术方案、制造总方案和客户服务总方案，在当年珠海航展上展示样机，赢得100架启动订单。按计划，C919大型客机2011年将转入工程发展阶段，2014年首飞，2016年交付用户。

2010年3月18日，我国自主研制的第一架大型民用直升机AC313首飞成功。该机完全按照适航条例研制，整机性能达到国际第三代直升机水平，标志着中国和欧、美、俄一样具备了自主研制大型直升机的能力。AC313型直升机最大起飞重量为13.8t，可一次性搭载27名乘客或运送15名伤员，最大巡航速度255km/h，最大航程为900km。该机严格按照防盐雾、防湿热、防霉菌标准设计，适合海洋气候条件和其他恶劣环境，可在－40℃～50℃温度范围内正常使用，最大飞行高度6000m，能在海拔4500m的机场起降。

AC313 直升机以复合材料球柔性旋翼系统、发动机全权限数字化电子调节控制、大面积复合材料结构(使用面积占全机体的 50%)、综合化航电系统、数字化设计制造和最新适航安全性标准等为标志,实现了我国大型运输直升机整体技术水平的跨越。

近年来,我国智能弹药——末敏弹技术取得瞩目成果。继自主研制成世界一流的火箭末敏弹武器之后,我国又取得了炮射末敏弹关键技术的重大突破和跨越,在总体设计、抗高过载、小型化、稳态扫描、多模复合探测等方面取得了一批具有自主知识产权的核心技术;研制成功的多模复合探测识别系统,在探测识别、抗干扰、环境适应、瞄准定位等性能方面均达到较高水平;同时还出版了具有原创性技术和理论成果的专著《末敏弹系统理论》、《灵巧弹药工程》;基本形成了我国末敏弹先进的设计、分析、仿真、试验、评估的方法和理论体系,使我国成为继美、俄、德等国之后能自主研发先进末敏弹的国家。

在动力机械工程方面,我国实现了 1000MW 超超临界燃煤发电机组成套装备设计、制造技术完全国产化和批量供货,至 2010 年年底已有 25 台投入运行。目前,我国完成制造和投入运行的 600～1000MW、600℃/600℃的超超临界发电机组数量占据世界首位。1000MW 超超临界燃煤发电技术的研发与应用项目首次提出了我国发展超超临界火电机组的技术选型方案;完成了 3 种不同型式的 1000MW 超超临界机组的设计开发、制造和材料加工性能研究;完成了整套超超临界电站设计和运行技术的研究,并取得了多项专利技术;形成了我国完整的超超临界电站设计和制造体系,并已经在多个超超临界电厂的建设中得到了实际应用。该成果标志着我国发电装备制造水平进入国际先进行列,对于实现我国火电结构调整、提高电力工业总体水平和促进我国经济可持续发展,均具有重要意义。

在机械工程领域,我国大型复杂整体构件成形制造关键技术与装备取得突破进展。在核电等高端大锻件技术研发和制造方面,我国基本掌握了 600t 级特大型钢锭的制造技术和大型锻造过程材料组织控制技术,解决了封头、管板类件、复杂筒形件、主管道件和特大型轴类件等锻件锻造质量控制难题;“二代加”核电核岛主设备全部锻件实现批量生产,“三代”核电 AP1000 核岛锻件全部研制成功;700MW 级水电机组锻件实现批量生产,1000MW 级火电超超临界机组重要锻件研制成功;核电等高端大锻件实现国产化,在建国家核电重点项目材料和产品的制造任务基本由国内承担,已建和正在建造多台 1.5 万～8 万 t 锻造液压机,自由锻液压机的等级和数量已进入世界前列。世界上最大的 3.6 万 t 大口径钢管垂直挤压成套装备,以及具有国际先进水平的 45MN 大型快速锻造液压机组也投入使用。发展了基于局部加载与等温成形有机结合的关键成形技术,为突破装备能力限制实现钛合金大型复杂构件成形一体化高性能制造提供了技术支撑;解决了变形与组织控制多项关键技术,成功研制了满足航空锻件要求的目前国内最大的钛合金复杂隔框锻件。

三峡水电站右岸机组实现了用空冷技术代替水冷技术的重大技术突破,生产出世界上单机容量最大的 700MW 全空冷水轮发电机。我国自主研制的三峡右岸电站水轮发电机组提前一年投入运行,达到国际先进水平,稳定性优于国际同类机组。

在新能源方面,用锂离子掺杂技术成功制成创造物理吸附储氢纪录[77K 和 1bar 下,储氢量 6.1(wt)%]的三维共轭微孔材料;研制的具有高吸收系数的有机染料 C217 制作

的染料敏化太阳能电池的光电转换效率(9.8%)居世界领先地位;在把造成污染的大型海藻浒苔以及乳牛粪便等变为生物燃油方面取得了重要进展。

在核能发电技术方面,我国已通过引进第三代 AP1000 核电技术并加以消化吸收,研制出具有自主知识产权的我国第三代先进核电技术,这将进一步提高我国核电设计、装备制造水平,加快核电技术进步的步伐。与此同时,以快堆、高温气冷堆技术为基础,我国正在开展第四代核电技术的研发工作。

煤制烯烃是一项符合我国一次能源资源结构特点、确保我国能源供应的战略措施,甲醇制低碳烯烃(DMTO)技术是其中的关键环节。在长期研发的基础上,2010 年 8 月,世界首套、全球最大的神华包头 DMTO 装置投料一次成功,一周内即生产出合格聚烯烃产品,甲醇转化率 100%,烯烃选择性 80.3%,标志着采用我国自主知识产权 DMTO 技术的煤制烯烃生产示范项目取得突破进展。目前,DMTO 专利技术已在国内 8 家企业实施,总规模达到年产 393 万 t 烯烃,由 DMTO 技术带动的新兴产业正在形成。

二、加强科技成果转化应用,加快经济发展方式转变

科技成果转化为生产力,是国民经济建设和社会发展的现实需要。加快转变经济发展方式,推动产业结构优化升级,关键是要将创新成果转化为现实生产力,把知识、技术转变为物质财富,形成规模产业,推动产业结构的优化升级。近年来,许多学科在促进科技成果转化上做出了有意义的探索和尝试,将科技创新和体制机制创新密切结合,以企业为主体、市场为导向、产业化为目标,充分调动资源,促进产业集群发展,建设创新服务平台,为促进科技成果转化、加快转变经济发展方式做出了贡献。

化学学科在国际领先的拥有完全自主知识产权的煤化工新技术产业化方面取得重大进展。我国科研机构与企业合作实现了世界首套年产 20 万 t 煤制乙二醇工业化示范装置的投产运行,生产出合格的乙二醇产品。煤制乙二醇技术全部采用工业 CO、NO、H_2、O_2 和醇类为原料来制备乙二醇,具有碳转化效率高、反应条件温和、催化剂选择性高等显著优越性。该技术具有较大的技术覆盖性,不仅可生产高附加值的乙二醇,还可以生产草酸酯、草酸、草酰胺、碳酸二甲酯等重要化工产品。我国在世界上率先实现了煤制乙二醇成套技术的工业化应用,可以替代现有的以石油为原料的路线生产我国紧缺的乙二醇,改变了我国大量进口石油生产乙二醇的格局。

在粮油学科领域,大豆磷脂生产关键技术及产业化开发取得重要进展。该项目开发了大豆磷脂精制除杂、酶促非水化磷脂转化、高效薄膜蒸发耦合等技术,解决了磷脂原料精制、磷脂组份分离纯化及磷脂改性关键技术难题,从油脚中提取出食品、保健品、药用及工业用 4 类 15 种磷脂产品。独创了具自主知识产权的磷脂加工技术,创立了我国磷脂加工产业体系,提升了我国油脂工业的核心竞争力。该项目获授权国家发明专利 8 项、实用新型专利 1 项,制定国家/行业标准 2 项;在 20 家企业建立了 46 条生产线,每年减少废水排放 300 万 t;产品替代进口并销往韩国、土耳其等,使进口磷脂大幅降价,扭转了进口磷脂垄断国内市场的局面。

在机械工程领域,科技工作者自主研发了纳米颗粒复合电刷镀技术,实现了磨损失效零件的高性能修复延寿;发明了纳米颗粒复合电刷镀液制备方法,以及金属基体上纳米颗

粒复合电刷镀层制备方法，制备了性能优异的纳米复合刷镀层；研制出自动化刷镀机，解决了纳米复合电刷镀工艺中的工序自动切换、镀液连续供给与循环利用、工艺参数实时监控等系列技术难题，实现了纳米颗粒复合电刷镀再制造成形工艺过程的自动化；研发出重型柴油机发动机连杆、发动机缸体等典型零件自动化纳米电刷镀再制造成形专用设备，提高了再制造成形零件的质量和生产效率，再制造连杆生产效率提高 10 倍以上。自动化纳米电刷镀再制造发动机缸体，突破了发动机缸体缸筒无法原尺寸再制造的难题，显著延长了缸体服役寿命，节能节材效果显著。自动化纳米颗粒复合电刷镀再制造成形技术实现了装备典型零部件再制造的产业化生产。纳米颗粒复合电刷镀技术和纳米减摩自修复添加剂复合应用，有效解决了高风沙等苛刻条件下装备零件的再制造延寿难题。该成果已在几十家单位获得应用，解决了飞机、舰船、重载车辆等装备磨损失效关键零部件的高性能再制造延寿重大难题，实现了再制造成形技术的产业化应用。

在基础农学领域，转基因抗虫棉实现了产业化生产。抗虫棉是我国独立开展的转基因育种，成为打破跨国公司垄断、抢占国际生物技术制高点的成功范例。我国先后成功研制了单价、双价转基因抗虫棉，并将成果转化、推广，创造了巨大的经济、社会和生态效益。2009 年，转 Bt 抗虫棉花种植面积已达 400 万 hm^2，占棉花种植总面积的 70％，其中国产抗虫棉占 93％；国产抗虫棉累计推广面积 1.27 亿亩以上，增收节支上百亿元。

在农业高效用水方面，我国获得了一批具有自主知识产权的技术和产品，在部分关键技术上取得突破，初步构建了具有中国特色的现代节水农业技术体系和发展模式，推动了农业高效用水技术进步。在节水农业基础理论方面，初步建立了抗旱节水型作物鉴定评价技术，筛选和培育出一批抗旱节水新材料和新品种，提出了水分亏缺补偿响应机制的节水高产与营养补偿技术，构建了主要作物生命需水数据库，为大面积提高植物水分利用效率和建立高效农田灌溉系统提供了理论与技术支撑，确定了华北和西北地区主要农作物非充分灌溉模式和关键技术，建立了主要作物调亏灌溉、控制性根系分区交替灌溉等技术，提高了作物用水效率。研发了激光控制平地铲运设备和相应的液压升降控制系统，使灌水均匀度提高 20％～30％，灌溉水利用率提高 30％～40％。在节水产品创制方面，研发了一批环保高效低成本的雨水集蓄新材料；研制出 SWR－4 型管式土壤剖面水分传感器实验样机，可替代进口 TDR/FDR 同类仪器。开发的 PY 系列、ZY 系列和 GJY 系列喷头，性能达到国际先进水平。在重点缺水地区建立了现代节水农业技术集成示范区，大田棉花膜下滴灌、旱作雨水集蓄高效利用和行走式蓄水保墒抗旱灌溉等综合节水技术的应用面积达到世界之最。“西部干旱地区节水技术及产品开发与推广”项目的膜下滴灌技术极大地提升了农业生产水平，推动了节水器材、地膜、滴灌专用肥、农业机械及自动化滴灌控制设备等相关产业的发展。在农业化学节水调控关键技术与系列新产品产业化开发方面取得突出进展，建立了我国北方 8 种类型区、24 种作物农业化学节水调控的模式化使用技术。在项目科研成果的支撑下，形成了节水设备与制剂生产企业群，产生了显著的经济效益。

在造纸制浆方面，我国科技人员在非木材化学制浆造纸清洁生产技术方面取得了新成果，以麦草替代木材形成了具有国际先进水平的麦草清洁制浆及其废液资源化利用集成技术体系，研发出新的工艺和技术装备，初步创建了麦草制浆造纸循环经济技术模式，

为节约林木资源，大幅度降低污染物排放量做出了贡献。

在纺织工程领域，高等院校与纺织机械生产企业紧密结合开发针织设备，在经编、纬编等方面推出一大批创新技术与设备，研发了数字化经编装备的关键技术，主要就经编数字提花技术、经编高速技术、数字多轴向铺纬技术、经编 CAD/CAM 技术等关键技术展开系统研究，在此基础上开发出具有国际先进水平的电脑多梳贾卡经编机、电脑无缝经编机、电脑高速经编机、电脑双轴向经编机和电脑多轴向经编机等系列数字化经编装备整机，以及与之配套的经编装备集成控制软件和经编织物设计软件，形成了多项自主知识产权并实施产业化，打破了长期以来的国外垄断，使我国经编装备水平跃入国际先进行列。

提高飞机的安全性、经济性、舒适性和环保性是我国自主研制飞机的重要目标。结合照明人机工效学，“以人为本”的飞机照明设计理念，建立准确、高效的飞机照明设计与评价体系，是我国飞机设计和安全运行中亟待解决的重大难题。照明科技人员在飞机驾驶舱、客舱和舱外照明的工效学机理研究、产品和测控设备设计方面均取得了重要进展，形成了适用于新光源 LED 的驾驶舱照明设计规范、导光板、信号灯和雷暴灯设置的工效学依据，驾驶舱照明调光机理、客舱情景照明关键模式设置依据和方案；自主研发飞机舱照明调光测控系统，并建成了我国首个 3D 视景的模拟驾驶工效学实验平台。

三、完善基础研究体系，促进学科交叉融合

基础研究是科技创新的核心动力。加强基础研究是提高我国原始创新能力、积累智力资本的重要途径，是跻身世界科技强国的必要条件，是建设创新型国家的根本动力和源泉。近年来，我国不断加大基础研究投入力度，基础研究体系不断完善，促进了各学科之间的交叉、渗透和融合。

我国化学家提出并建立了“壳层隔绝纳米粒子增强拉曼光谱”(SHINERS)技术。表面增强拉曼光谱(SERS)对于表面物种具有独特的选择性和超高检测灵敏度，与溶液中同种分子的光谱信号强度相比，吸附在某些金属表面上的分子的光谱信号强度可增强10^6～10^{10}倍，SERS 因此成为目前极少的达到单分子检测水平的光谱技术。但是，SERS 所研究和实际应用的材料体系几乎局限于金、银、铜三种金属，并且还需要将这些金属进行表面粗糙化或制备成纳米粒子。长期以来，科学界普遍认为 SERS 无法成为可广泛应用的检测分析技术。我国化学家针对 SERS 的材料普适性和形貌普适性很差这两个瓶颈问题，将实验、仪器研制和理论研究相结合，通过长期系统研究，用实验和理论计算证实，一些广泛应用于化工和能源的过渡金属体系也分别具有 1～4 个数量级的表面增强效应，更新了 20 余年来科学界普遍认为这些过渡金属体系不具有 SERS 效应的原有观点，并由此进一步将 SERS 研究拓展至紫外光激发波段，建立了 UV－SERS 技术。先后建立了 SERS 与机械裂结法结合的 MCBJ－SERS 技术，并发展了针尖增强拉曼光谱(TERS)技术，在分子水平上获得了纳米间隔中的导电分子结的结构信息，与国外同行合作，提出并建立了“壳层隔绝纳米粒子增强拉曼光谱”(SHINERS)技术。首次在电化学条件下获得了铂、铑等各种原子级平滑单晶上的表面拉曼光谱，成功检测到半导体硅表面的成键物种、活细胞壁的组分乃至橘子皮的残留微量农药。该方法使得 SERS 得以检测各类材料的最表层化学组分和应用于任何形貌的基底。SHINERS 作为新型超高灵敏度的普适检

测技术，将在食品安全、环境保护、医学诊断、材料表面分析、公安等领域具有广阔应用前景。

我国还在棉铃虫对 Bt 棉花抗性风险评估及预防性治理技术的研究与应用方面取得重要进展：①在国际上创造性地提出了利用小农模式下玉米、小麦、大豆和花生等棉铃虫寄主作物所提供的天然庇护所治理棉铃虫对 Bt－Cry1Ac 棉花抗性的策略；②通过阐明棉铃虫对 Bt 棉花抗性的演化规律和风险评估，提出以严格禁止种植生长中后期杀虫蛋白低表达的 Bt 棉花品种和商业化 Bt－Cry1A 类转基因玉米、大豆、小麦等为核心的抗性预防性治理技术体系；③首次揭示了棉铃虫钙粘蛋白和氨肽酶 N 基因突变导致对 Bt 棉花产生抗性的分子机制；④建立了由 DNA 分子检测、单雌家系检测和生长抑制检测组成的棉铃虫抗性早期预警与监测技术体系，可分别进行抗性基因、抗性个体和抗性种群 3 个水平的抗性检测和监测。研究成果为我国 Bt 转基因抗虫棉安全性评价与种植管理以及 Bt 作物研发的顶层设计提供了科技支撑。

阿尔茨海默病（AD）和帕金森病（PD）等神经变性病是严重危害人类健康的疾病，我国正进入老龄化社会，相关的研究因而尤为重要。我国科学家对 AD 和 PD 的病因、发病机理、早期诊断和治疗策略进行了系统研究，建立了 PD 患者临床数据和标本库，新确认和发现两种中国人家族遗传性 PD 基因；发现甲醛可能是 AD 致病因素，并建立了甲醛诱导的“Tau 蛋白错误折叠球形中间产物的分子模型”；发现了 Tau 蛋白过度磷酸化是保护细胞免于凋亡的重要因素，提出了“神经细胞退行性变性死亡”的新概念；发现多巴胺和 FGF2 的相互作用是神经元—胶质细胞网络的关键环节；建立了磷酸化 α－SYN 转染的 PD 细胞模型；初步建立了较完善的疾病早期预警和早期诊断综合体系，将有助于提高疾病的早期诊断率；获得了一批具有自主知识产权的先导化合物，为进一步研发神经保护药物奠定了良好的基础。

我国药学科技工作者在海洋特征寡糖关键制备技术与方法及海洋药物开发方面取得了重要进展，构建了国内外第一个海洋糖库，库中的海洋特征寡糖已在国内外广泛应用，为糖化学及糖生物学研究提供了大量的模板分子；发现了特征寡糖的某些构效关系规律，建立了寡糖的定向分子修饰技术；据此开发了 4 个上市海洋新药和 4 个处于不同临床阶段的一类海洋新药及相关功能制品，所制备的特征寡糖为医药、食品、化妆品、军工及农业等行业提供了活性寡糖原料。寡糖系列制品质量稳定，单体纯度高，主要技术参数和质量标准达到国际同类制品的水平，具有潜在的开发应用价值。

中国土壤分类实现从定性向定量的跨越。由于土壤是一个不均匀的连续体，分类难度大，世界上至今尚无统一的土壤分类。我国土壤科技工作者经过 20 多年的系统研究，建立了全新的以诊断层和诊断特性为基础以定量化为特点，既可与国际交流又充分体现中国土壤特点的谱系式、可检索中国土壤系统分类；创建了一系列我国特有的诊断层和诊断特性，如季风亚热带的低活性富铁层，干旱土的干旱表层、盐磐层，以及青藏高原的草毡表层，还有一系列人为土层，不但解决了我国土壤分类问题，而且还被国外借鉴。在世界上首次系统地建立了人为土纲的分类体系，使纷乱复杂的人为土得以定量的区分和科学的表达。中国人为土已被国际分类组织（WRB）全盘接受并成为其标准，对国际土壤分类作出了贡献。我国还在土壤胶体化学、农田温室气体排放、污染土壤修复、养分资源管理，

以及土壤退化机理等方面取得了一批重要研究成果。

多学科交叉综合与集成研究是提升和发展现代土壤学的新趋势。新兴土壤学研究方向及分支学科的诞生和涌现，得益于与土壤学内部分支学科的融合和土壤学与其它基础科学的渗透融合。比如，微生物学、微形态学和土壤颗粒与土壤结构的交叉研究，派生出土壤微生境和微生态研究方向；而临界带（critical zone）土壤的研究，则是整合了微生物学、水文学、生态学、环境科学、地球化学、地质学、大气科学的知识和技术，在考虑土壤过程、功能及服务上与地球系统科学表层过程研究接轨，使得土壤学在解决地球各圈层交互作用，以及诸如农业与面源污染、土壤与全球变化、跨界面和跨流域环境污染与控制等问题上的能力大为提高。

热声制冷技术是一种利用热声效应的新型能源转换和利用技术，该技术完全不需机械运动部件，采用环保气体（氦气、氮气或空气等）作工质，具有完全环保、高可靠和高效率等突出优点和发展潜力，是目前国际上能源领域和制冷领域最为活跃的研究前沿和研究热点之一。我国科技工作者提出了聚能型行波热声发动机的概念，研制出世界上压比最大、效率最高（32％以上）的热声发动机；首次研制出完全无运动部件液氢温度（18K，－253℃）的低温热声制冷机，是热声制冷机迄今达到的最低制冷温度，在天然气液化、氢液化等领域具有重要应用前景；首次研制出在－20℃（冰箱制冷温区）制冷量达到 300～500W 级的双行波热声驱动室温热声制冷机，其制冷量及效率突破了传统驻波制冷低效率的瓶颈，为替代氟里昂制冷技术提供了一种新途径。

四、着眼科技改善民生，促进社会和谐发展

科技发展的出发点和落脚点都是改善民生。2010－2011 年，22 个学科中有一批具有自主知识产权的科技成果在改善民生、促进社会和谐方面发挥了重要作用。

粮油学科开展的粮食储备“四合一”新技术研究开发与集成创新项目，针对我国粮食储备特有的仓型大、粮堆高、储期长等国情，集成创新了以智能粮情检测、低剂量环流熏蒸、智能通风和高效谷物冷却 4 项技术为一体的“四合一”储粮新技术；建立了中国储粮生态系统理论体系；创新了多段变温——缓苏干燥新工艺、高效粮食装卸新装备、多用途散粮汽车和整仓 CO_2 气调储粮新技术；系统解决了我国储备粮防霉保鲜、抗性害虫治理和降耗减排问题。该成果应用到全国 31 个省市自治区总计 6000 多万 t 仓容的中央和地方粮食储备库，推广国产新型装备 1.6 万台套，培训技术人才 1 万余人，获发明专利 6 项，实用新型专利 21 项，制定国家和行业标准 11 项，累计获得 290 多亿元的经济效益，使我国粮食储藏技术总体跃居国际先进水平，部分技术超过欧美等发达国家。

我国科技工作者研发的高效短流程嵌入式复合纺纱技术，是我国拥有自主知识产权的新型纺纱技术，不仅可应用于棉麻毛丝纺纱领域，实现超高支纱线的纺制，而且可使传统纺纱难以利用的原料可纺，具有资源优化利用及充分利用、缩短加工流程、降低能源消耗及原料消耗等优点。该项技术改善了成纱质量和纤维利用率，实现了传统纺纱中不可纺纤维的复合纺和超高支纱的开发；应用该技术毛纺上纺纱可以达到 500 公支，棉纺可以达到 500 英支，实现了用低等级纤维原料纺高支纱和具有多花色品种纱线的纺制。

近几年，我国心理学科在基础和交叉研究方面取得了很多进展。在认知神经科学研究领域，我国学者关于知觉与注意的多项研究论文成果被国际权威学术期刊刊登，知觉研究由视觉、听觉向触觉、嗅觉以及多感觉的融合等领域扩展，关于汉语认知与发展的研究也在蓬勃发展中。在社会认知神经科学领域，我国学者在经济决策、中国人的自我等问题上研究成果显著。在心理健康领域，我国学者近年来持续开展了针对各个年龄阶段、各个职业群体的心理调查工作，建立了《中国人心理健康量表》全国常模。

在麻风病学科领域，中国科学家采用国际最新的全基因组关联分析方法，通过对11400 名麻风病患者及健康对照者的研究，发现了 7 个麻风病的易感基因，取得了具有世界领先水平的重大原创性成果。该研究也是世界范围内最大的传染性疾病的全基因组关联分析研究，研究使用的病例样本来自山东、江苏、云南和安徽数十家麻风病防治机构，研究团队利用国家人类基因组相关单位全基因组关联分析实验平台和分析技术，历时 3 年首次从分子生物学水平阐明了麻风病的发病机制。这一发现对其他传染病如结核病等的防治同样具有重要借鉴意义。成果鉴定专家认为，这是国际上第一个麻风病的全基因组关联分析研究成果，是我国科学家在发现复杂疾病易感基因方面取得的重大突破。

我国科技人员和医务工作者合作，研发出具有自主知识产权的“黎元”远程脑外科机器人系统。该系统用机器人取代了传统的脑外科手术定向仪框架，用机器人进行手术模拟和定位引导，医生远程控制机器人作为操作平台进行直接手术，实现了无框架立体定向脑手术和远程医疗外科机器人应用技术的突破。与传统手术相比，该手术方法不仅减少了病人的痛苦，也缩短了手术时间，降低了医疗成本。该系统已在 20 多家医院推广应用，并成功实施了 5000 余例手术。

药物非临床安全评价是直接关系公众用药安全的关键技术，目前已成为新药注册国际互认的前提。为了保障公众用药安全，突破国际技术壁垒，中国药品生物制品检定所历经十余年建设与发展，通过国际合作，引进国际 GLP 标准，整合毒理、药理、病理、分析等多学科技术力量，率先在国内创建了符合国际 GLP 标准的安全评价技术体系，先后通过国家 GLP 认证、日本 JICA 认证和国际 AAALAC 认证，率先成为国内获得国际认可的安全评价机构。针对疫苗、基因治疗、单抗和蛋白多肽 4 类创新生物药物，建立了免疫毒性、生物分布、组织交叉反应、PK/TK 等评价技术体系，并运用该体系完成了 29 项创新生物药物的安全评价，其中 8 项已通过国家新药审评，为国内外评价同类药物提供了重要技术手段与方法，为国家制定药物评价指导原则提供了依据。通过对全国 245 家 2493 人次技术骨干进行培训，为我国推行 GLP 标准发挥了重要的示范和辐射作用。在应对和技术处置甲氨蝶呤、鱼腥草、欣弗等重大药物不良事件中，该平台发挥技术优势，及时、准确地确定药害原因，为不良事件的科学定性及行政执法提供了重要依据，保障了公众用药安全。

我国在天然药物、中药治疗帕金森病的研究方面取得了重要进展。药理学工作者在神经退行性疾病的研究中，围绕神经细胞保护和中枢神经递质平衡理论，从 50000 余种化合物中，筛选发现了国家 1.1 类化学新药百可利。这种新药具有调节中枢神经递质平衡，保护神经元功能，防止神经元损伤，促进受损神经元恢复，并能够有效解除帕金森动物模型震颤症状等疗效，且副作用较小。该新药目前已完成临床前研究，研究结果证明，百可

利对帕金森病有明显的治疗作用，可以改善帕金森病症状，缓解病理过程，达到防治帕金森病的目的，有望成为新一代治疗帕金森病的药物。

五、问题挑战交织并存，学科建设任重道远

综上所述，上述22个学科近年来取得了长足的发展：学术交流更为广泛，国际合作更加活跃；基础学科领域取得了一批具有世界水平的重大成果，前沿技术学科领域攻克了一批核心关键技术；学科间的交叉融合，促进了新的学科增长点涌现；科技成果转化步伐正在加快，有力地支撑了社会进步；科技创新在服务国家重点产业、重大工程建设等方面发挥着越来越重要的作用；越来越多的科技成果正在成为培育和发展战略性新兴产业的重要推动力，成为改善民生、促进社会和谐的重要力量。

但是，我们也应清醒地看到，按照建设创新型国家的时代要求，以及与发达国家先进科技水平相比，上述学科发展也反映出我国学科建设或多或少还存在着差距和问题，同时也面临着严峻的挑战，具体表现在以下几个方面。杰出的科技领军人才严重缺乏，科技原始创新能力整体还比较薄弱；符合高新技术与战略产业发展需要的学科体系还不够完善，学科间集成创新的整体水平还不太高；各学科之间的发展还不平衡，一些学科与国外差距还比较大；科技成果转化率还比较低，与市场脱节现象较为严重；产学研用创新体系还不健全，科技成果评价的导向存在问题；发表论文数量很多，高水平原创性论文数量偏少。学科建设任重道远。

今后一段时期，尤其是"十二五"期间，中国科协和全国学会将立足发挥学术共同体的独特作用，更加重视学科发展研究，坚持不懈地推进学科建设和学术交流，以学科发展研究以及相应的发布活动带动各个学科整体水平的提升，在增强国家自主创新能力中发挥更加有力的作用，以推进创新型国家和和谐社会的建设。

(1)高度重视学科自主创新能力的提高。要充分认识到基础前沿研究是创新之源泉，始终坚持创新导向，大力加强基础学科研究和前沿高技术研究，支持各学科科学家的自由探索和围绕国家战略需求的科学前沿领域的开创性研究，以抢占科技前沿制高点。

(2)高度重视学科布局的优化和完善。要充分认识到超前部署是创新之必然，通过优化和完善学科的布局，构建一批重大创新基地和创新服务平台，促进各学科的均衡发展。

(3)高度重视高新技术对提升传统产业的支撑作用。要充分认识到支撑引领是创新之责任，不断创新组织管理体制机制，更好地发挥科研组织建制化和多学科综合优势，推进高新技术成果的转化和推广应用，培育一批高新技术龙头企业，促进传统产业升级换代。

(4)高度重视科技改善民生能力的提升。要充分认识到改善民生是创新之根本，坚持以人为本，把改善民生作为根本出发点和落脚点，基础研究和技术发展方向应努力寻找民生关注点。经济社会发展必须更加依靠科学技术，科技工作必须更加面向经济社会发展服务。

(5)高度重视创新人才培养和创新环境建设对学科建设的决定作用。要充分认识到造就人才是创新之关键，把创新型人才队伍和创新环境建设作为根本任务，加大对优秀创

新团队的稳定支持，加强面向生产一线的实用工程人才、卓越工程师和技能人才的培养，培养和造就一大批创新型领军人才和创新创业科技人才团队。

(6)高度重视扩大和深化科技对外开放对学科发展的重要作用。要充分认识到开放合作是创新之智举，各学科应进一步扩大和深化科技对外开放，主动实施平等互惠的国际科技合作计划，加大参与国际大科学计划的力度，支持本学科的科学家参与国际组织工作，积极发挥我国科学家在国际科技组织中的作用。

第二章

相关学科进展与趋势

第一节 化 学

一、引 言

近两年来，我国的化学学科取得了重大进展，突出体现为：基础研究更扎实、深入，新兴学科发展迅速，传统学科不断涌现新生长点，面向国家、社会重大需求和面向实际应用的成果数量与质量显著提高，学科分布格局更趋于与发展要求相适应、与国际趋势相符合和与国情结合更密切，研究重点更注重可持续发展，原创性成果不断涌现，学术交流更广泛，学术论文的数量和质量明显提升的总趋势得到进一步发展。我国化学学科的国际影响进一步扩大，受到国际学术界的更大关注，国际学术地位得到进一步提升，化学已成为我国的优势学科。

二、本学科总体成就和研究进展

2009～2010 年，化学化工类获国家颁发的自然科学奖、科技发明奖和科技进步奖共 113 项，在所有学科中呈领跑之势，充分证明我国化学学科的发展。无论是基础研究还是技术和应用创新研究，我国的化学学科对科学、国民经济和社会发展都作出了十分重要的贡献。其中，有机光电功能材料领域连年获奖的成功经验值得总结、借鉴。不过，从获奖项目的分布看，应该更加重视从技术发明到工业应用的集成创新能力的提高。

我国已发表的化学学科论文的数量居世界第二位，总被引频次和篇均被引频次都有明显增长。2010 年前 7 个月应邀在国际最高水准（影响因子超过 10）的 7 份化学综述类期刊上发表的论文数量达到 68 篇，达到了前所未有的数量。但是，必须充分认识到这些论文中目前属于原创性和国际前沿、热点领域的学术成果还不够多，绝大多数论文的学术质量也待更进一步提高。统计数据表明，我国的化学期刊得到平稳发展，在高水平期刊的培育等方面取得了一些突破。

三、本学科主要分支学科的研究进展

（一）配位聚合物

配位聚合物是当前无机化学学科重要且非常活跃的研究前沿之一。在配位聚合物的分子组装方法、用于储存气体的微孔配位聚合物、磁性配位聚合物、光电配位聚合物、用于手性分离和催化的配位聚合物等方面的成果表明，我国的配位聚合物研究已经形成了自己的特色，在国际上占有一定的地位，我国该领域的一些科学家在国际上已具有相当影响力。如我国发现了目前已知的乙炔气体有效储存量最大（在安全压力 1.5 大气压下的储存能力是普通气瓶 40 倍）的三维多孔结构三氮唑铜微孔金属有机框架化合物 MAF－2；得到了可以显示反铁磁性、亚铁磁性和铁磁性的过渡和鑭系元素配体参与的含金属类富勒烯簇；制备了显示明确的与顺电相—铁电相变化伴随的介电异常的铜—硒酸类矾化合

物分子基铁电体和一系列具有独特稀土发光性能的杂化材料；成功地合成了一系列光致变色金属有机配位聚合物和发光颜色可调控的单基质白色发光对氰基苯甲酸盐的银配位聚合物。我国科学家还在生物无机、功能陶瓷材料和其他无机功能材料等方面取得了进展。

(二)有机化学及相关新兴交叉学科

从包括合成、反应、机理、催化、金属有机、天然产物合成与分离、资源化学和生物质的绿色应用、化学生物学 8 个方面，我国科学家对有机化学及相关新兴交叉领域的进展作出了贡献。比如：实现了由铜和铁等普通金属催化的碳碳键形成、催化条件下高效简捷直接与多氟芳烃键合形成碳碳键的反应、芳香化合物的不对称氢化、采用水为反应物的具有明确区域和立体选择性的丙二烯类亲电反应等；以 H_2O_2 为氧化剂的烯烃环氧化、以氧气为氧化剂的醇氧化和用离子液体、双金属等催化的 CO_2 转化等绿色反应以及纤维素、木质素等多类可再生生物质资源的绿色转化取得重要进展；提出了双金属有机合成试剂及其“协同效应”、“自担载”手性催化剂、组合催化剂和资源化学研究中“共生反应”等概念，以及对催化的不对称氧氢插入反应机理进行了理论阐释；发现了基于捕捉活泼鎓叶立德中间体的多组分新反应、在温和条件下没有金属参与的合成芳香硼酸酯的新方法以及使用了过渡金属催化的惰性 C—O 键活化和底物中 C—O 的选择性断裂的各种偶联反应；开发出了多种小分子手性催化剂和手性卡宾催化剂以及对复杂天然产物、临床重要药物合成非常有用的构筑模块；成功合成与分离了数十种天然产物。化学生物学方面，在化学小分子探针的构建及机制研究、生物体系中相互作用信息的获取新方法、信号转导的化学生物学研究及基于信号转导途径的重要标记物、靶标和先导结构的发现等基于化学小分子探针的信号转导研究以及中药小分子的作用机制和干细胞研究等方面取得了系列成果和突破性进展。

(三)物理化学涉及的分支学科

纳米材料与化学方面，新结构形态(石墨酮和石墨炔)的发现、金属富勒烯套娃的制备、水分子在碳纳米管中流动的理论模拟、纳米水力发电的机理及可行性、单分子手术等方面的进展受到了国际的关注。分子动力学研究中，首次成功观测到了理论预测的反应共振态分波所引起的振荡峰，构建了 $H+SiH_4$ 反应的 12 维高精度从头算势能面，并提出和命名了 2 种新机理。在热力学方面，离子液体的分子间相互作用等基本问题的系统深入研究为其在化学反应中的应用提供了理论依据。催化研究中，由贵金属铂表面的配位不饱和亚铁纳米结构实现了室温条件下分子氧的高效活化，并在世界上首次实现了质子交换膜燃料电池真实操作条件下氢气中微量 CO 的完全脱除；在温和条件下超临界 CO_2 中用钯—路易斯酸体系以近乎 100％的效率和选择性将苯酚完全转化为环己酮；补偿的施受主共掺杂方法、光催化反应氧原子交换机理以及单分子层水在锐钛矿 TiO_2 的表面吸附的微观图像的获得等为制备高效 TiO_2 基光催化剂和调控光催化反应提供了科学依据。新能源方面，用锂离子掺杂技术成功得到创造物理吸附储氢纪录[77K 和 1bar 下，储氢量 6.1(wt)％]的三维共轭微孔材料；由研制的具有高吸收系数的有机染料 C217 制作

的染料敏化太阳能电池的光电转换效率(9.8%)居世界领先地位;变造成污染的大型海藻浒苔以及乳牛粪便等为生物燃油取得了突破。胶体与界面化学方面,提出了超分子表面活性剂的概念,构筑了一种在水溶液中能自组装形成超长纳米纤维的超分子表面活性剂;提出了"自模板法",构筑了多种一维有序螺旋结构;发展了一种以阳离子有机分子通过静电相互作用与具有多个电荷的无机多金属氧簇阴离子组装形成有机—无机杂化超分子反胶束的方法;制备了高度有序、不同形貌的蜂窝状薄膜;用胶体晶体模板法实现了新型图案化晶态材料的合成;由表面分子组装构筑了二维 Kagome 网格结构。此外,在刺激响应性小分子凝胶、生物传感以及超亲水和疏水性、超疏油表面的研究等方面也取得了明显进展。

(四)分析化学

在微纳流控分析系统研究方面取得了系列研究成果:建立了液塑法 PDMS 芯片和喷腊打印法纸芯片制备技术以及以物理吸附和化学修饰相结合的 PDMS 表面修饰技术;发展了多种微流控芯片上液滴操控技术;研制了包括微型电极、微型化电化学检测器、手持式吸收光度计和质谱检测集成化微流控芯片分析系统等多种微流控系统用的仪器设备;成功实现了微流控分析系统在样品预处理、蛋白质高效酶解、细胞培养及检测、核酸和免疫诊断与药物筛选以及纳流控技术在酶富集等方面的应用。在仪器分析新方法、生物芯片、电化学发光、传感、荧光探针、循环伏安和有机物毒性、天然产物和中草药分析等方面也取得了重要进展。特别值得指出的是,提出并建立的壳层隔绝纳米粒子增强拉曼光谱(shiners)方法对谱学发展具有重要意义。

(五)聚合物科学技术

提出了调节聚合物的组分和螺旋纳米纤维旋向的方法;构建了典型的 ABC 星型三嵌段聚合物体系溶液相自组装的完整相图;实现了嵌段共聚物在选择性溶剂中和在水/空气界面上的自组装;制备出了嵌段共聚物柱状胶束、棒—线团刷状聚合物和杂化聚合物中空微球和碗状复合微球等不同形貌的聚合物;提出了"连续点击偶合合成"用于非对称双烯化合物聚合、单体自组织辅助的无催化剂点击聚合、由长链"点击"反应获得星状 8 环聚合物和全部都是双偶联的、支化度 100%的超支化聚合物的合成方法;设计合成了高效、高选择性催化 CO_2 与脂肪族环氧烷烃共聚反应的热稳定单活性位点催化剂和双功能催化剂以及能够高顺 1,4 -选择性聚合异戊二烯的催化体系;得到了主链与侧链同时含有液晶相结构与转变的双重取向有序结构甲壳型液晶聚合物和兼具液晶性和发光的共轭聚炔;得到了显示可逆温度和 pH 双重响应性的超分子凝胶、电致变色聚二炔/碳纳米管复合纤维、具有(刺激响应性、生物相容性、生物降解性和荧光性等)多功能性的含二硫键超支化聚(酰胺-胺)、溶胶-凝胶可逆转变的聚乙二醇与环糊精准轮烷凝胶三元体系;突破了高代数树枝状分子不能形成凝胶限制的周边用间苯二甲酸二甲酯功能化的聚苯醚树枝状高分子凝胶、形貌可控聚苯胺的多级超结构;阐释了包括绝缘基质增强的半导体电荷传输的导电聚合物导电机制;得到了一系列用于药物缓释和输送的生物高分子和酶;获得了理想综合性能的再生蚕丝蛋白纤维;淀粉基聚合物的热加工取得了系列成果。

(六)有机光电子材料及器件

我国的有机光电子材料及器件研究在国际上具有重要影响。在由聚合物主体和小分子掺杂剂构成的掺杂类和单一聚合物类有机/聚合物白光器件研究中，开发出了多种性能居国际领先水平的白光体系，合成了一系列高效蓝、红光材料，制备出了高效固态白光发射电化学池；研制成功了组装的聚合物太阳能电池的填充因子、开路电压和能量转换效率均为文献报道最高值的受体 C_{60} 衍生物；制备出宽光谱(300～1450nm)响应且其暗电流和噪音远低于窄带隙无机半导体光检测器的聚合物光检测器；高性能有机场效应管研究中的界面工程和高度结构有序有机半导体分子薄膜的制备及其理论研究以及器件微型化研究取得了重要进展。

(七)应用化学

在过去的两年中，世界首创万吨级“煤制乙二醇”工业化示范获得成功；世界上第一套也是最大的甲醇制烯烃工业生产装置投料试车一次成功；研制出大容量钠硫储能电池和全钒液流储能电池，储能系统已成功示范运行；建成了发明的纳米材料绿色印刷制版技术的中试线；油田废水处理以及处理后废弃物的高值化应用新技术获得成功。这些独创或世界先进水平的突出进展具有巨大的经济与社会效益，是科技服务于国民经济发展和国家急需的突出范例，也是科技工作者坚决落实建设创新型国家方针的实际行动。此外，离子液体润滑剂、燃烧化学的诊断、古建筑用糯米灰浆成分之谜的破解等应用化学科技也取得重要进展。

(八)环境化学

环境化学在围绕持久性有机污染物的生成与降解机制、污染源的识别与污染控制、污染特征与环境行为、毒性与健康效应等方面的研究都有所突破，特别是对手性持久性有机污染物的研究，不仅处于该方面研究的前沿，还对其发展起到了一定的引领作用。比如：利用环境中持久性有机污染物的手性，研究其在环境中的降解和转换过程；以手性持久性有机污染物的对映体比例值作为示踪工具，在我国一些典型区域开展了识别手性农药来源的“新”与“老”以及追溯其在水和大气中归宿的相关研究；对映体选择性胚胎毒性、内分泌干扰效应、免疫毒性以及藻类和植物的对映体选择性研究取得了一系列创新成果，发现了 α－HCH 对映体选择性的穿越血脑屏障是导致(＋)－α－HCH 在脑组织中发生富集的主要原因；开发了短链氯化石蜡的分析方法。在多环芳烃、农药残留和重金属等污染的特征和控制方面的研究也有进展。

四、本学科发展趋势和展望

未来，化学学科有三大发展趋势：①化学将向更广、更深层次的方向延伸；②绿色化学将引起化学化工生产方式的变革；③化学学科将不断满足社会发展提出的新的需求，在解决战略性、全局性、前瞻性重大问题中将发挥更大的作用。

第二节　心理学

一、引　言

心理学研究的目标是人类意识的生物基础、机制和起源。《科学》杂志在创刊125年的周年特刊中提出了当代最重要也最具挑战的科学问题，其中排在第二位的就是心理学问题。随着物质生活的提高，人们更加需要了解自己精神方面的特征、机制、本质，心理学在追求这个目标的过程中，在全世界迅速地发展。

当前的心理学发展显现出以下几个特点：①多学科交叉研究趋势明显，越来越多的生理学、生物学、物理学、基因组学、生物化学、医学、计算机科学、社会学、数学、逻辑学研究人员加入到对心理现象和机制的研究中来；②多层面系统研究发展迅猛，几乎所有的心理学问题，都有人试图在基因、分子、生理生化、脑定位、脑功能、行为、计算机建模和数学建模等不同层面进行认知神经科学或认知科学研究；③心—身关系的研究厚积薄发，人们普遍意识到心理因素在各种心身疾患的症状及其治疗和干预中的重要作用，国民身心健康需求促进新医学正向“生物—心理—社会—工程”模式转化，并开始获得显著的经济效益和社会效益；④跨文化心理研究方兴未艾，文化对人的心理发展、认知加工和行为方式的影响已经得到全世界心理学界的公认，同时涌现出更多的需要从跨文化角度研究的心理学问题，心理学的国际和地区合作不断加强；⑤学科地位和作用日益凸显，全球化、信息化、老龄化和城市化进程加快，灾害频发，催生了许多心理行为问题或心理疾患，国家、政府和民众都开始期盼心理学发挥更重要的作用，心理学科的地位不断提升。

二、当前本学科研究的重点问题

当前心理学研究的重点问题有以下几个方面：

(1)意识的本质和其生物学基础仍然是心理学界最感兴趣的问题。与此相应的是，对潜意识和阈下刺激的影响的研究得到更多的重视。

(2)行为(广义的行为，包括记忆、决策等)的脑机制是当前研究的热点。现代脑成像技术不仅使得研究者可以研究未受损伤的、正在活动的脑，而且能更精确地定位脑的功能部位和活动过程。各类功能定位的研究方法已经广泛用于心理学各个分支的研究工作，而且仍然处于上升的趋势。

(3)群体行为的生物学基础和社会学因素的影响也是当前心理学研究的前沿问题。在人类的经济决策问题上，美国心理学家卡尼曼教授正是因为此方面的贡献，于2002年分享了诺贝尔经济学奖。如今，对人类群体行为的研究已经远远超过了经济决策范围。这可能和当前人类面临的新的非传统威胁有很大关系。

(4)健康心理学是最近20年心理学发展最快的领域之一。它从心理因素的致病性和心理因素对健康的保障性两个大的方面，从生物心理学、认知心理学、异常心理学、社会心理学等方面全面地展开研究，已经获得很多成果，表达了人类对健康和长寿的追求，改变

了人类对传统意义的简单的身体健康的观念，是人类对生活意义的认识的一次极大的飞跃，在发达国家已经使得原有的简单的身体导向的医学观念正在快速地提高为身体的、心理的、社会的三维度的全面的医学观念，为其国民的健康和幸福提升了保障水平和理论指导。

(5)人类心理的基因基础在有条件的国家也得到更多的重视。由于基因科学和基因技术的发展，心理学有了更多可能去探索心理问题的基因基础。

三、本学科最新研究进展

近几年我国心理学在理论研究和社会应用两方面都取得了长足的进展。在认知神经科学的研究中，我国学者关于知觉与注意的多项研究被《神经科学杂志》(*Journal of Neuroscience*)、《当代生物学》(*Current Biology*)、《美国科学院院刊》(*PNAS*)、《PLoS 生物学》(*PLoS Biology*)、《心理科学》(*Psychological Science*)等具有国际影响力的权威学术期刊刊登。知觉研究由视觉、听觉向触觉、嗅觉以及多感觉的融合等领域扩展。关于汉语认知与发展的研究也正在蓬勃发展中。在社会认知神经科学的研究中，我国学者在经济决策、中国人的自我等问题上成果显著。在心理健康领域，我国学者近几年来持续开展了针对各个年龄阶段、各个职业群体的心理调查工作，建立了《中国人心理健康量表》全国常模。

此外，随着社会的发展和变化，新的心理问题也随之而来，由此在我国发展起了一些新的心理学分支，以满足解决社会问题的需要。例如：研究互联网相关情景下，人的心理、行为及其规律性的网络心理学；采用心理学的方法和技术来研究灾害对个体和群体心理与行为的影响，揭示其发展和变化规律，并探讨有效应对和干预方法的灾害心理学。

最后一项值得一提的进展就是近两年来在我国建立的大型心理特征基础数据体系：一是中国科学院心理研究所承担的《国民重要心理特征调查》的研究工作；二是北京师范大学认知神经科学与学习国家重点实验室承担的“中国儿童青少年心理发育特征调查”的研究工作。这两项工作不仅在规模上打破了我国心理特征调查样本的记录，而且系统、科学地对我国国民心理特征进行调查和监测，建立了包含多个指标的国民心理特征基础数据体系，这对于揭示我国国民心理特征毕生发展规律，推动心理科学及相关生命科学、社会科学等学科的发展，促进全民心理健康，建立科学的社会指标体系等均有着重大的意义。

除上述进展以外，还有以下 7 个反映近两年心理学发展热点或取得了突出成就的研究领域。

1.《中国心理健康量表》的编制及应用

介绍中国科学院心理研究所以自主研究的《中国心理健康量表》为核心工具对全国范围的不同群体进行测查的数据结果，为了解我国国民心理健康状况提供了重要资料。

2. 灾害心理行为研究与心理援助

回顾了“5.12”汶川大地震以来，我国研究者在灾后心理创伤领域内的研究进展。同时，总结了我国心理学工作开展灾后心理援助工作的主要内容与成就，包括为政府灾后心

理援助工作提供决策依据、开展灾后枢纽人群培训、探索灾后心理援助管理和工作模式并进行灾后心理健康知识的普及。

3. 中国儿童青少年心理发展特征常模的研究进展

我国第一项全国范围的大型研究“中国儿童青少年心理发育特征调查项目”，该项目通过全国31个省市自治区的100个区县的取样，实现了全国范围的儿童青少年代表性取样和测查，建构了我国首套具有全国和区域代表性的儿童青少年心理发展特征常模。

4. 中国人的自尊：特征、相关因素及培养

对我国学者的自尊研究进行了梳理和归纳，总结了中国人的自尊特点。

5. 中国人价值观：特点、取向及模型

综述了关于中国人价值观特点，这些研究对象涵盖对工人、农民、中学生、大学生、专业技术人员等群体，发现了中国人价值观总体表现为积极向上的特点。

6. 幸福感研究新近成果和进展

以当今热门的幸福心理学为主题，对幸福感近年来的研究成果进行了回顾和总结。从幸福感的概念界定、测量方法、影响因素以及决策和幸福感等方面展开论述和讨论，并提出我国心理学者在幸福心理学领域的未来研究方向。

7. 药物成瘾精神依赖的生理心理机制研究进展

精神依赖是药物成瘾长期存在的原因也是治疗的难点。该专题就此主题总结了近年来关于成瘾记忆生理心理机制的研究取得了一些重要进展。

四、本学科国内外研究进展比较与前景展望

总体看，我国心理科学发展的状态，与我们整个国家发展的状态具有非常高的同步性。与发达国家相比，我国心理学的总体研究水平、科学产出、人才培养、实际应用都有很大的发展的空间。与发达国家的心理学相比，以下几个方面的差距非常明显。

(1)我国心理学的科学地位不如发达国家。在我国，对心理学的重视仅限于概念上，尽管我国领导人经常提及心理学的重要性，但在落实方面，心理学在我国的科学地位，远远不如发达国家。例如在美国，在国家层面有直接给予心理学申请的基金。而在我国，心理学还是放在其他学科之中。在我国教育体系的归类中，也没有心理学的一级分类，心理学是隶属于教育学，或者其他学科，这与发达国家的差别也是非常明显的。

(2)由于对心理学的总的投入不足，我国从事心理学基础研究，或者有条件从事心理学基础研究的人员非常少。

(3)我国心理学研究的范围比较局限。我国心理学人员多数在师范类高校，从事的多是教育心理学研究。心理学全谱系至少有30个学科分支，在我国从事教育心理研究以外的学科的人数非常有限，表现为贫乏状态下的进一步的不平衡。

(4)我国心理学研究多数是应用和应用性研究。但是，由于缺少基础研究的支撑，这些应用研究多数的水平难以提升。这和发达国家的心理学研究主要从事基础研究也是很大的不同。

(5)我国社会各界对心理学的认识影响了心理学的发展。在很多场合,因为不同的原因,将心理健康问题与精神病问题混为一谈。在发达国家的医务系统中,心理学者是不可或缺的组成人员,而在我国常常以精神病人员代替心理学人员,由此产生了很多基本的和实际的问题。

(6)在实际工作中,常常忽视了心理学。比如,在发达国家,任何一种新的机器系统,特别是武器系统的研制过程中,从一开始就有专门的心理学人员参加,在我国则缺少这样的认识和举措。

(7)对心理学的应用,缺少法律层次的保证。在我国还没有与心理学和心理健康相关的统一规定(或者法规),政出多门,标准不一,服务水平差异巨大,都影响了心理学的应用;而社会的应用必然影响心理学的人才培养和研究工作的发展。

然而,我们也看到,心理学在我国越来越受到党和政府最高层的重视。在党的十六届四中全会的决议中,专门用很大的篇幅指明了心理学工作的任务。与此同时,心理学自身所具有的探索人类意识的吸引力、人类对自身精神世界了解的渴望、人类对健康的追求、人类对他人行为的判断的需要和人类社会各个方面事业发展必须符合人的心理特征、满足人的心理需求的必然性,都在推动心理学的加速发展。可以预料,在今后十年之内,我国心理学必定有一个大面积、高水平的发展时期。为了保证和促进这个发展,需要在以下几个方面给予更多的重视。

(1)加强对心理学基础研究的投入。

(2)改进心理学的人才培养体系。

(3)支持心理学的国际合作,特别是邀请发达国家的心理学教学和研究人员来我国工作,扩大我国的心理学的影响。

(4)在政策上支持心理学的发展,除了经费投入以外,在心理学能够发挥作用的企事业单位设立心理学的工作岗位。条件成熟时,制定“心理健康促进法”,以保障国人的心理健康、促进社会稳定、提高工作效率。设立教育体系和基金支持体系中的心理学的一级学科,使学科的发展有制度性的保证。

(5)适度放松申请新的学术刊物的审批,增加心理学学术期刊种类,使我国心理学研究者的成果能够得到发表和交流,使国家的投入能够发挥实际的效果;增设英文期刊,使我国心理的研究成果能为国际科学体所共享,同时也提高我国心理学科学的国际影响力。

(6)重视心理学的普及工作。从小学起设置少量心理学的基本课程,帮助国人从小了解自己,促进人的发展。通过各种形式的心理学知识的普及,提高国民科学素养和心理素养。通过媒体和科普读物提供心理学知识,帮助国人更好地生活和发展。

第三节　机械工程(成形制造)

一、引　言

成形制造,主要包括铸造成形、塑性成形、焊接成形、材料改性与控制工程、表面工程

以及再制造成形，是支撑国民经济可持续发展与国防建设的主要技术，为我国航空航天、重大装备高端制造、能源工业与汽车工业的发展做出了重大贡献。成形制造是材料质量不变或增加，但又能实现零构件成形成性一体化成形的物理过程，也是涉及多学科交叉融合、高度非线性的技术密集、知识密集和高增值的过程。通过创造合适的成形方式与成形条件，成形制造可发展成为高性能精确成形制造技术，成为少无废料产生、绿色、节约型的高性能轻量化零构件高端制造的主流技术，在实现节能减排、发展低碳经济、建设创新型国家等方面将发挥不可替代的作用。我国正在实施的国家与国防中长期科技发展规划以及“大型飞机”、“载人航天与探月工程”与“高档数控机床与基础制造装备”等一系列科技重大专项与重大工程，对发展先进成形制造技术都有迫切而重大的需求，迫切要求先进成形制造朝着高性能、轻量化、高精度、低成本、高效率、能源高效利用与资源节约、环境友好的方向发展。上述客观作用、重大需求与学科发展前沿使先进成形制造研究总体发展趋势聚焦在高性能精确成形制造上。其发展已成为体现一个国家工业综合实力、竞争力和科技水平的重要标志之一，对推动我国国民经济、国防建设和社会发展具有重大意义。

二、本学科近年的最新研究进展

(一)铸造成形领域

近年来，节能、环保、高效和低成本铸造成形技术研究发展较快，对提升我国铸造技术水平、增强核心竞争力起到了重要作用。我国通过凝固成形原理、技术与装备的集成创新，形成了调压铸造成套技术，解决了铝、镁合金大型复杂优质薄壁铸件成形难题。基于数字化的快速铸型无模化制造技术具有数字化、精密化、柔性化、绿色化、短周期、低成本等特点，也得到了快速发展，已开发出国内首台铸型数字化加工机，能够完成水玻璃砂型、树脂砂型、覆膜砂型等多种铸造用砂型的加工制造；与激光选择性烧结快速成形技术相结合，实现了汽车发动机缸体、排气管等复杂铸件的快速制造。目前基于激光的金属复杂零件直接成形已成为航空航天等领域的研究热点，在钛合金大型复杂承力结构件激光快速成形的工艺、组织和性能控制等关键技术方面取得了多项重要进展，已实现在先进飞机、航空发动机和口腔修复体等上的应用。实现了基于相场法和元胞自动机法的凝固过程及微观组织的多尺度数值模拟，为我国单晶涡轮叶片质量控制提供了理论依据。

(二)塑性成形领域

近年来，我国在核电等高端大锻件技术研发和制造取得突破性进展，基本掌握了600吨级特大型钢锭的制造技术和大型锻造过程材料组织控制技术，发展了封头、管板类件、复杂筒形件、主管道件和特大型轴类件等锻件的锻造成形技术，使我国“二代加”核岛主设备全部锻件实现批量生产，“三代”核电AP1000核岛锻件全部研制成功，700MW级水电机组锻件实现批量生产，1000MW级火电超临界机组重要锻件研制成功，实现了核电等高端大锻件国产化，在建国家核电重点项目材料和产品的制造任务基本由国内承担。已建和在建多台1.5万～8万t锻造液压机，自由锻液压机的等级和数量近几年已进入世界前列。世界上最大的3.6万t大口径钢管垂直挤压成套装备以及具有国际先进水平的

45MN 大型快速锻造液压机组已投入使用。发展了基于局部加载与等温成形有机结合的省力关键成形技术，为突破装备能力限制、实现钛合金大型复杂构件成形成性一体化高性能近净成形制造提供了技术支撑。研究解决了变形与组织控制多项关键技术，成功研制了满足航空锻件要求的、目前国内最大的钛合金复杂隔框锻件。此外，在凸轮轴和偏心轴等非回转体轴类楔横轧精确成形、载重汽车轻量化车轮辗—旋联合精密成形、大型非规则空间曲面零件多点成形技术和成形装备、利用内凹形预成形坯降低内高压压力、大飞机和先进军机的“血管”类关键轻量化构件——铝合金、钛合金大直径小半径弯曲薄壁管精确数控弯曲稳健成形成套工艺与模具技术以及大型复杂环件径轴向热力耦合辗轧成形全过程宏微观 3D－FEM 模拟模型及其控制仿真等方面，也已取得了重要进展。

(三)焊接成形领域

近年来，我国在大型结构的整体焊接工艺、焊接变形控制、接头性能调控以及焊接结构完整性评价研究方面取得重要进展，其成果已应用于三峡船闸、水轮机转子、蜗壳及鸟巢结构的焊接制造中。鸟巢结构焊接技术成果获 2010 年国际焊接学会 UGO GUERRERA 奖。焊接材料的洁净化、均匀化、细晶化和低碳化技术成果在西气东输二线工程中得到应用。开发出新型激光－电弧复合焊接工艺方法，已应用于高级铝合金轿车制造中；固体激光－熔化极电弧复合焊接技术已在高强钢军工部件焊接中得到应用。已基本掌握航空常用材料的电子束焊接工艺，研制了高压电子束焊机，可完成 4m×2m 范围内任何焊缝的焊接，并开发了钛合金大型构件焊接工艺技术，最大焊接厚度可达 105mm，解决了大厚度钛合金焊缝成形、缺陷控制以及焊接变形抑制难题。焊接数值模拟、自动化焊接与智能化焊接研究方面也取得了长足进步。

(四)材料改性与控制工程领域

从原子电子结构理论出发，进行成分与微结构设计，设计并制造出以 Aermet100 钢为代表的系列高强钢，提出了相应的合金化与强韧化的精确热处理基础理论，优化设计出的热处理工艺技术用于高强钢改性，解决了以飞机起落架为代表的关键基础构件长寿命与高可靠性制造难题。提出了稀土化学热处理新理论和高效高性能工艺技术体系。在既保证热处理零部件变形均匀性又实现性能设计的数值模拟方面取得了处于国际领先的成果。材料纳米改性已经成为充分发挥材料潜力，提高装备制造业产品的使用性能、寿命和可靠性的关键科学技术，近年来我国学者在该方面也取得了重要进展。

(五)表面工程领域

发展了纳米复合表面工程理论和技术体系，实现了纳米材料在机械工程领域的实际应用，研发了纳米颗粒复合电刷镀技术、纳米硬膜技术、纳米热喷涂技术、纳米自修复技术等，实现了装备关键零部件的修复延寿。通过在润滑油中配加纳米金属 Cu 颗粒、矿物微粉等成功开发了系列纳米减摩自修复添加剂，对发动机气缸—活塞环摩擦副的自修复效果十分明显，修复后的活塞基本达到了“零磨损”。研制的复合层状硅酸盐、稀土化合物及表面改性剂的金属表面强化减摩修复剂，具有修复、表面强化和精细磨合等功能，可在金

属表面形成具有一定厚度的含 FeC_3、Fe_3O_4 及铁镁硅酸盐纳米晶的高硬度修复层，从而显著提高摩擦部件耐降低摩擦副表面粗糙度，改善润滑状态，达到节能降耗的效果。发展了多种适用于空间环境和核环境的高性能特种润滑材料。发展了 MoS_2 - Au - RE 三元复合膜、梯度多层 Ni - Cu - Ag 复合膜、多层无机和金属纳米复合膜、TiAgN 纳米复合膜等具有不同特点的空间技术润滑薄膜，已成功应用于“神舟”、“尖兵”等多种航天型号，解决了空间运动部件的长寿命特殊润滑难题。作为“神舟七号”飞行执行的唯一舱外科学试验任务，进行了多种类型空间润滑材料在轨搭载科学试验，取得了空间环境暴露对多种固体润滑材料性能影响的第一手数据，为进一步发展高性能空间润滑材料奠定了重要基础。发展了具有自主知识产权的耐强辐射聚酰亚胺固体润滑涂层，已在国产高温气冷堆和其它反应堆的轴承、齿轮、滑板、凸轮、链条、联杆等几百个部件上获得了应用，解决了核反应堆机械在高温氦气强辐射条件下的特殊润滑问题。此外，在太阳能集热选择性吸收薄膜材料制备装备和技术、工程化超润滑复合碳膜技术以及纳米复合微弧氧化陶瓷层技术等方面也取得重要研究进展。

（六）再制造成形领域

我国已经探索形成了“以高新技术为支撑，以恢复尺寸、提升性能的表面工程技术为依托，产学研相结合，既循环又经济”的中国特色的再制造模式。再制造成形技术方法、材料、设备和产业化应用等获得了快速发展。自主研发了纳米复合电刷镀再制造成形技术，实现了磨损失效零件的高性能修复延寿再制造，研究成果已在几十家单位推广应用，解决了飞机、舰船、重载车辆、工程机械等装备关键零部件再制造延寿重大难题。发展了再制造成形应力应变控制理论与方法、再制造成形质量评价和寿命预测理论与方法。研发了自动化再制造成形技术，自动化高速电弧喷涂再制造成形、等离子熔覆再制造成形、激光熔覆再制造成形等技术方法，实现了再制造产业化应用。研制出了具有野外伴随和现场抢修功能的再制造成形工艺设备，实现了大型设备贵重零部件的现场高性能再制造成形。多家科研院校和企业应用激光再制造成形技术，解决了冶金、石化、电力、交通等不同工业领域装备关键零部件的再制造成形。针对航空零件的激光再制造开展了系统研究，在成形工艺、组织的定向凝固及力学性能、激光成形件热处理等方面取得了重要进展。

三、本学科国内外研究进展比较

我国铸造技术和铸造机械的发展水平与国外相比有较大的差距，我国铸件存在的尺寸精度低、表面质量差、质量稳定性差、铸件性能低和能耗大等问题，这就迫切需要对凝固精确成形与高性能控制进行系统深入的基础研究和技术创新，包括清洁能源中的大型叶片和高推重比航空发动机高温合金单晶叶片高质量铸造成形、金属大型整体和复杂关键结构件激光快速成形等。

发达国家在轻量化车身高强度板材整体冷、热冲压精确成形和高效整体壁板时效成形、内高压成形和轻合金大直径薄壁管精确数控弯曲成形的技术研发方面已经达到了工业实用化程度，而国内则有明显差距。我国楔横轧成形技术研发处于国际领先水平，但我国在以轴承环件精密冷轧成形技术为代表的高端基础件高性能高效精确成形自主创新能

力方面还十分薄弱，以至于重要主机的轴承还主要依赖进口。大型复杂整体构件高端成形制造与国家重大需求和国际水平有很大差距，迫切需要开展成形成性一体化控制技术以及省力成形关键技术研发。

近年来，国民经济的发展和国防建设的需要促进了我国先进焊接成形技术的快速发展，但与国际水平比较还有较大差距，尤其在轻质高强材料优质高效焊接及超常条件下的焊接、焊接自动化技术、钎焊扩散焊技术与焊接数值模拟方面。

发达国家已迈向热处理场的精确调控阶段，我国热处理数值模拟处于国际领先水平，但总体上与国外热处理技术先进水平相差较大，尚不能满足装备制造业对高性能和高可靠性的需求。

我国学者在纳米电刷镀技术、纳米热喷涂技术、材料表面自身纳米化技术、纳米减摩自修复添加剂技术和纳米复合微弧氧化陶瓷层技术等先进纳米表面工程方面的研究和应用处于国际先进水平，但在用于纳米表面工程的纳米材料和纳米功能涂层的制备以及涂层的纳米加工等方面与国际先进水平还存在较大差距。

我国在再制造成形基础理论研究以及激光再制造成形、纳米复合再制造成形等关键技术研发和应用方面具有国际领先水平。我国的再制造成形技术以恢复零件原始尺寸、提升零件性能为目的，在零件延寿和节能减排效果等方面，优于国外普遍采用的尺寸加工再制造成形技术方法。但是，在再制造成形工艺设备性能可靠性和配套性方面还存在较大差距。

四、本学科发展趋势及展望

(一)铸造成形

以发展高性能凝固精确成形技术为主要目标，发展多能场下高性能、高洁净、高均质大型零构件的精确凝固成形；数字化无模精铸、高性能金属复杂零构件的激光等快速凝固精确成形；高温合金定向及单晶凝固成形过程工艺—组织—性能的精确控制。

(二)塑性成形

以发展高性能大型/复杂件高效节约型精确成形成性一体化制造技术为主要目标，发展轻质高强板材复杂件刚性模具整体冷、热冲压成形、柔性增量成形技术；超高内压、热态内压成形技术，高性能轻合金管多约束精确成形技术；高效、节约型整体加载、局部加载及其结合精确成形与高性能协同控制先进技术；特大型高性能构件的成形成性一体化质量控制以及局部加载省力成形关键技术；微细结构件的低成本批量微成形技术；基于多场耦合全过程多尺度建模仿真与优化的数字化精确塑性成形技术。

(三)焊接成形

以发展优质高效焊接与超常条件下焊接技术为主要目标，发展轻质高强材料激光电弧复合焊接、超声—搅拌摩擦复合焊接，超声—钎焊及超声—扩散连接，溶焊—钎焊复合焊接等优质高效焊接新方法；大型复杂结构与特种环境下的先进焊接技术、焊接数值模拟

及焊接过程传感与焊接质量控制技术等。

(四)材料改性与控制工程

以发展各种整体和表面处理技术与装备来实现对材料和成形零部件成分、组织结构和性能与变形的精确调控为主要目标,发展实现高性能与高可靠基础构件制造的组织结构多场化、复合化和精密化调控方法,包括满足组织结构设计、多场下组织结构演变规律及其调控理论、组织结构演变可视化与精密热处理优化、复合场下精密热处理参数的智能化控制。

(五)表面工程

以发展高性能、低能耗、绿色的表面工程技术为主要目标,发展极端高温高压下零部件防腐蚀和氧化的涂层技术;提高水力发电涡轮机和风力发动机叶片的使用寿命的表面工程技术;提高发动机效力和性能的热障涂层、清洁控制涂层、抗氧化/耐腐蚀的涂层和耐磨涂层技术;适应环境保护要求的节能降耗的功能性表面技术。

(六)再制造成形

以发展智能化、复合化、专业化等适合批量化生产的再制造成形技术为主要目标,加强自动化再制造成形技术及其工艺设备研发和应用,并由宏观尺度向微纳观尺度发展,由纯机械零部件领域的再制造向机械/电子复合、机械/功能复合等以机械系统为载体的多功能复合领域发展,并从再制造成形的基础理论、关键技术、技术标准以及专门人才培养等方面予以重点突破。

第四节　农业工程

一、引　言

我国正处于从传统农业向现代农业转变的关键时期,农业工程学科作为建设现代农业、转变农业发展方式的重要科技支撑,担负着重大的历史责任和使命。随着我国现代农业的迅速发展,农业工程学科领域的研究重点在注重理论和机理突破的同时,对现代农业产业发展和新农村建设的有关工程问题的解决能力有了明显的提升,农业工程学科的社会地位和认可度日益提高,农业工程领域所从事的研究和技术推广得到前所未有的重视和支持。随着农业现代化和国家工业化、城镇化同步推进战略的提出,加快现代农业和新农村建设对农业工程科技发展提出了全面、系统的新要求,日趋激烈的国际竞争也要求我国的农业装备、信息技术和设施水平能尽快缩小与发达国家的差距。因此,加快提高农业工程学科的创新能力和研究水平,建立面向现代农业生产的工程技术支撑体系,培养一大批农业工程领域的技术服务和学术创新人才,具有重要的作用和意义。

二、本学科近两年发展概况

2009～2010 年，我国农业工程学科所属的农业机械化工程、农业水土工程、农业生物环境工程、农村能源工程、农业电气化与自动化工程、农产品加工与贮藏工程和土地利用工程等领域的发展取得了长足的进步，获得了一批创新性成果，科技成果受益面日益增大。

(一)农业机械化工程领域

研究领域进一步扩展，从主要粮食作物转向经济作物、水果和蔬菜等。科研成果也更加丰富，在玉米不对行联合收获机、北方一年两熟区小麦免耕播种关键技术与装备、干旱半干旱农牧交错区保护性耕作关键技术与装备的开发与应用、农业装备技术创新工程四个方面分别获得国家科技进步奖，在水稻直播机械化、甘蔗生产机械化、油菜直播机械化、丘陵山区机械化、块根茎类种植和收获机械化、精准农业、农垦地区农业机械化、牧草生产机械与装备等方面也取得了一批达到国际先进水平甚至领先水平的创新性成果。

在国家农机购置补贴政策和农业机械化工程科技成果的支持下，全国农业机械化水平继续快速发展。2009 年年底，全国农机总动力达到8.75 亿 kW，主要作物耕种收综合机械化水平达到 49.1%，其中小麦、水稻和玉米的耕种收综合机械化水平分别达到 89.37%、55.33%和 60.24%。玉米机械化收获取得重大进展，仅山东省玉米的机收率就达到 70%；大豆、花生、油菜的耕种收综合机械化水平分别达到 68.68%、36.34%和 23.83%；马铃薯、棉花的耕种收综合机械化水平分别达到 23.23%和 47.83%；甘蔗、甜菜等经济作物，柑橘、苹果等水果以及牧草的机械化生产及加工都有很大的发展。

(二)农业水土工程领域

研究范畴已逐步拓宽至农业高效节水理论、农业节水灌溉新技术与节水灌溉设备、中低产田改良的排水技术、农业水资源持续利用理论与工程技术、灌区用水管理、农业水土环境监测修复与保育、农村供水工程、农业高效用水的工程技术等领域。

在农村水利尤其是农业高效用水方面实施了一系列国家级重大科研项目："西部干旱地区节水技术及产品开发与推广"获 2009 年国家科技进步二等奖，"农业化学节水调控关键技术与系列新产品产业化开发及应用"获 2010 年国家科技进步二等奖，"精量高效灌溉水管理关键技术与产品研发"获 2009 年大禹奖一等奖等。另外，获得了一批具有自主知识产权的技术与产品，在部分关键技术上取得了突破；初步构建了具有中国特色的现代节水农业技术体系与发展模式，推动了农业高效用水技术进步；促进了农业节水科技产业化进程，产生了显著的经济社会效益和环境效应。

(三)农业生物环境工程领域

不断融入新材料与新技术，已发展成为集建筑、信息、电子、计算机、机械、化工、生物、管理等多学科于一体的综合性交叉性边缘性学科，集中体现了现代农业的特征与水平。

设施园艺取得了丰硕的科技成果，"都市型设施园艺栽培模式创新及关键技术研究与

示范推广”和“温室关键设备及有机基质的开发应用”分别获得 2009 年和 2010 年国家科技进步二等奖；日光温室光温环境动态模拟模型得到不断丰富和完善，相应的计算机软件开始试用，对于科学设计日光温室结构将发挥重要作用；大型植物工厂研发取得明显进展。国家标准《GB/T 23393—2009　设施园艺工程术语》于 2009 年颁布实施。

畜牧工程领域，随着国际上对畜禽健康养殖和动物福利的不断重视，我国畜牧工程科学技术方面得到不断创新与发展。在规模化猪场母猪精确饲喂舍饲散养工艺，生猪及其产品可追溯体系，云南省健康养猪生产工艺模式研究应用及产业化示范，蛋鸡生产模式，微酸性电解水在畜禽养殖场和设施农业中的无害化消毒应用等方面取得了创新性研究成果。

（四）农村能源工程领域

“太阳能和浅层地热能在建筑中利用的关键技术开发与应用”项目获得 2009 年国家科技进步二等奖。“农作物秸秆能源化利用资源调查与评价研究”获国家能源局 2008～2009 年度软科学研究优秀成果二等奖。制定的农业行业标准《农作物秸秆资源调查与评价技术规范》已被国家采纳，用于指导全国农作物秸秆资源调查与评价工作。

农村沼气 CDM 项目开发取得了实质性进展，并已成功注册两个沼气 CDM 项目。基于该项目组提出的“AMS Ⅲ－R/Ver.1－农户/小规模农场农业活动中的甲烷回收方法”获得了联合国 CDM 执行理事会的批准。在风资源评价中，以卫星遥感技术为主要信息源，以数字图像处理和信息提取技术为手段，反演地面（特别是近海岸）风场参数（风速、方向），已逐渐从试验走向成熟。在秸秆沼气方面也取得了一定的突破，我国已建成约 10 座规模化秸秆沼气工程并投入正常运行。2009 年，农业部在黑龙江、内蒙古、天津、河北、河南、山东、山西、陕西等 13 个省（市、区）又安排了 16 个试点工程。生物质固体成型燃料项目目前正处于试点示范阶段。已发布《NY/T 1878—2010　生物质固体成型燃料技术条件》、《NY/T 1879—2010　生物质固体成型燃料采样方法》、《NY/T 1880—2010　生物质固体成型燃料样品制备方法》、《NY/T 1881—2010　生物质固体成型燃料试验方法》、《NY/T 1882—2010　生物质固体成型燃料成型设备技术条件》、《NY/T 1883—2010　生物质固体成型燃料成型设备试验方法》等 13 个项目农业行业标准，正在加快构建我国生物质固体成型燃料标准体系。在太阳能热利用方面，力诺集团与清华大学研发了“中温太阳能真空集热管和中温真空管集热器”两项新产品，首创了钛、铝双靶磁控反应溅射技术，改进了真空排气工艺，研发了 150℃的全玻璃真空集热管，首创了工作在 150℃的新型竖单排、横双排无盖板、横双排带盖板三种中温太阳能集热器。我国的晶 Si 电池、非晶 Si 电池、多晶 Si 薄膜电池、CdTe 电池、CI(G)S 电池、DSSC 电池等太阳能光伏电池及应用系统的关键技术正逐步实现突破，使太阳能光伏电池转换效率不断提高、成本逐渐下降，相对完备的太阳能光伏发电技术体系正逐步建立。

（五）农业电气化与自动化工程领域

研究方向和领域进一步拓展，科学内涵不断丰富，已发展成为集电气工程、电子工程、计算机工程、通信技术、生物和生命科学技术以及信息化技术于一体，同时开展科学研究、

系统集成和工程应用的综合性重点学科。

在农业传感与自动化基础理论研究方面，如土壤和环境参数检测、可控环境生产自动化控制等领域的基础和前沿理论研究取得了突破性进展，部分成果处于世界领先水平。在精准农业关键技术研究与示范工程建设上，提出了作物生长发育理化参量和农田信息遥感反演理论方法体系，研制了便携式和机载农田信息采集软硬件产品和无线传输系统以及与国产拖拉机配套的变量施肥、喷药机具和收割机智能测产系统，对于引领我国农业科技创新具有重大意义。在精准农业变量施肥装备关键技术及应用，农作物水分综合信息获取与先进传感技术研究，烟叶近红外技术的系列应用研究，新农村供电模式及综合示范工程建设，区域电网无功优化及电力综合测控技术，多功能智能配电装置，电力综合测控终端，农村电网智能型控制与保护开关，有载调压变压器智能调压系统，分布式农网电能质量监测分析系统，农村小型可再生能源发电技术与装备，热像测温与故障定位巡检机器人，农业环境无线智能监测系统，SWR 系列土壤水分传感器和 TSC 系列土壤水分测试仪产业化，基于相位检测原理的 TDR 土壤水分测试仪，便携式无线高清图像采集仪，接触式叶片叶绿素、氮素、水分一体化测定仪，玉米品种认知与精确应用系统，水产集约养殖数字化集成系统，基于自动视觉检测的棉花异性纤维在线识别方法研究，基于物联网技术的矿山土地复垦监管系统研究，农村电力与农业传感器领域科技成果转化及应用方面都取得了创新性成果并开展了科技成果转化及应用。

(六)农产品加工与贮藏工程领域

开发了以生物技术、纳米技术以及细胞分子水平为基础的一系列新技术、新工艺、新方法和新产品，建立了一批产业化示范基地。在重大关键和共性技术与理论方面取得了先进性和创新性的科技成果。中国工程院组织开展了中国农业工程科技中长期(2011～2030 年)发展战略研究(农产品深加工与产品安全工程科技发展战略专题研究)。现代科学技术的日新月异给农产品加工与贮藏学科提出了新的科学问题，我国社会经济和农产品加工行业的发展以及世界经济环境，特别是金融危机等也对农产品加工与贮藏学科提出了新的国家战略需求。近年来，农产品加工行业的发展承受着很大压力，但是仍然保持了较为稳定的增长势头。

(七)土地利用工程领域

紧密结合土地管理实践，在土地利用工程的理论、技术和方法等方面进行了研究，取得了新的进展：土地开发整理的理论与技术方面取得的进展主要集中在土地整理景观生态规划设计、土地整理潜力与效益评价、耕地后备资源开发评价和土地整理新技术等方面；工矿废弃地复垦与生态恢复方面取得的进展主要有生态化恢复模式、复垦改良修复技术以及土地复垦信息技术开发与应用等，有效地丰富了工矿区土地复垦理论和技术体系；土地评价与等级提升的进展主要集中在农用地分等方法的改进与优化、农用地分等成果的应用以及耕地等级折算等方面；城乡统筹与节约用地研究主要集中在村庄整治发展方向与整理模式、村庄整理潜力测算与效益评价以及村庄整理机制创新等方面，提出了村庄整理的集中典型发展模式，划分了村庄整治潜力类型，有效地促进了村庄整治的科学

发展。

我国土地利用工程研究整体上还处于发展阶段，大多数土地整理复垦的主要目标仍是增加耕地数量，尚未进入以提高土地质量和改善生态环境为主要目的的高级阶段。对土地利用工程工作提出了新的、更高的要求，逐步实现从注重数量向数量、质量、生态管护并重的方向转变，从土地资源开发利用向土地资源集约节约和构建和谐社会方向转变。因此，深入开展以土地利用工程为核心的理论、方法与应用研究，建立土地利用工程可持续发展的理论与方法体系是非常必须和紧迫的，土地利用工程学科的发展面临着重大的机遇和挑战。

三、本学科近两年发展成就和标志性成果

(一)队伍建设

农业工程学科队伍建设取得显著成绩，学科学术队伍的整体实力显著增强。罗锡文教授于2009年当选为中国工程院院士，李延斌教授和张源辉教授分别由浙江大学和中国农业大学申报并入选国家千人计划，中国农业大学李洪文教授和浙江大学应义斌教授入选教育部长江学者奖励计划特聘教授，华南农业大学罗锡文教授、浙江大学何勇教授和沈阳农业大学李天来教授被评为国家教学名师，江苏大学袁寿其教授荣获何梁何利基金科学与技术创新奖，浙江大学应义斌教授获宝钢教育基金优秀教师特等奖，中国农业机械化科学研究院陈志研究员、中国一拖郭志强研究员、浙江工业大学张立彬教授、国家农业信息化工程技术中心赵春江教授和浙江大学应义斌教授获全国优秀科技工作者，一批中青年骨干教师获教育部新世纪优秀人才等称号。

(二)科学研究

获得国家技术发明二等奖1项、国家科技进步奖二等奖10项，新增科研课题2 030项，新增科研经费11.81亿元；其中国际合作课题9项、国家级课题540项。国际合作课题和国家级课题经费占总经费的58%；社会委托项目发展很快，总经费近亿元，说明农业工程学科在我国农业科技创新中发挥重要作用的同时，服务社会工作也很有成效。在承担课题方面取得长足进步的同时，学术论文和发明专利在数量和质量上均有不菲的成绩，2009～2010年共在SCI和EI收录期刊及一级学报上发表学术论文4117篇，其中SCI收录论文603篇，EI收录论文1569篇，授权发明专利达416件。

(三)人才培养

农业工程学科在2009～2010年共有283名博士研究生毕业并获得博士学位，其中留学生3名；招收博士研究生469名，其中留学生24名；出站博士后37名，进站博士后88名，其中国外博士后4名。获得全国优秀博士学位论文1篇，全国优秀博士学位论文提名论文3篇；获得国家教学成果一等奖1项，国家教学成果二等奖4项。

(四)平台建设

2009～2010 年,新建国家重点实验室 1 个、国家工程实验室 2 个、国家工程研究(技术)中心 2 个、教育部重点实验室 4 个、农业部重点实验室 2 个以及一批省级重点实验室和教育基地等。这些科研、教学和科技推广基地的建立和建设必将改善农业工程学科的科研和教学条件,为科技成果推广提供了支撑。另外,国家"985"平台第三期对 4 个单位的农业工程学科进行了建设,投入经费达 15330 万元;国家"211"工程对 8 个单位的农业工程学科进行了建设,投入经费为 4713.65 万元,为农业工程学科的研究工作提供了有效的硬件支撑。

(五)国际交流

2009～2010 年,主办国际学术会议 18 次,参加人数为 2662 个,其中国外代表人数为 557 个。主办国内学术会议 53 次,参加人数为 7000 余人。有力地促进了农业工程学科不同研究领域的学术交流与合作。农业工程学科队伍中共有 395 名研究人员、教师等到国外进行合作交流、讲学和参加国际学术会议等,其中 187 人次出国参加国际学术会议。学科积极邀请农业工程学科各研究领域的专家学者来国内讲学,共长期聘请外国专家 14 人次,从事合作研究和教学,短期邀请外国专家 176 人次。在项目合作和交流上,与国外大学和研究机构签订了 12 份国际合作协议,成立了 4 家国际合作机构。农业工程学科专家学者的国际影响力日益提升,有 29 人次在相关国际学术组织任职、49 人次在国际学术刊物中担任主编或编委、2 人受聘为美国堪萨斯州立大学的客座教授,在国际学术舞台上发挥着越来越积极的作用。

(六)学术出版

出版农业工程学科领域的专著 85 部、教材 117 部,特别是由沈国舫院士、汪懋华院士主编的"中国农业机械化发展战略研究"系列丛书的出版,对加快促进我国农业机械化、推进我国现代农业建设具有重要的战略意义和学术价值。由农业工程学会主办的《农业工程学报》期刊质量稳步上升,国内外影响逐步扩大。《农业工程学报》在多年被 Ei Compendex Web、CABI、CA、CSA 以及俄罗斯《文摘杂志》等国际重要数据库收录的基础上,2009 年被 Ei Compendex(核心)收录。中国科学技术信息研究所 2009 年、2010 年影响因子分别为 1.024 和 1.126,首次进入中国自然科学类"百种中国杰出学术期刊"。《农业机械学报》是农业工程类中文核心期刊,2008 年起《农业机械学报》被 Ei Compendex(核心)收录,目前已被国内外 10 余种数据库、检索系统收录。由中国农业工程学会(CSAE)和(美国)海外华人农业、生物与食品工程师协会(AOCABFE)共同主办的《国际农业与生物工程学报》(*International Journal of Agricultural and Biological Engineering*),是一本中美合作的国际英文刊物,季刊,国际稿件占 60%以上。国际农业与生物工程学会(CIGR, http://www.cigr.org/)会刊于 2010 年 4 月 7 日落户中国,由中国农业机械学会和中国农业工程学会联合承办,将成为推动中国农业工程领域科学家参与国际学术交流与合作的平台和桥梁。《国际农业工程学报》(*International Agricultural Engineering*

Journal, *IAEJ*)是亚洲农业工程师学会(AAAE)的会刊,1992 年创刊于泰国亚洲理工学院(AIT),2010 年随亚洲农业工程师学会秘书处落户中国农业机械化科学研究院(CAAMS),已相继被近十家国际知名检索系统收录,包括 Ei Compendex。

四、本学科发展趋势与展望

经过 2009～2010 年的发展,我国农业工程学科的科研水平、队伍建设和人才培养、国际交流等方面取得了长足的进步,又取得了一大批创新性成果,在此基础上展望"十二五"的主要发展趋势和方向。

(一)农业机械化工程领域

将重点围绕农机农艺相融合,强化节能减排技术和低碳型农机研发,利用机、电、液、仪一体化技术实现农业机械化作业的高效率、高质量、低成本和改善操作者的舒适性与安全性,利用智能信息技术、嵌入式系统和微电子机械,形成性能价格比更为优良和环境友好的农业装备。

(二)农业水土工程领域

将从强调作物产量转变为提高作物品质,日趋关注农村供水与饮水安全及人居水环境的改善,从着重对自然科学技术的研究,逐步转变为自然科学技术与管理及经济学研究的有机结合和融合,利用信息技术、新材料和学科交叉等手段,加强现代节水农业理论和技术创新,提升我国节水技术研究和设备开发的水平。

(三)农业生物环境工程领域

将重点围绕中国特色设施农业生产模式的科学化、标准化、定型化和设施农业产业升级等重大科学和关键技术问题,加速实现日光温室现代化,加强物联网等高新技术在设施园艺领域应用的研发,并构建开放式的研发体制。在设施农业工程工艺模式优化、生物环境信息检测与控制、设施新材料与农业建筑工程、设施农业节能减排、设施农业优势区域布局与发展规划等方向上予以加强和发展。

(四)农村能源工程领域

将依靠现代科技开发农村新型能源,以提高热能利用效率、降低生态环境污染、促进能源产业和循环经济发展。加强研发和推广的方面还有:生物质能方面主要包括沼气和生物质固体成型燃料、能源作物、纤维素乙醇、生物柴油,太阳能方面主要是太阳能光伏设备技术,以及风能利用技术改良、地热能的开发和评价等。

(五)农业电气化及自动化领域

研究方向将着重体现在农村电力与新能源发电、农业电子与自动化、农业(农村)信息化技术三个方面。发展重点为村镇智能电力技术研究、智能农业检测与控制关键技术研究和农业(农村)信息化关键技术研究。

(六)农产品加工与贮藏工程领域

将向着保证农产品加工制品营养全面、卫生安全、适应人类膳食结构的调整和变化的方向发展,现代技术将广泛应用于农产品加工各个环节;农产品加工与贮藏设备向高效、节能、环保方向发展;农产品资源利用趋于综合;农产品加工过程的质量管理日益受到重视;注重加工过程中的研发和创新活动等。

(七)土地利用工程领域

将从单纯的田块合并、提高土地利用效率向着生态环境恢复和整个农村发展转变,研究的热点集中在土地综合整治关键技术体系上,发展重点为土地开发整理理论与方法创新和实践、土地复垦与生态恢复、土地评价与等级提升、统筹城乡与节约用地技术的研发等。

五、促进本学科发展的措施与建议

1.构建农业工程科技创新综合平台

农业工程科技创新是以应用为目标,以工程技术与生物技术和经营管理技术结合为前提,以综合、集成、组装为特色,但现实却是农业工程自身的学科领域和专业间的联系与合作还很不紧密,自身的综合集成问题尚未很好解决,与生物技术、经济管理等学科领域的结合更为薄弱。因此,需要通过观念、体制、机制的创新和突破来解决这些问题,构建体现产业特色和工程特色的战略研究平台、科技研发平台和集成应用平台。

2.做好农业工程科技创新顶层设计

就是要根据国家社会经济发展战略需求、国际农业工程科技发展的一般规律和我国国情特点、农业工程科技创新的重大问题和薄弱环节,按照为农业产业服务、为现代农业服务和整体、综合、系统的原则,通过开展农业工程理论研究、技术研究和建设研究,提出农业工程学科和科技发展路线图、区域农业工程技术集成与建设方案,提出重大政策和重大项目建议。

3.组建农业工程科技创新联合团队

整合全国相关学科科研院所的力量,搭建一个资源共享、人才共享、成果共享的开放式农业工程科技创新平台。通过建设战略研究平台,集中学科领域知名专家学者,构建一支具有战略思维、综合协调和引领学科发展能力的高层次战略研究队伍。通过建设科技研发平台,按照学科领域构建一支具有学科特色、区域特色、产业特色和官产学研用密切结合的农业工程创新人才队伍。通过建设工程集成与应用平台,按照共性和区域性两个层面,构建一支以应用为目标、集成为特色的科研、设计、生产(制造)、建设、管理人员有机结合的农业工程师队伍(咨询师、设计师、建造师),为农业工程科技成果的有效转化和现代农业建设提供全面技术支持与服务。

4.发挥农业工程科技创新整体作用

要积极利用农业工程学科集成创新的优势,围绕区域性特点和产业化目标,针对市场

需求和提高效益效率，开展生物技术与工程技术、农机与农艺、资源与环境、加工与储运、产品与市场的集成研究和科技创新，攻关结合的瓶颈技术，组装成套技术，形成为农业大产业服务的“体系技术”，提供整体性、区域性、行业性工程技术和工程建设集成的、优化的解决方案，努力满足现代农业建设对农业工程技术的迫切的、迅速增长的技术需求，为现代农业建设提供工程技术支撑和装备设施保障。

5. 进一步加强实质性国际交流和合作

2009～2010 年，我国农业工程学科在国际国内学术交流方面取得了显著成绩。亚洲农业工程学会移驻中国，几个农业工程类国际学术期刊的发行，都加强了我国农业工程学科在农业工程国际学术交流中的地位。国际学术交流日益受到各高校和学术组织的重视。相对而言，重大国际合作项目的数量不多，国外学者到国内长期进行科研合作也不多。因此，需要进一步加强实质性国际合作，努力使我国正在成为农业工程学科的国际学术交流中心之一。

第五节　制冷及低温工程

一、引　言

制冷及低温工程学科是围绕营造低于自然环境温度的微环境或物质状态所展开的科学研究、工程实施和相关设备装置制造。它是现代科学研究和现代工程技术赖以实现的重要平台，也是现代食品工程、建筑环境、医疗体系三大民生服务体系的重要技术支撑。

低温技术营造从接近绝对零度到 120K 范围的低温，是超导、远红外观测和成像等技术的关键；也为受控核聚变、正负电子对撞机等许多现代科学研究装置解决关键问题。而 120K 到常温带的制冷技术，则广泛用于重化工业和能源产业中的气体分离、液化；食品的冷藏、保鲜和冷藏链；低温生物医学工程中细胞、血液、皮肤、软骨等生物材料的保存和冷冻外科手术；建筑舒适性空调和为科研与生产过程提供的低温、恒温、干燥、恒湿的微环境；航天、航空、航海、潜水和陆地交通工具的生命保障系统；大型土木工程的冷冻工法及材料的低温改性等。制冷技术是现代科学技术、现代产业、现代化生活都不可缺少的支撑技术。

研究表明，目前我国制冷系统及其辅助系统的运行目前消耗的能源占全国总的能源消耗量的 20%。在现有运行基础上，尚有 20%～30%的节能空间，节能潜力很大；作为主要制冷方式的蒸汽压缩制冷所使用的制冷剂 HCFC 属于破坏大气臭氧层、具有较强温室效应的物质，将被逐渐停止使用。节能减排、保护大气环境还是制冷学科必须面对并承担的社会责任与历史使命。

在制冷空调、冷藏保鲜等领域，我国是世界上最大的设备制造国和消费市场。吸收式制冷机、房间空调器、冰箱、冷藏展示柜等设备，产量均占全球生产量的一半以上。制冷行业对我国的经济发展和对外出口有重要影响。

近年来，我国制冷学科有不少重大创新和进展，但总体上看，相较我国制冷行业众多

的数量第一的国际地位，在基础研究上、高端产品上、整体制造水平上以及系统运行的能源效率上，我国还处在相对落后的地位。除少数突出的研究成果外，总体上缺少原创、核心和领先技术。主要原因是制冷学科的基础研究跟不上应用需求的发展，整体的科学研究水平落后于制冷设备制造和制冷技术应用领域的发展，中国制冷学术领域在国际学术界的地位滞后于中国制冷企业和工程应用界的国际地位。

二、本学科主要进展和国内外研究比较

制冷及低温工程学科涉及众多学科和领域，现就主要内容的进展和国内外状况比对如下。

（一）新型制冷技术

我国在热声制冷方面的研究总体水平处于世界前列。在基础理论研究方面，提出交变流动热机和制冷机的介观热力学理论，指出交变流动热机的理想循环不是斯特林循环，纠正了 200 年来的错误认识；提出热声转换的非线性理论，建立了弱非线性的热声学解析理论，解决了传统线性化热声理论的重大理论困惑；提出了揭示可压缩交变流传热机制和设计的“交变流复传热学”理论框架。在热声制冷新流程方面，我国与美国几乎在国际上同步且独立地开展了高效率的行波热声压缩机和行波热声制冷技术，特别是我国提出了采用变截面谐振管抑制非线性耗散的“聚能型热声发动机”技术，一举获得了国际上的最高压比，率先研制完全无运动部件的液氮和液氢温度制冷机。在室温热声制冷方面，我国提出了双行波热声制冷流程，并研制了在冰箱制冷温度下有数百瓦制冷量的实验样机，其制冷性能居于国际前列。

我国在磁制冷材料的研究方面处于国际前列，所提出的铁基合金材料的性能优于美国和欧洲的，而且具有价格低廉、合成制作工艺简单等优势，但在磁制冷样机研究方面与最先进的美国有差距。我国总体在磁制冷、激光制冷、半导体制冷等方面的研究整体落后于世界先进水平。

美国在室温回转式取得零温跨下接近 800W 制冷量的结果，而中国则仅取得 50 度无负荷的制冷温跨。而激光制冷主要研究工作涉及激光制冷材料和激光系统，我国还没有实际开展这一方向的研究工作，与国外差距很大。美国近年来在半导体制冷材料研究上也有大的突破，而我国的基本研究上处于停滞状态。

（二）制冷工质替代

我国积极参与制冷工质限制和替换的各项国际行动，是各相关协议的签约国。为了保证中国制冷业的发展，我国必须发展一条有中国特色的自主创新性制冷工质替代路线。通过相关的共同努力，初步形成我国的工质替代路线及制冷工质替换的国家方案。并在混合工质研发上取得了国内外认可的成果，并已有一系列共沸和非共沸混合物专利；在工质热物性测量和热物性推算上也有了新的进展。为了与各类替代工质相适应，国内研究界和企业界相继开展了大量的替代工质应用性研究，并取得显著进展。

发展天然工质也是解决制冷工质替换另一条技术路线。我国在采用 CO_2、NH_4 和碳

氢化合物作为制冷工质的研究方面也取得了一定的进展，开发出拥有自主知识产权的用于氨和 CO_2 复叠制冷系统的螺杆压缩机，其性能达到世界先进水平，并积极开发 CO_2 热泵热水器和用于汽车空调的 CO_2 压缩机。针对回收膨胀功这一 CO_2 制冷机的特殊需求，提出多项发明专利并试制出引射器、膨胀机等样机。开发出采用碳氢化合物为工质的冰箱，并已大量出口。然而在应用 CO_2 工质方面，我国无论是压缩机还是应用系统，都与世界先进水平有较大差距。我国还参与了测试和评价压缩机性能相关国际标准的讨论和制定，建立了 CO_2 制冷系统综合性能实验台，为我国相关标准的实施做好了准备。

（三）低温生物医学

我国在生物材料的体外保存方面，将纳米技术与低温医学工程相结合，开展了热学和生物学方面的系列研究，在组织、细胞、血液的保存研究上都有重要进展，已经建成 7 座脐血干细胞库，不同的医院先后建立了精子库、角膜库、皮肤库、血管及软骨库等，为需要移植的病人提供了有效的组织替代物，为生命科学研究进展提供保障。为满足医学生物材料保存的需求，我国还在－40℃以下的低温冰箱上有重大创新和优化，首次采用同一种机械式制冷技术实现了“全温区系列机械式制冷低温冷冻储存箱”，比国际通用技术产品能耗降低 30％以上、生产效率提高 30％以上、硬件成本降低 20％以上，全温区系列已实现规模生产并批量出口。使我国一跃成为全面掌握先进低温冷冻储存箱核心技术和生产技术的国家，同时也满足了低温生物医学工程发展的需求。

在低温外科手术技术与装置方面，我国近年也有显著进展。我国将纳米技术与低温工程学相结合，发展先进肿瘤微创治疗方法的技术理念，相继开展的机理分析、试验研究和医疗仪器的研制等方面取得系列进展，提出独创的冷冻刀技术方案，研究出相应装置，正等待全面的检验和实验，以正式进入临床使用。

与国外相比，我国此领域的研究多数仍属于跟踪性的研究，自主创新的东西仍然较少，低温生物学的基础研究仍然很薄弱，医学生物材料保存的应用范围也远不及发达国家，冷冻外科所用冷刀还依靠进口，我国自行提出并研制的冷冻刀等手术器械距批准临床使用还有较大差距。

（四）制冷设备的研发

我国目前是世界上制冷设备生产的大国，在这一领域已基本上形成完整的生产能力，在家用制冷设备（白色家电）、螺杆式制冷机、吸收式制冷机等方面是世界上最大的生产商和代工制造者，制造能力基本上达到国际先进水平。

在小型冷冻冷藏设备上，我国已具备旋转、涡旋压缩机的研发、设计和制造能力；在小型变频压缩机方面近年来有所突破，主要性能达到国际先进水平；在线性压缩机方面，也实现了零的突破，但与国际先进水平仍有差距。

在大、中等规模制冷机领域，我国目前已经成为世界上螺杆压缩机的主要研发基地之一，近年来在转子型线设计及优化、转子啮合间隙带密封特性的转子刀具设计及加工、内部压缩过程微观特性的理论及可视化研究、螺杆压缩机设计计算软件等方面获得突破，整体上处于国际先进水平。但三螺杆压缩机研究开发还缺少核心技术，与国外有一定差距。

我国在离心式制冷机方面，由于 20 世纪 90 年代的一段停滞，目前相对落后。近年来几个企业开始加速开展离心式压缩机和系统的研发，目前已引进并二次开发出大型三元计算软件对叶轮和进口导叶、出口扩压器进行优化设计，通过改进空气动力学特性和热力特性以提高能效。为配合国家向境外投资大型液化天然气项目的需要，已开始进行为年产百万吨级 LNG 液化厂配套的混合制冷工质大型离心式压缩机的研发工作。但在设计方法、加工工艺等方面还有一定差距，主要的关键技术基本上由国外相关企业掌握。尤其是在代表离心式制冷机发展的未来的磁悬浮离心压缩机方面，目前发达国家已陆续开发出成熟产品，但我国仅有初步工作，与国外有很大差距。

在吸收式制冷方面，我国近 20 年来发展迅速，在技术水平和生产规模上处于世界领先地位。近年来在新的工质对、系统流程、降膜换热结构等多方面又有所发展，在制造工艺上也有很大改进。除了制冷应用，目前在工业余热、热电联产等方面又提出大量的吸收式热泵的应用，由此也在流程和装置结构方面有重要突破。

在吸附式制冷方面，我国也处在世界领先地位。在工质、流程、装置结构等方面近年来都有突破，并成功的应用于建筑太阳能空调，大型客车空调、远洋渔船冷藏，并且开始尝试推广。

(五)食品冷冻冷藏链

我国的农牧渔产品的生产与供应方式目前正处在重要的转型期，从传统的就地生产就地销售的手工业模式正在向规模生产、长途输配、异地销售的工业化模式转型。由此产生对食品冷冻冷藏链研究、运行管理的巨大需求。近年来，我国在相关的基础研究方面有了重要进展，开始获得了一部分食品储藏基础数据，如荔枝、冬枣、大桃、食用菌等储藏物的储藏条件，使储藏期逐步延长；水产品无水或微水活体储藏也取得了一定的进展，实验研究已达到鲫鱼微水储藏 30 小时、无水储藏 16 小时。但与发达国家已建成的丰富完整的储藏数据库相比，我国还有相当的差距。

在冷冻冷藏工艺与设施方面，近年来相继开发出预冷、速冷、速冻和解冻设备，并得到一定程度的应用推广；在冷库的节能与安全运行方面，通过制定新的节能设计标准、采用新的末端方式，使新建冷库运行能耗有所降低。与发达国家相比，我国冷冻冷藏基础设施和相应设施的技术水平还有较大差距。

在冷藏运输方面，我国长期运力不足，成为冷藏链的瓶颈。随着铁路建设的飞速发展，提出发展冷藏集装箱技术和装备，依托铁路实现冷藏链发展的飞跃。这一新的技术路线的实施很可能带来冷藏运输技术和设备的大发展，与发达国家相比，我国冷藏运输设备制造技术研究力量仍很薄弱、加工制造和产业需求仍存在很大的发展空间。

在冷藏销售终端方面，我国是世界上最大的产品制造国，但主要技术均来源于国外，创新很少。利用国内市场的飞速发展和巨大需求的机遇，促进这一领域的创新，有可能形成其新的发展。

(六)建筑空调制冷

我国城镇民用建筑空调普及率已经超过 70％，民用建筑空调的在役运行容量和年生

产与销售量目前都处于全球第一。随着建筑节能工作的深入，各类热泵又被广泛地用于建筑冬季供暖和生活热水制备；而为工业、科研和医疗部门营造各种低温和恒温、干燥和恒湿、净化等特殊环境，也是空调制冷技术应用的一个重要领域。在这样巨大的市场需求的驱动下，相关研究已取得多项新的成果。

在地源、地下水源、地表水源和污水源热泵方面，我国取得重大进展。作为分析和设计地源热泵的基础，我国推导出各类地下埋管换热器的传热和蓄热过程的解析解或积分形式的解；率先提出能够直接从污水中采集热量而不对污浊物进行任何处理的装置和工艺流程，已大范围用于实际工程项目；为配合地下水源热泵的应用，广泛开展了水文地质与勘测方法的研究，以确定回灌的可能性和水源热泵的可应用性；提出独到的单井垂直采集与回灌技术，从而在适宜的地质条件下可以减少井位并确保回灌；率先提出涡旋压缩机中间补气的方法，解决了空气源热泵低温下压缩比不足、制热量不足的问题。目前我国用于各类建筑冬季采暖的热泵系统在总装机容量、单体规模、应用范围等各方面均处世界第一。

对民用和工业建筑的中央空调系统，我国率先提出温度湿度独立控制的空调系统新方案，克服了常规空调系统中难以同时满足温、湿度参数的要求，可比常规空调系统实现30％的综合节能效果。温湿度独立控制空调系统被普遍认为是中央空调未来的发展方向，需要开发研究系列的新型配套产品，成就一个全新的空调产业。我国已开发出用于东南潮湿地区采用溶液除湿方式的新型空气处理机组，其性能明显高于国外同类产品；转轮除湿方式在高性能吸湿剂研究与制备、蜂窝状陶瓷转芯成型工艺等方面取得了显著进展；开发出用于西北干燥地区的利用室外干燥空气进行间接蒸发冷却的机组，比蒸汽压缩制冷方式节能50％以上；开发出适用于高温冷冻水工况的高效离心式和螺杆式冷水机组，性能远高于常规制冷工况；研发出干工况风机盘管、毛细管辐射末端等相关产品。目前，此新型中央空调系统已初步形成规模，并开始在各类工程中推广应用，取得显著的节能和改善室内环境的效果。

(七)气体分离与气体液化

我国目前重化工业领域使用的大型气体分离设备大多还是从国外进口，而国内只能生产小容量装置。为配合能源领域的需求，我国在小型天燃气源、煤层气、油田伴生气的液化方面提出有效的流程，并开发出新型可移动设备，在世界上处领先地位。而在大型天然气液化方面，目前刚刚起步，与国外先进水平还有较大差距。

(八)大型土木工程中的制冷应用

我国提出基于制冷技术的新的工艺流程，解决大坝浇灌过程中混凝土热量排除问题，在三峡大坝、龙滩、小湾、构皮滩、彭水、景洪、南水北调中线等国内大中型水电项目和巴基斯坦、埃塞俄比亚、沙特、苏丹等国外工程中相继使用，取得显著成效；提出利用热管技术避免青藏铁路永久冻土消融问题，保证了青藏铁路的开通和正常运行；发展了冷冻法施工技术，解决了地下工程、煤矿和大型桥梁施工中的关键问题。这使冷冻法施工发展成为许多大型土木工程的一项行之有效的新型施工技术。

三、本学科未来重点发展方向

综上所述，我国制冷学科随着城乡建设、经济发展和人民生活水平的不断提高，得以飞速发展，然而仍不能满足现代化发展对制冷学科不断增加的需求。面对我国今后面临的民生建设、节能减排和现代化产业建设这三项重大任务，制冷学科必须加速发展食品冷冻冷藏冷链方面的研究，保证食品的安全、高质和低损耗供应；加速开展低温生物医学研究，以适应建设现代化医疗服务系统的需要；持续建筑空调制冷方面的研发，满足日益增长的对舒适型人居环境的需求和现代科技与工业对低温、恒温、干燥、恒湿环境的需求。另一方面，完成节能减排的任务、降低用于各领域的制冷系统的运行能耗、替换破坏大气环境的制冷工质已成为制冷学科重要的社会责任。为解决这一系列新的问题，制冷学科需要重点发展如下方向。

(一)制冷的基础理论研究

从热科学的新理论出发对现有制冷系统提出新的认识和分析手段；发展新的制冷方式，提出新的制冷循环与热力学设计方法、准则；建立物性测试平台，建立系统全面的材料物性数据库，包括食品物性、低温固体材料、制冷工质、气体分离中物性等基础数据；建立制冷与低温流动、传热研究平台，获得设计低温传热的流动和传热数据。

(二)工质(制冷剂)研究

把握好环保(ODP 和 GWP)、安全(毒性和可燃性等)、成本和能效之间的“折衷”平衡，研究适合于中国国情和引领国际趋势的工质筛选综合评价体系；在国家方案框架下实施我国逐步淘汰 HCFCs 的战略安排；立足国情发展 HC290 和 HFC32 替代 HCFC22 的研究，从适用领域拓展、核心应用技术、风险评估、制订应用标准等方面进行系统研究，使之得到市场的全面应用；加快掌握“天然工质”核心技术的步伐，开发高效安全的氨系统设备，CO_2 系统设备以及 HCs 系统设备。

(三)制冷关键设备的研发

制冷压缩机是制冷系统的心脏设备，也是制冷产品能效水平提升的关键。要重点研究制冷离心压缩机，突破高效叶轮设计、磁悬浮轴承、小间隙软密封和干气密封等关键技术，推动制冷离心压缩机的国产化；开发直线压缩机大型化技术，推动小型冷冻冷藏装置和家用空调器的进一步发展。此外，膨胀阀性能的深入研究和新的膨胀阀控制算法也将是研究的重要方向；各类换热装置的高效换热、流程匹配以及传热设计的精细化、准确化，都将是提高制冷设备性能水平、推出新型制冷装置的关键。

为完成上述任务，实现我国制冷学科的进一步发展，需要在政策和体制上解决如下 4 个方面问题：

(1)将制冷学科作为一级学科纳入各类学科管理目录，这样才能有利于学科的发展和基础建设。

(2)按照制冷学科这样的专业学科层面设置国家级重点科研项目,全面系统开展制冷学科相关问题的研究。

(3)系统地推进制冷学科的人才建设,防止很快将出现的各类制冷专业人才紧缺现象。

(4)加速制冷专业研究机构和研究能力平台的建设。

第六节　控制科学与工程

一、引　言

自动化服务于人,将人从单调而繁重的重复性工作中解放出来,使人能够更多地投入到创造性的工作中,进而拓展了人认知和改造世界的范畴。当今世界,自动化科学的发展已经成为衡量一个国家科技发展水平和综合国力的重要标准之一,而以自动控制和信息处理为核心的自动化技术也已经成为推动生产力发展、改善人类生活以及促进社会前进的源动力之一。

自动化是一门涉及学科多且应用广泛的综合学科,在我国的研究生培养体系中,自动化对应的一级学科"控制科学与工程"下属有 5 个二级学科,分别为控制理论与工程、模式识别与智能系统、系统工程、导航制导与控制、检测技术与自动化装置。经过几十年的发展,自动化学科的基础理论已经发展成熟,广泛应用到工业、农业、军事、交通运输、商业、医疗、服务和家庭方面。

二、本学科近两年主要研究进展

(一)控制理论与工程

控制理论工程在鲁棒控制、电力系统非线性控制、离散事件动态系统、量子控制等方面都取得了重要进展。清华大学卢强的团队开发的非线性鲁棒电力系统稳定器 NR－PS 分别于 2007 年和 2008 年在吉林白山水电站和丰满水电站投运,对于电力大系统非线性控制做出了重要贡献,获得 2008 年国家自然科学奖二等奖。段广仁等提出的鲁棒控制系统参数化设计方法建立了使闭环系统相似于某指定系统的反馈控制律的完全参数化解,并严格证明了自由度的完备性,此项成果获得 2008 年国家自然科学奖二等奖。曹希仁等提出了一个学习和优化的统一框架,为发展摄动分析、马氏决策理论、强化学习、自适应控制等学科提供了统一理论框架,作出了基础性的贡献,该研究获得 2009 年国家自然科学奖二等奖。吴热冰等给出了连续变量量子系统的最优控制策略以及基于量子 landscape 的一般控制方法。由燕山大学王益群教授等完成的"冷带轧机高精度液压厚度自动控制(液压 AGC)系统关键技术及应用" 项目在冷连轧、单机架和虚拟连轧系统设备级模型精度方面,全部达国际先进水平,获得 2009 年度国家科技进步奖二等奖。

(二)模式识别与智能系统

在模式识别基础理论、计算基因组学、脑机接口、针刺机理等方面有了较重要的发展。国内学者在特征降维方面处于国际前沿水平，南京理工大学在该领域的成果“特征抽取理论与算法研究”获得 2009 年国家自然科学奖二等奖。清华大学和美国冷泉港实验室合作，采用隐马尔可夫模型，首次将组蛋白修饰数据结合到基因转录核心启动子的预测上，得到了当前精度最高的核心启动子识别方法。清华大学的研究人员提出了一种基于听觉注意的认知脑—机接口新范式，该研究作为封面文章于 2010 年发表在 IEEE Transactions on Neural Systems and Rehabilitation Engineering 上。中国科学院自动化研究所田捷研究员团队以针刺时空编码理论模型的构建为研究切入点，验证了针刺中枢神经响应具有持续性效应这一重要假说，并且提出了重要的针刺中枢神经响应的时变概念。

(三)系统工程

在公共安全应急决策、信息服务、智能交通方面有重要进展。国家应急平台的研究最早于 2004 年在清华大学等单位开展，包括国务院应急平台，31 个省(自治区、直辖市)、新疆生产建设兵团、5 个计划单列市应急平台，20 个有应急智能的部门应急平台和 100 个部门值班系统。中国科学院自动化研究所王飞跃等将 ACP 方法用于交通领域，提出了平行控制与管理理论，并将该成果应用于广州等城市的交通管理实践中，在亚运会期间发挥了重要作用。

(四)导航、制导与控制

我国在卫星导航、惯性导航、飞行控制律设计研究、打飞机研制、伴飞卫星绕飞技术、登月工程方面取得了重要进展。国际上在无人机、大型运输机、高超音速飞机方面有了重要进步。2007 年、2009 年、2010 年发射了北斗系统的前五颗卫星，均获得成功。预计 2012 年，北斗卫星导航系统将提供覆盖亚太地区的导航、授时和短报文通信服务能力。在航天飞行器应用的推动下，机械轴承支承的惯性飞轮成功应用于“风云”系列气象卫星，磁悬浮支承的飞轮和控制力矩陀螺的工程化应用和产品研制取得了突破性进展。北京控制工程研究所吴宏鑫院士及研究小组以复杂航天器和工业过程为被控对象、以特征模型为依据，将智能控制与自适应控制结合建立了机遇特征模型的智能自适应控制理论。我国于 2008 年 11 月启动了首型国产大飞机专案，并于 2009 年 9 月在香港举行的亚洲国际航空展览会上展出了外型样机。2008 年 10 月，“神舟七号”伴飞小行星在经过 6 次变轨后成功实现了对飞船轨道舱的绕飞，攻克了伴飞卫星绕飞控制技术。2009 年 3 月 1 日，“嫦娥一号”卫星实现了成功撞月并传回了清晰的图像。在导航制导方面，虽然我国已经进步明显，但是还是和发达国家有明显的差距。

(五)检测技术与自动化装置

在传感器基础技术领域中，我国在高性能瓷料的研究上取得了突破，并在低烧瓷料和贱金属电极上形成了自己的特色并实现了产业化，使片式电容材料及其组件进入了世界

先进行列。中科院长春应化所研发的“电化学气体传感器”被评为“2006 年中国科学仪器及分析测试行业十大新闻”，标志我国在这方面实现了突破，整体达到国际先进水平。

三、本学科新兴、交叉学科的研究发展

自动化除了在以上的传统方向上有了重要发展，其特点还表现为在新兴方向、交叉学科和新兴应用方面具有旺盛的生命力，下面几点值得关注。

(一)网络时代信息的管理和控制

互联网的深入普及，已经深刻改变了人类的生活。由于网络连接的广泛性，信息的传播速度非常之快，网络虚假新闻的破坏力大大加强。而“人肉搜索”通过网络汇聚人的力量，其影响已经引起广泛注意。在网络时代，网络公关能力起着至关重要的作用。正是基于此，“社会计算”的研究应运而生。国际上许多大学和高新技术公司都在从事社会计算相关的研究和开发工作，代表性的有美国亚利桑那大学、卡内基梅隆大学、南加州大学、IBM、微软等。我国中国科学院自动化研究所在社会计算方面取得了重要成果，并且成功举办了第一、第二届全国社会计算会议。

(二)有人参与系统的管理和控制

自动化发展的早期，控制对象主要是机械、压力、温度等物理对象；但是发展到现在，人的参与越来越明显。比如，在公共应急方面，首先要考虑的就是人员的安排；在化工生产、核电方面，主要考虑人员的位置、情感、工作效能等；在交通方面，要充分考虑到人、车、路的相互关系；在社会计算上，人的重要性更为突出。由于人本身的不精确性，有人参与的管理和控制比起传统控制更具有挑战性。

(三)无人系统和群集系统

一方面是对人类自身认识的发展以及对人、社会的管理和控制，另一方面是完全无人干预情况下的自治系统的研究。无人系统是无人机、无人车、无人潜航器和无人水面艇等无人设备的总称。这些设备一方面要自治，另一方面要实现“无人/无人”的协同操作方式，具有复杂性、分布性、异构性、不一致性等特点。这方面的研究对于容错控制、自主导航、环境感知、自主决策和规划都提出了挑战。而相应的应用必定会对军事、民用等带来深刻的改变。

(四)向生物、医学方面的渗透发展

对于生物系统的研究已经是自动化学科的重要分支。除了生物信息学之外，系统生物学、脑机接口等的研究引起了广泛注意。在生物、医学方面的研究必定是自动化学科的重要发展方向之一。

(五)在一些新兴工业方面的研究

随着传感器和网络的发展，物联网的研究已经非常紧迫，物物互联将对人类的生产生

活带来重要的改变。大飞机、高速铁路、磁悬浮列车等基础工业的发展是我国工业发展历程上的一件大事，相应地，是对自动化控制应用的机遇和挑战。出于节能减排、可持续发展的需求，我国大力发展核电，需要自愈特性仪表控制技术、数字化和智能化保护技术、结合人机智能的机器人技术、三维仿真建模技术等的支持。这些新兴工业必定带动自动化理论和应用的进一步发展。

四、本学科发展趋势和展望

由于数代人的持续努力，我国的经济保持高速增长的态势。一个国家的发达程度往往和科技程度成正比，科技会促进社会经济的发展，而经济的发展又会对科技发展提供支持。我国的自动化研究和应用水平取得了长足的进步，但是还不可过于乐观，我国和国际先进水平还普遍存在差距。在 21 世纪，高科技的作用将更加明显，而自动化水平作为国家发展的标志，其重要性不言而喻。随着经济的发展，我国对自动化学科的研究趋势将更为转向基础理论的研究和新兴交叉方向的研究。也正是从这两点作为突破口，我国才更有可能在 21 世纪达到并且引领世界先进水平，成为一个科技强国。我们必须再接再厉，争取在基础研究和重大应用方面都达到国际先进水平，为我国的发展做出切实的贡献。

第七节　航空科学技术

一、引　言

随着创新型国家建设进程的不断深入，航空科技的战略性地位更加突出。2008 年，国家对航空工业进行了重组，并加大了对航空科技创新的支持力度，从而使航空科学技术进入到新的快速发展阶段。

二、本学科近两年主要研究进展

(一)飞机总体

近年来，我国在飞机总体技术方面取得的主要进展包括：C919 展示样机正式亮相，并赢得了 100 架启动订单；“蛟龙 600”水陆两用飞机正式立项；“海鸥 300”水陆两栖飞机首飞成功。此外，为了提高飞机总体设计技术，我国先后开展了多项飞机总体设计技术专题研究，取得了一批新的研究成果。

(二)直升机

2009～2010 年，我国在直升机研制、生产能力方面取得长足进步。2009 年 12 月 17 日，中法合作研制的 EC－175/Z－15 直升机在法国马赛成功首飞。2010 年 3 月 18 日，大型民用直升机 AC313 在江西景德镇首飞成功。通过开展直升机技术预先研究，我国在直升机的多学科优化设计技术、直升机隐身技术、倾转旋翼机、直升机制造技术等方面取得

了一批新成果。

(三)无人飞行器系统

在信息技术的推动下,无人机已经成为发展速度最快的机种。目前,我国研制的“翼龙-1”长航时无人机已经进入测试阶段,并进入国际市场。在无人直升机方面,我国研制的 WD100 等多种型号的无人直升机已经成功试飞。此外,还研制成功了 ASN211 微型扑翼无人机。

(四)航空动力

经过多年的建设和发展,我国航空发动机行业在基础设施和条件建设方面发生了巨大变化,试验、测试、加工能力大大提高。目前,我国已经掌握了第三代航空发动机的设计和生产技术,并拥有大批先进的发动机整机和零部件试验和生产设备,为大涵道比涡扇发动机的研制和生产提供了保证。

(五)飞行力学

近年来,我国针对先进飞行器设计的需要,在消化、吸收国外先进研究成果的基础上,通过自主创新、发展,在非线性飞行动力学、弹性飞行动力学、非定常气动建模、民机飞行品质和适航性研究等方面取得了新的突破。

(六)飞行试验

随着航空工业的发展,我国飞行试验技术有了长足的进步。在型号飞行试验方面,我国已经基本能按《中国民用航空规章》适航标准进行新研民用航空产品的合格审定试飞;在研究性飞行试验方面,我国飞行试验机构已经可以进行空气动力学、飞行力学、结构完整性、动力装置和机载系统设备的专题研究试飞和特定项目的攻关试飞,并且掌握了一批比较先进的飞行试验测试技术。

(七)飞行技术

随着航空运输业的快速发展以及新技术的逐渐应用,我国飞行技术发展迅速,取得了许多进展。开发成功了“A320 系列训练器”、“小鹰 500 练习器”、“737 座舱及警告训练器”等训练设施,飞行训练技术稳步提高。

(八)航空安全管理

近年来,我国航空安全管理的技术和方法有较大的进展,特别是在与安全管理密切相关的人为因素、安全信息管理、风险管理、事故调查等方面,在理论、模型、技术和应用方面,都有不同程度的发展和进步。

(九)空中交通管理

为了适应我国航空运输飞速发展的需要,我国民航空管系统重点围绕国际民航组织

提出的未来航行系统(FANS)、新航行系统(CNS/ATM)和全球一体化的基于性能的空管系统的理论和技术体系，开展相应的技术跟踪、研究、试验和应用工作，并在通信、导航、监视、空管、气象等重点领域取得新的进步。主要包括基于性能的导航(PBN)开始推广、自动相关监视(ADS－B/C)的应用和研发取得显著进展。

(十)航空地面保障

目前，国内在航空地面保障特种底盘车辆方面已形成一定的研发与制造能力；在航空应急救援设备和运行管理方面已经形成了较为完备的方案；国内的助航灯光技术已相对成熟；还针对特殊情况下航空地面保障运行情况开展了相关的研究，开发了地面指挥调度管理系统，并成功应用。

(十一)航空可靠性系统工程

我国航空可靠性工作从 20 世纪 80 年代初对在役飞机及设备进行定、延寿工作开始，经过将近 30 年的发展，在基础理论和应用技术方面都取得了很大成就。在基础理论方面，传统的基于概率的可靠性系统工程基础理论已经基本成熟，初步形成了一套理论和方法，产生了以效能为目标的性能与可靠性一体化综合集成理论等标志性成果。在应用技术方面，已形成了一套军用飞机、导弹等典型航空产品 RMTSS(可靠性、维修性、测试性、安全性、保障性)要求的论证设计方法和手段，包括度量技术、分解技术、权衡技术、仿真技术等，已初步具备了科学合理地开展 RMTSS 要求论证与设计的能力。

(十二)航空复合材料

我国航空复合材料结构应用技术的发展从 20 世纪 80 年代开始，经过了 20 多年的科研攻关，先后对复合材料在飞机垂尾、前机身、平尾、机翼等结构件的应用进行了研究，积累了大量的设计、制造经验。近年来，我国在复合材料树脂基体研究、陶瓷基复合材料工程化、高性能碳/碳复合材料低成本制备技术等方面取得新突破，建立了比较完整的复合材料测试标准体系。同时，在复合材料的工程应用方面也取得了新的进展。

(十三)测试技术

随着装备的发展和技术水平的提高，用户对航空产品测试性的要求越来越高，测试技术受到各方用户和国防工业部门的普遍重视。近年来，我国航空测试技术取得了一些新的主要进展：测试性大纲修订工作基本完成，综合测试正在向航空产品全寿命周期纵向集成的方向发展，故障预测和健康管理(PHM)技术取得初步进展，新型传感器技术在航空测试领域得到应用。

三、本学科国内外研究比较

(一)近两年世界航空科技的主要进展

近年来，越来越多的国家加入到航空科技领域里的竞争。为了加快航空的发展，美国

出台了“2011～2040 财年飞机投资计划”；欧盟启动了“绿色天空计划”；俄罗斯则对航空工业进行了深度的改组，并要求俄罗斯航空公司必须购买国产客机。随着各国政府支持力度的加大，航空技术进入了新的快速发展时期，相继取得了一系列的突破。其中比较重要的标志性技术应用进展是：①新一代宽体客机——波音 787 首飞成功；②俄罗斯全隐身战斗机研制取得进展；③美国、日本启动第六代战斗机的方案研究；④高速直升机技术取得突破；⑤太阳能飞机技术取得重大进展；⑥高超声速动力技术取得新的突破；⑦机载激光武器试验取得成功；⑧美国空军先进复合材料货机完成首飞。

（二）航空科技的国内外差距

目前，我国已经研制成功了“歼－10”战斗机，ARJ21、“新舟 600”支线飞机和直 15、AC313 直升机，在飞机总体、气动、结构、航空电子、航空机电等专业的技术研究取得了长足进步。但与国外先进水平相比，我国航空科技仍然存在比较大的差距。

1. 飞机总体

与国外发达国家相比，我国军民机技术发展不均衡；对新技术研究较少，技术储备不足；缺少自主开发的设计工具，数据积累不够。

2. 直升机

目前，国外已经发展了单旋翼带尾桨直升机、共轴直升机、纵列直升机、交叉式双旋翼直升机、倾转旋翼直升机等多种直升机，而我国所有的型号设计均采用了单旋翼带尾桨的传统构型。此外，在直升机控制、制造技术和无人直升机技术等方面，我国与国外也存在比较大的差距。

3. 无人飞行器系统

在无人飞行器系统方面，我国与国外的主要差距是：机种少，性能落后；无人机动力、设备和元器件配套困难，无人机系统的训练手段不完善。

4. 航空动力

就发动机总体技术指标而言，我国与国外先进水平相比仍有很大差距。在设计技术方面，我国尚未走完一个从部件研究—核心机—验证机—型号研制的全过程；在试验技术方面，我国还不具备大流量自由射流式和高涵道比发动机模拟高空试验设备，缺少一些关键的部件或系统试验设备。

5. 飞行力学

与欧美、俄罗斯等航空发达国家相比，我国在飞行力学方面尚存在较大的差距，主要表现在三个方面：①预先研究力量较薄弱；②飞行力学顶层设计牵引作用欠缺；③飞行力学大系统仿真与试验研究不够。

6. 飞行试验

与航空发达国家相比，我国飞行试验技术的差距主要为：未形成完整的飞行试验体系；无足够的飞行试验技术储备；试验机数量严重不足；现有试验场地不满足未来发展的需要；试飞员培养能力严重不足。

7. 飞行技术

新一代飞行程序设计方面，我国还没有 RNP AR 程序设计的经验，不得不反复地以高昂价格进行程序开发。在模拟训练设备研发方面，到 2010 年底尚无自行研制 D 级飞行模拟机，国内民航采用的模拟机清一色是进口设备，仅有一台“新舟 60”飞机的 C 级飞行模拟机。

8. 航空安全管理

我国民航安全管理技术与国外的差距主要表现在：安全管理的技术和方法相对落后；安全信息的收集手段不完善，安全信息报告政策、标准以及规范性方面存在一定的不足；安全经济学研究滞后；事故调查技术仍有欠缺，航空医学鉴定技术在疲劳、特殊药理作用的取证方面与国际先进技术存在较大差距。

9. 空中交通管理

欧美航空发达国家为了不断保持和强化空管技术领域的核心竞争力，纷纷加大对空管技术研发的投入，技术创新步伐不断加快。我国空管基础研究与国际先进水平有较大差距，对国外产品依赖度高；国际标准提交数量有限，核心技术受制于人。

美国建成了完善的陆基空管系统和较完善的卫星导航、导航增强等系统，在 Next-Gen 中将进一步研发星基空管系统，并实施新的基于性能的运行概念。欧洲正在加速建设自己的伽利略卫星导航系统和增强系统，对航空数据链、自动相关监视等进行验证。中国的星基空管系统技术处于探索阶段。

10. 航空地面保障

我国航空地面保障技术与欧美国家相比的差距主要是：技术复杂、直接接触飞机的设备还主要依靠进口；缺乏飞机深度维修技术和装备；突发应急事故保障能力弱。

11. 航空可靠性系统工程

我国航空产品 RMTSS（可靠性/维修性/测试性/安全性/保障性）的总体水平还比较低，与国外存在比较大的差距。主要表现在：基础理论研究滞后；应用技术与工程应用能力不足；基础建设尚不完善。

12. 航空复合材料

近年来，我国在碳纤维、复合材料结构件等方面已经取得了一些重要进展，但是与发达国家相比，仍然存在很大差距。主要表现在：复合材料的性能仍然较低，迄今我国的复合材料只能在飞机次承力和非承力结构上应用，还不能用于主承力结构；复合材料表征分析能力和手段仍需完善；民机复合材料结构制造能力仍然处于初级阶段，自动化制造装备与配套的材料技术刚刚起步，低成本制造技术的工程应用尚未突破，基础研究与工程技术开发存在脱节现象。

13. 测试技术

由于缺乏有效的测试性设计方法和设计手段，致使我国航空产品的测试性设计与发达国家存在很大差距。

由于缺乏统一的技术体系建设，国内航空产品的综合测试技术没有形成类似联合技

术体系结构(JTA)的标准和规范,从体系上很难实现全寿命周期测试和跨机型平台测试。总体体系弱和基础产品弱等问题的存在,使得综合测试系统尚难以达到通用化的目标。

国内 PHM 技术刚刚起步,还远远落后于 PHM 典范 F-35 的水平,而且由于其涉及的基础支撑技术在国内普遍落后,研制难度很大,关键技术要全面突破尚需时日。

国内机载传感器以及航空专用测试技术与国际先进水平差距明显,特别在航空发动机测试技术方面,我国还没有掌握动态参数测量技术,高温、高压、高转速、强振动的发动机上遥测及非接触测试技术几乎是空白。

结构试验测试技术方面,尚未形成完整的强度测试体系,虚拟试验测试基础研究薄弱,虚拟模型的建立和验证、模型库、知识库建立技术与国外有差距。

四、本学科展望与对策、建议

(一)我国航空科技所面临的战略需求

为了加快航空工业的发展、促进创新型国家建设,航空科学技术工作面临以下主要战略需求。

1. 支持型号发展

目前,以 C919、ARJ21、蛟龙 600 为代表的新型航空产品研制已经到了关键阶段,必须集中力量,全面攻克这些型号研制、生产、服务、保障中的各项技术难关,确保产品的质量、性能和安全性,为国防建设、航空运输和通用航空事业的发展提供适用可靠的装备。

2. 带动技术进步

温总理在《让中国的大飞机翱翔蓝天》一文中,明确指出:“人们说大型飞机是现代制造业的一颗明珠,就是因为大型飞机是现代高新技术的高度集成,能够带动新材料、现代制造、先进动力、电子信息、自动控制、计算机等领域关键技术的群体突破,能够拉动众多高技术产业发展”。随着科技创新工作的不断深入,我国在材料、信息、能源等技术领域不断产生新的突破,在新技术成果的集成应用和工程研制应用中正在发挥越来越明显的引领作用,同时航空科技也对这些新兴技术领域的进步产生强烈的需求牵引和技术互动。

3. 增强创新能力

我国航空工业是在修理、仿制的基础上,逐步走向自行研制的,航空科技工作也正在由跟踪模仿型向自主创新型转变。为了增强我国航空科技的自主创新能力,必须加强对前沿技术的探索研究,这不但可以为自主创新增添新的技术元素,而且对于带动相关技术的发展也具有非常重要的意义。

(二)关于重点研究方向的建议

针对我国航空科技发展的环境和战略需求,建议重点发展以下航空技术:①绿色航空技术;②新航行系统技术;③新一代直升机技术;④先进气动布局技术;⑤主动结构技术;⑥自主控制与决策技术;⑦高推重比/高功重比发动机技术;⑧高性能复合材料技术;⑨纳米材料与航空应用技术;⑩故障预测和健康管理技术。

第八节　兵器科学技术

一、引　言

兵器科学技术是一门综合性的工程技术学科，主要研究各类兵器的构造原理、设计理论、战术技术性能及系统论证、工程研制、试验、生产、使用、储存、维修等的理论和技术。进入新世纪，以信息、材料、能源技术为先导的高新技术快速发展，推动着兵器科学技术不断进步。在 60 周年国庆阅兵中，新型主战坦克、履带式步兵战车、8×8 轮式步兵战车、155mm 自行榴弹炮、122mm 自行火炮、远程多管火箭炮、120mm 轮式迫榴炮、四管 25mm 弹炮结合自行高炮、反坦克导弹发射车、空降步兵战车、两栖装甲突击车等一批新型武器装备组成的方阵通过天安门，接受了党和国家领导人的检阅，壮了国威、军威，集中展示了近年来我国兵器科学技术发展的成就和水平。

本年度学科发展报告，选择兵器火力系统相关学科作为兵器科学技术学科的主题，以“兵器发射理论与技术”、“弹箭推进增程理论与技术”、“弹箭精确化理论与技术”和“高效毁伤理论与技术”4 个专题展开，反映近两年我国兵器火力系统相关学科的发展现状、与国外先进水平的差距以及发展趋势。为了保持学科发展的连续性，报告对兵器学科近年来的总体发展状况也做了必要的阐述。

二、本学科近年来研究进展

我国在装甲兵器、身管兵器、制导兵器、弹药、水中兵器等产品技术研发以及含能材料、防护、燃烧与爆轰、弹道学、信息、材料与制造等基础技术研究方面均取得了重要进展，为我军研制、生产了一批新型武器装备。

(一)装甲兵器技术领域

初步确定了适应现代作战需求的装甲兵器体系，基本实现了系列化、通用化和标准化，能基本满足我军对装甲兵器的需求。若干基础与关键技术研究取得进展，研制和开发了一批具有自主知识产权的新型装甲兵器，初步形成了以三代装备为骨干的装甲兵器体系，越野机动性得到较大提高，装甲兵器在综合性能上实现了跨越式发展。

(二)身管兵器技术领域

在系统总体技术、新概念新原理新结构武器技术、提高初速与增大射程、提高火力密度、提高机动性与快速反应能力、提高自动化和信息化技术等方面都取得进展，身管兵器的效能和综合性能有了较大的提高。

(三)制导兵器技术领域

在总体设计、气动布局研究、发动机设计、飞控系统设计、制导导引技术等方面取得进

展，正从传统的无控兵器向制导兵器过渡。

（四）弹药技术领域

在弹道修正、简易制导、落点精度控制、灵巧引信、火工品综合性能等方面开展了研究，目前弹药品种基本齐全。

（五）含能材料技术领域

非 CHON 型超高能量密度化合物研究取得进展，新型粘合剂多功能化（如含能化、钝感其它组分）及配方、工艺技术得到了创新发展，调节火炸药燃烧特性的新型纳米级燃烧调节剂有新的探索实践，碳纳米管材料制备技术取得突破，新型功能助剂以及合成高能炸药的强氧化反应介质日益受到重视，高热值金属燃料用于火炸药配方，提高能量水平和功效性能已成为火炸药技术发展的方向之一，对传统火炸药的功能助剂进行绿色化、无毒化改造已引起重视。

（六）兵器信息技术领域

开展了动态组织与随遇入网、战场资源共享、战场任务单元模块化结构等技术研究，实现了战术信息系统各要素功能接口的一体化设计；研制出一批新器件，先进热像仪、微光像增强器进入装备应用阶段，红外、微光技术的科研条件明显改善；掌握了升降桅杆的应用及对精度的控制、多种光电传感器以及多传感器集成与信息融合技术，实现了搜索与跟踪一体化、高精度侦察与制导的一体化；多基地雷达、动态寻北光纤捷联惯导、车载稳定/导航一体化、微型侦察仪等系统及其关键技术研究取得进展；光电对抗武器及其基础技术的研究进一步提高了光电对抗能力。

（七）兵器材料与制造技术领域

通过“千台数控增效工程”的实施，数控机床加工效率提高 1～2 倍，快速研制能力大幅度提升；在非硅 MEMS 技术领域，高承载金属毫米级零件、厘米级系统的研究取得进展；针对硅微加速度传感器、硅微惯性陀螺，开展了硅微 MEMS 加工方法、原理和应用的研究工作，取得了阶段性成果；开发了铣磨抛光非球面补偿软件，中大口径非球面光学元件超精密磨削及研磨抛光技术实现了突破；通过三大工艺计划的实施，节能降耗工艺、绿色制造工艺和数字化制造水平都得到了提高。

三、近年来本学科火力系统相关学科的主要研究进展

（一）兵器发射理论与技术

近年来，我国在电热化学发射、电磁轨道发射等新型发射技术方面取得了重大进展。目前，电热化学发射的关键技术取得突破，有望实现工程化应用；电磁发射的高功率脉冲电源、发射效率、轨道炮设计等技术取得了进展，已研制出实验原理样机，实现超高速。

研制出新型模块装药，实现炮口初速的明显提高；研制的转管发射系统，实现高射频；开展了平衡炮等特种发射技术的研究，以适应特殊的应用条件；开展了兵器安全性和发射

动力学的研究，有效提高了兵器的发射安全和射击精度。

（二）弹箭推进增程理论与技术

随着炮弹底排减阻与火箭推进复合增程技术的应用，炮弹的射程大幅提高；开展了固体冲压发动机、高效能固体火箭发动机、脉冲爆轰发动机、凝胶推进剂火箭发动机等推进技术的研究，将高效能固体火箭发动机和固体冲压发动机应用于战术火箭武器，其射程明显提高。

开展了高能推进剂、高强度轻质发动机壳体材料的研究，有效提升了发动机的性能；开展了气动减阻、电磁减阻技术的研究，可用于提高射程；弹箭一体化技术取得重大突破，可实现对纵深点、面目标实施有效压制和精确打击。

（三）弹箭精确化理论与技术

近年来，末敏技术、弹道修正技术、制导和末制导技术、简易控制技术等取得重大进展，多种制导与精确化弹药不断问世，大幅度提高了目标的命中率；特别是我国末敏弹药技术取得令人瞩目的成果，继自主研制成世界一流的火箭末敏弹武器之后，又取得了炮射末敏弹关键技术的重大突破和跨越，在总体设计、抗高过载、小型化、稳态扫描、多模复合探测等方面拥有了一批具有自主知识产权的核心技术。研制成功的多模复合探测识别系统在探测识别、抗干扰、环境适应、瞄准定位等性能方面均达国内最好水平。基本形成了我国末敏弹先进的设计、分析、仿真、试验、评估的方法和理论体系，使我国成为继美、俄、德等国之后能自主研发先进末敏弹的国家；开展了制导弹箭的总体设计、气动布局、制导控制系统、制导体制、制导器件、试验和半实物仿真技术的研究，取得了进展，部分成果已应用于新型制导弹箭或无控弹箭的制导化改造之中。

（四）高效毁伤理论与技术

在微纳米晶复合材料弹芯技术方面，开展了复合材料配方、工艺技术的研究，并研究了其侵彻机理和自锐效应；开展了钨合金弹体材料工艺技术的研究；开展了复合材料弹托技术的研究，可使穿甲弹的消极质量减少；开展了重金属药形罩和含能药形罩技术研究，取得了重要成果。

研究了活性破片材料配方、工艺、战斗部结构及威力评估等，在多模毁伤元形成及转换机理、起爆控制技术等方面取得了突破；研究了建筑多层靶的侵彻规律和装药安定性问题，开展了高速侵彻的机理研究。

完善了目标易损性评估理论，进行了典型目标的易损特性研究与评估；掌握了云爆战斗部对典型目标的毁伤特性，以及穿、破甲靶后效应特性和靶后效应考核试验方法；建立了破片杀伤型战斗部攻击典型目标的毁伤模型。

四、国内外本学科火力系统相关学科发展比较

（一）兵器发射理论与技术

国内高初速发射技术尚不成熟。在常规固体发射药火炮上，虽然采用了多种方法提

高炮口初速，但仍处于研究阶段，技术还不成熟；电热化学发射关键技术虽取得重大突破，但在系统集成、电磁兼容、武器化结构及连续供弹技术方面与国际先进水平尚有一定差距。电磁发射在武器化方面与国际领先水平还有差距。

在火炮高射频发射方面，无论在基础研究还是关键技术和生产工艺方面与国外先进水平还有一定的差距。在火炮内弹道、装药设计、兵器发射安全性和发射动力学方面，与国外先进水平的差距是缺乏系统的、完整的应用基础研究。

（二）弹箭推进增程理论与技术

国外先进国家底排/火箭和火箭/滑翔复合增程技术已成熟，两种类型的复合增程炮弹都已有产品，增程炮弹的射程已超过 100km，低成本制导火箭的射程已超过 300km，我国尚有明显差距。

国外先进的固体冲压发动机、脉冲爆轰发动机、凝胶推进剂发动机和微小型涡喷发动机等新型推进技术比较成熟，部分技术在弹箭设计中已得到成功的应用。我国尚未达到可靠应用于弹箭设计中的程度，不少关键技术还未突破。

国外先进国家在固体火箭发动机设计中已大量采用性能好的改性双基、复合及 NEPE 推进剂，在发动机零部件设计中大量采用高强度复合材料和抗高温耐烧蚀 C/C 复合材料。这些材料在我国尚未被广泛应用，我国的含能材料与复合材料性能有待提高。

（三）弹箭精确化理论与技术

与国外制导弹箭的类别和数量比较，国内的品种较少；在制导精度与整体性能上仍有较大差距。在制导技术上，国内多模制导及各种复合制导技术与国外先进水平尚有一定差距，制导模式单一，抗干扰与全天候作战能力不足；我国对先进的控制理论仍在探索中。

（四）高效毁伤理论与技术

我国目标易损性研究的整体水平与国外先进水平尚有一定差距，国外已有近 60 年的系统研究历史，国内的研究起步较晚。

高速撞击条件下钢筋混凝土硬目标、岩石等的侵彻机理研究不完善。国外已经得到了速度为 2000m/s 以上的对钢筋混凝土硬目标、岩石等的侵彻机理，国内对高速撞击条件下的弹靶破坏机理和深侵彻弹道特征研究尚有差距，没有建立高速碰撞条件下弹靶模拟与等效方法。

国内新型毁伤技术尚不成熟。美国在控制常规战斗部产生不同爆炸威力的方法、发展毁伤威力可调战斗部、多模 EFP 战斗部、低附带毁伤战斗部等方面已经成功应用，而国内尚处于原理研究阶段，未达到实用化程度。美俄的电磁脉冲弹已转入外场实验或投入使用，微波弹、评估弹技术也获得了一定的突破，国内的差距较明显。国外无源干扰战斗部技术发展已进入第三代，国内总体水平则处于第二代。

国内在高能/超高能含能材料研究上起步较晚。对不敏感炸药研究较少，尚没有定型装备武器弹药的炸药装药，高能及超高能含能材料的研究和应用差距较明显。

五、本学科火力系统相关学科的发展趋势与展望

(一)探索新型发射原理,提高初速与射频,实现兵器发射性能提升

实现高初速的重要途径是发展新原理发射技术,目前最有发展前景的是电热化学发射技术和电磁发射技术。在电热化学发射方面,重点突破电源小型化和武器化关键技术,实现电热化学发射技术成果向装备的转化。在电磁发射方面,开展高效电源技术研究,进一步提高弹丸初速和发射稳定性,建立完善的测试系统和理论体系。

为了增大防空反导系统末段火力拦截的空域范围及火力密度,需解决高初速、大射高的中口径火炮的高射频供、输弹技术及轻型化问题。

需提升传统火炮的内弹道性能、改进传统火炮的结构,进一步提高炮口初速和射频。

(二)大幅度提高弹箭的射程,实现兵器远程化

开展简易控制、低成本火箭复合增程技术研究,重点开展增程发动机、外弹道及其控制技术的研究,进一步提高火箭的射程。

开展炮弹推进、增程和减阻技术的研究,重点解决发动机效率和抗高过载、炮弹减阻、复合增程等技术难题,实现炮弹射程大幅度提高。

发展固体冲压发动机、脉冲爆轰发动机、凝胶推进剂发动机等新型推进技术,提高发动机的综合性能,为进一步提高弹箭射程提供技术支撑。

(三)发展智能化弹箭,提高目标命中率

发展末敏弹、弹道修正弹、制导和末制导弹箭等智能化弹箭,提高其对目标的命中率,是兵器火力系统的主要发展方向之一。

先进的制导控制部件是提高制导弹箭性能的基础,大力发展低成本抗高过载微机电制导控制部件的研发、加工和生产。

系统化和一体化是未来武器装备的发展方向,提高立体机动作战能力是智能化弹箭为适应未来战争的重要发展方向。制导方式多样化是提高智能化弹箭性能的重要方向。

(四)发展灵巧毁伤、高能低易损毁伤与新型毁伤的弹药,实现对各类目标的高效打击

灵巧毁伤技术是信息化战争对毁伤提出的新要求,弹药的无人值守、智能决策、信息共享、联合毁伤是信息化弹药发展的主要方向;信息与网络技术是未来信息化战争的核心,需发展电磁脉冲、微波毁伤等新型毁伤技术以及有源和无源干扰技术,强化信息毁伤理论。

有效毁伤深层工事目标是各军兵种所面临的共性技术问题,其中串联战斗部、高速侵彻战斗部、高能钝感炸药和智能引信是当前和未来研究的核心。机动目标的毁伤技术也是当前和未来研究的重要方向。

发展复杂作战空间内的目标探测、环境识别、战场态势感知、多模精准毁伤自适应控

制、自主攻击控制的新原理、新方法和新技术，以及多目标分类、敌我识别、特征提取等毁伤控制的基础理论和核心技术。

第九节　纺织科学技术

一、引　言

纺织工业作为我国传统支柱产业、重要的民生产业和国际竞争优势的产业，在繁荣市场、扩大出口、吸纳就业、增加农民收入和促进城镇化发展等方面发挥了重要作用。我国纺织生产规模和出口贸易均居世界首位。

二、本学科近两年研究进展

(一)纺织工业科技进步

我国纺织工业加快了科技进步，作为推进产业结构调整和产业升级、学科发展的重要支撑，围绕创新能力提升和技术装备升级积极开展工作，已取得显著成效。

1. 纤维材料技术进步成效显著

一批高新技术纤维材料产业化取得突破，碳纤维、芳纶 1313、芳砜纶、超高分子量聚乙烯、聚苯硫醚、玄武岩纤维等高性能纤维以及竹浆纤维、麻浆纤维等生物质纤维已实现产业化生产，正在进一步开发系列品种、扩大应用，多数技术及产品已达到国际先进水平。芳纶 1414、新型溶剂法纤维素纤维已取得中试成果，填补了国内空白，产业化生产技术正处于研究阶段。新型聚酯 PTT 树脂合成已突破中试实验，纤维生产加工及产品开发实现产业化生产。

国产化生产技术和装备的开发应用能力显著提升，有力地推动了化纤行业的快速发展和产业结构的优化调整。

化纤产品功能化、差别化水平提高，2010 年化纤差别化率达到 43％以上。

2. 纺织加工技术和产品开发取得明显进步

技术装备水平的提高，促进了纺织品生产加工水平的提升。棉纺自动化、连续化、高速化新技术的国产化攻关和大规模的推广应用提高了生产效率和产品质量。毛纺行业无结纱比例超过 60％，大中型毛针织企业基本实现纱线无结化；精梳产品 100％无梭化，粗梳产品 80％无梭化，产品质量大幅提高，接近世界先进水平。桑蚕自动缫丝机的推广应用使生丝质量水平平均提高 1.5 个等级，应用比例由 20％提高到 85％。

加工新技术推动了高档纱线的发展。紧密纺、喷气、涡流纺、嵌入纺等新技术的采用使纱线产品种类更加丰富，天然纤维纺纱支数大大提高，纱线质量显著提升。嵌入式复合纺纱技术已在毛纺行业得到产业化应用，开发出了羊毛 500 公支的高支纱线，棉纺、麻纺行业正在进行产业化研究。半精梳毛纺加工技术取得突破。特种动物纤维绒毛分梳及改

性加工技术达到世界领先水平。

织造、染整工艺技术进步提高了纺织面料的质量和功能化水平。新型电子提花装置的大量应用、经纬编新型面料的开发、多种纤维的混纺交织以及织物结构的创新大大丰富了纺织面料的品种，我国棉纺、毛纺、针织面料及一批化纤面料已经达到或接近国际先进水平。印染行业自主研发了活性染料冷轧堆前处理及染色、数码印花、涂料印花等一批印染新技术，大量采用了电子分色制版、自动调浆、在线监测等先进电子信息技术，大大提高了面料质量的稳定性和附加值。面料后整理由抗菌、抗皱等单一功能的整理发展至为提高织物附加值而进行的多功能整理，应用也越来越广泛，突破了服装、家纺等传统消费品领域，逐渐拓展至电子、航空、建筑等产业用领域。

3.绿色环保技术开发和应用进展较快

一批节能、节水的新技术实现研发突破，并在行业中推广应用。棉纺行业推广采用节能电机、空调自动控制等技术。化纤行业推广差别化直纺技术、新型纺丝冷却技术等实用节能型加工技术。印染行业节能降耗的新工艺技术研发和推广成效显著。

资源循环利用技术取得进展。废旧聚酯瓶回收利用技术得到有序推广，技术不断升级。应用再生纤维用于家纺填充料的技术已经开发出三维中空纤维等新品种，卫生性能也显著改善；用于生产可纺棉型短纤维、有色纤维等差别化纤维、中等强度工业丝的新技术也已实现突破，正在加强推广应用。

4.产业用纺织品发展迅速

高性能纤维应用水平的提高使产业用纺织品的性能大幅提升。高强高模聚乙烯、芳纶、芳砜纶、聚苯硫醚等高性能纤维材料产业化取得重大突破，推动了防弹防刺复合面料、耐高温针刺环保过滤分离用复合非织造材料、防喷溅阻燃防护服等产业用终端产品的研发。新型溶剂法纤维素纤维、聚乳酸纤维等生物质纤维原料的研发成功地促进了抗菌、可降解的医用卫生材料的开发应用。

产品加工技术取得突破性进展。非织造技术取得重大突破，直接梳理成网技术使加工流程大大缩短，高速加固技术大幅降低了运行成本，同时在产品的各向同性、均匀度、手感、厚薄等性能上显示传统纺织材料无法比拟的特点。产业用经编和立体编织技术的进步大大拓展了复合骨架材料的加工领域，突破了风力发电叶片、卫星支架、火箭喉衬等加工难度极大的产业用纺织品成型技术。重磅织造技术、多层在线复合技术推动了高强土工布、高档医卫材料等产业用纺织品的发展。

产品研发创新为促进国民经济相关领域的发展做出贡献。国产土工合成材料在青藏铁路建设工程中应用，成功解决了高原地质裂缝、冻土隔断、保温、防渗等系列难题。采用芳纶、聚苯硫醚等高性能纤维研制的环保过滤材料不但可将火力发电污染粉尘排放截留效率提高 5 倍以上，还可在废渣中分离回收珍贵的稀有金属，创造了较高的经济效益。轻质高强的高性能复合材料不但满足了航空航天、新能源等领域的需求，还在制造业中逐步替代部分传统钢材，促进了低碳发展。病毒阻隔精度高的一次性手术服、口罩等医疗用产品有效降低了交叉，保障了人们的生命健康安全。婴儿和老年人一次性尿布（裤）、妇女卫生巾、擦拭布、湿巾等卫生用产品大大改善了人们的生活质量。

5.纺织机械工业自主创新能力及制造水平大幅提高

大容量涤纶短纤成套设备,新型清梳联合机、自动络筒机等高效现代化棉纺生产线,机电一体化喷气、剑杆织机,均已实现批量生产;部分产品达到国际先进水平,有效替代了进口,国内化纤、棉纺装备自主化率显著提高。纺粘、熔喷、水刺非织造布设备以及电脑提花圆纬机、电脑自动横机、各种经编机等针织设备均已研发成功,并快速、大量推向市场,大大降低了纺织企业的装备成本。印染工艺参数在线检测与控制技术已经完成工艺点的检测,单机台的监测与闭环控制系统也研发成功,进入推广阶段。印染设备领域发展了大批具有节能、节水、减排的新产品,国产前处理设备、连续染色设备和印花设备已经可以替代进口。

6.信息化技术得到推广应用

产品设计数字化和生产制造自动化水平得到较大提升。CAD、CAM 等产品研发设计数字化技术得到广泛应用,有效提高了产品创新能力和市场反应速度。计算机测配色和分色制版等技术的广泛采用,使印染后整理水平大幅提高。现场总线技术和远程通信技术等在纺织装备领域得到推广。在线生产监测系统的一些关键技术取得突破,并在企业得到应用,为物联网在纺织行业的应用打下基础。

企业管理信息化取得较大进展。规模以上纺织企业应用企业资源计划系统(ERP)逐步推广,其中化纤、纺机、棉纺企业应用比例较高,大型骨干企业普遍采用。

(二)纺织科学技术进步

近两年纺织科技成果丰硕,学科发展迅速。涌现出一批约 300 项优秀项目成果,其中 12 项获得国家技术发明奖和科技进步奖一、二等奖。这批获奖项目覆盖面广、科技含量高、经济效果好,反映出纺织行业在落实科学发展观、建设创新型国家方面的重大进步。

三、本学科目前存在问题和发展目标

近年来全球纺织产业在获得突出成就的同时,也面临着重大挑战,过度的成本竞争、资源供给矛盾的日益突出,正成为纺织产业进一步发展必须突破的障碍。

纺织产业是最早实现机器化大生产的制造部门之一,高效率、低成本是其持续追求的主要目标,与此相应,也容易造成产业趋同、低价竞争的发展格局,影响产业在充分培育比较优势基础上的可持续发展。同时,纺织产业基本上属于资源加工型产业,较大程度地依赖于棉、麻、丝、毛等天然纤维资源和生产合成纤维的石化原料资源,对能源和水资源的消耗也很大;产业越是高速发展,与可供资源的矛盾就越突出,寻求与资源的供给平衡并提高资源使用效率的压力就越大。纺织产业在纤维生产、纺织加工、染整加工、服装制造、产品消费等过程中,都不同程度地存在着对环境的污染和对人体的不健康影响,随着人类对自身生活环境和生活质量的关注,纺织产业正面临着生产技术和产品的重大变革。

纺织产业的传统发展模式,直接导致了全球纺织业的发展困惑和冲突。发达国家将劳动密集型、资源依赖型和污染产业部门移向境外,造成本国的产业空心化和就业压力,而发展中国家某些产业部门则将成本与价格压力转化为劳动者、社会和环境的压力或演

化为过度竞争。与此同时，发达国家一方面不断指责发展中国家的低价竞争，另一方面又不断对其施加成本压力。这些矛盾思维造成全球范围内的纺织贸易冲突，严重影响纺织产业的和谐发展。

现代纺织应倡导和谐的可持续发展观，即应体现人与自然、人与人及国家与地区间的和谐。现代纺织应通过新技术、新材料、新工艺的采用，即应通过加工对象、加工技术手段、加工路线与形态的创新，努力寻求与资源的供给平衡，并提高资源使用效率、减少对环境的破坏、保护与改善环境，维护组织与组织、阶层与阶层、劳动者与投资者、生产者与消费者以及这一代与下一代的公正与平等；通过实施 WTO 框架下国际间的互利互惠的分工、竞争与合作，达到国家地区之间的共同繁荣。

现代科学技术的发展为和谐、可持续发展的现代纺织提供了技术支撑。全球性的信息化浪潮正影响着各个产业的发展进程，利用信息技术来嫁接改造传统纺织产业已成为业界人士的共识；具有特殊性能的新材料不断涌现，不仅有助于丰富纺织产品种类、提升产品性能，而且为纺织产业获取和利用新的资源提供了新的源泉；生物技术与传统纺织产业相结合，正使其生产方式和发展轨迹发生革命性的变化。在现代高新技术的导引下，一方面，传统纺织技术的现代化进程将不断推进，使纺织工业的生产效率不断提高，产品品质不断得到改善，由此形成纺织品供给与消费者需求的高层次良性互动；另一方面，通过合理开发、利用现有的自然资源，开辟新兴资源的利用途径，改进现有纺织生产方式，实现纺织生产高效率、高质量与人类生存环境的协调统一，有助于应对纺织产业大量消耗人类赖以生存的自然资源、不同程度地污染自然环境的发展挑战。

四、对本学科发展的政策建议

近年来，我国纺织行业实现了重大的转变和提升。纺织工业科技含量和创新能力大幅提高，自主研发、集成创新、引进消化吸收再创新硕果累累，大量科技成果的产业化成为行业在新时期增长的最重要支撑，较大地提高了纺织产业的全要素生产率。这说明我国纺织工业正在转变发展方式、调整区域布局、发展现代产业体系、提升产业核心竞争力。但经历了全球金融危机冲击和面临棉花等原料价格大幅波动之后的形势，让我们更加清醒地看到，正在发生的转变和提升还远远不够，还存在许多粗放、不协调、不可持续的因素。世界和我国的情况都在发生深刻变化，我国经济社会呈现出新的阶段性特征，纺织工业也进一步呈现转变发展方式、加速产业提升的紧迫性。我们要集中力量加快转变发展方式、加快产业提升、积极推进中西部地区承接纺织工业转移，这是发展纺织工业现代产业体系、提高产业核心竞争力的必然要求。

1. 认真实施《纺织工业“十二五”科技进步纲要》中提出的各项攻关与产业化项目

2. 加大科技投入，支持技术创新和进步

以增强企业自主创新能力为核心，支持纺织行业提高创新能力。考虑纺织工业在经济、创汇和就业方面的贡献程度，加大对纺织工业的基础学科、共性技术的研发投入，扶持或搭建几个国家级的科研创新平台。对自主创新成果的产业化加大支持力度，引导量大面广的中小企业推广应用有市场和成熟的先进适用技术。

3. 完善人才政策，促进人才结构优化

为全面推进纺织人才的发展，各级政府可通过财政和货币政策，有针对性地加大对纺织人才建设工程的投资力度，推动纺织行业人才服务平台的建设。纺织行业协会和学会组织，要加强行业人才政策的制定工作、监督和检查市场和企业人才政策的执行；并通过募集社会资金，以纺织人才培养基金的方式，奖励对人才培养有突出贡献的单位和个人。企业要建立人才奖励制度，对优秀科技创新人才给予物质奖励和表彰。

4. 加大面向广大中小企业的支持力度

大力建设服务于中小企业的技术服务平台，开展工业设计、技术咨询、知识产权战略实施、节能降耗、清洁生产和污染防治技术应用等服务，帮助企业研发新产品、新技术、新工艺，增强创新能力，形成具有自主知识产权的技术和产品。推动产学研联合，促进技术成果转化、适用技术推广和创新资源共享。

帮助中小企业提高管理水平、提高科学决策和经营管理能力，支持建立针对中小企业的管理咨询服务机构，指导企业加强现场管理、提高清洁生产水平。

中西部地区可制定针对劳动密集型企业的就业政策，根据就业强度，给予一定的优惠政策。

第十节　制浆造纸科学技术

一、引　言

公元 105 年东汉蔡伦所发明的造纸术已被世界公认为中国古代四大发明之一，奠定了当代造纸工业发展的基础。1000 多年来，造纸技术为推动人类文明进步以及世界文化、科学和信息的传播起到了极其重要的作用。

18 世纪末期，欧洲的产业革命使造纸业由手工生产逐渐发展为机器生产。我国机制纸的生产始于 1884 年，此后的半个多世纪内，中国造纸工业发展缓慢，技术水平低下。虽然自第一家机制纸厂（上海华章纸厂）建成至今已有百余年历史，但现代化的中国造纸工业是近 30 年才快速发展形成的，我国的造纸工业终于迎来了一个高速增长阶段。

目前，我国已经成为世界造纸工业最重要的生产与消费中心。自 2009 年起，我国纸和纸板产量和消费量已超越美国，居世界第一位，同时拥有世界上产量最大的制浆设备和幅宽最宽、车速最高和自动化水平最先进的造纸机。许多国际知名的造纸装备、化学品、造纸织物和商贸服务等公司的主要业务都集中在中国，很多国际性的造纸业跨国公司已在中国建立自己的生产基地和技术研发中心。我国造纸企业的总数在逐年减少，但纸和纸板产量却呈快速增长。近年来，在产业结构、产业布局、原料结构、装备技术水平、污染治理、环境保护和可持续发展方面取得了长足进步，生产工艺和产品质量得到稳步提升。造纸工业发生的巨大变化得益于制浆造纸科学技术的进步。

但是，我国造纸工业在高速、持续增长的过程中，也面临愈来愈严峻的压力和障碍：纤

维资源短缺、水资源匮乏、污染排放负荷高、重大技术装备依赖进口。这些问题是产业进一步发展必须解决的问题，也是制浆造纸学科技术今后发展的重点方向。

二、本学科发展概况

制浆造纸工程学科隶属于工学门类一级学科、轻工技术与工程中的二级学科，具有相对独立、自成体系的理论和知识基础构成。目前制浆造纸学科已形成了一个以制浆工艺、造纸工艺、机械装备、化学品、环境保护技术为核心领域的现代化应用科学技术体系。

目前我国从事制浆造纸科学技术研究开发的科技资源配置合理、层次清晰、分工有序，主体是行业相关科研教育机构和企业技术研发部门，按科技资源设置方式、活动性质和业务重点可分为专业科研机构、教育科研机构、企业技术中心三类，其中包括国家设立的制浆造纸工程国家重点实验室、制浆造纸国家工程实验室、造纸与污染控制国家工程研究中心，7 个国家认定的企业技术中心以及 20 余所设立制浆造纸专业本科教育的大学。三类科研机构作为行业技术创新和开发应用的主体，与林业、机械、化工、印刷、非金属矿等其他国内外相关行业的科研机构密切合作，共同推动着中国造纸工业技术水平的快速发展。

在国家传统产业技术进步政策推动和行业技术升级需求迫切的环境下，我国制浆造纸学科技术发展进程明显加快。针对制浆造纸学科技术领域的中文科技文献资料的初步统计分析表明，制浆造纸科学与技术学科近 5 年的重点研究方向主要集中在制浆技术、环保技术和造纸装备领域，这 3 个研究方向发表论文数量为 6205 篇，占总的研究性学术论文数量的 71％；学科技术专利申报方面，公开的发明专利主要集中在特种纸技术、制浆技术和造纸装备 3 个领域，合计占总数的 69％；实用新型则明显集中在造纸装备和特种纸技术两个领域，其数量占总数的 89％。

“十一五”期间，制浆造纸作为国家支持的传统产业技术升级学科之一，开展了一批重大国家科技计划项目研究，重点研究方向主要集中于资源高效利用和重大装备方面。主要项目包括“林纸一体化运行模式研究与示范”、“国产高速造纸机的研制”、“造纸工业关键技术研究”等国家科技支撑计划项目，以及科技部、发改委和环保部等部委下达的数十项科研项目。与此同时，学科也取得了丰富的技术成果，获得 4 项国家科技进步奖和几十项省部级科技奖励，这些技术成果极大地促进了学科发展，并推动了造纸工业总体技术水平的提升。

三、本学科主要研究进展

近年来，我国制浆造纸科学技术的进步和发展迅速，在节约资源、保护环境、提高质量、增加效益等方面均取得长足的进步，正朝着高效率、高质量、高效益、低消耗、低排放的现代化工业技术方向持续发展，呈现出技术集成化、生产清洁化、资源节约化和林浆纸一体化发展的趋势。本学科国内技术进展主要体现在以下五个方面。

(一)制浆科学技术

在高得率制浆技术方面，目前正朝着高强度、高白度、低能耗、低污染的技术方向发

展，其中化学机械制浆技术成为国内主流高得率制浆技术，形成了以杨木、桉木等速生材或木材加工剩余物为原料生产高得率浆的成熟技术体系。

在废纸利用技术方面，国内科技工作者在废纸再生过程中性质的变化及纤维衰变的机理、废纸离解与净化原理与工艺、废纸脱墨原理与方法、胶黏物障碍的产生机理与控制机制、生物酶脱墨技术与工艺以及废纸再生新技术等方面进行了较为深入的研究，推进了废纸制浆理论与技术的进步。山东华泰纸业集团李建华等人研发的“废纸生产低定量高级彩印新闻纸”项目获2006年国家科学技术进步奖二等奖。

非木材原料化学制浆技术方面，传统的间歇蒸煮技术已逐步被新型节能、高效的蒸煮技术所取代，置换蒸煮、氧脱木素、ECF漂白、封闭筛选、高效黑液提取和碱回收技术取得突破，并逐步推广应用。目前麦草和竹材清洁制浆关键技术已可以集成应用，技术水平在国际上领先。

（二）造纸科学技术

为满足现代化造纸机向宽幅、高速方向发展的需求，主要以引进、消化、吸收方式，应用了一系列造纸过程节水节能和产品品质改善技术。稀释水流浆箱技术改善了网部成形均匀性；靴式压榨技术提高了脱水效率；袋式通风技术降低了湿纸幅在干燥部的单位能耗；软压光技术改善了纸产品的印刷适应性能；纸机自动化控制系统（DCS）和纸张质量控制系统（QCS）等技术使得造纸全过程实现自动化控制。上述先进技术的国产化也取得明显进展。

造纸配浆技术领域，国内科技工作者在扩大非木材浆和高得率化学机械浆使用比例方面进行了大量的研究并取得突出成效，目前一些企业胶版印刷纸生产中高得率化学机械浆配用量超过了20%，明显节约了木材资源。

纸加工技术方面，国内研究重点是高配比研磨碳酸钙涂布工艺与技术，以及含化学机械浆的高档文化用纸涂布技术。此外，涂布本色牛皮箱纸板所需的高遮盖性涂料配方和涂布技术研究也已获得实用性技术成果。

（三）制浆造纸装备技术

造纸业的快速发展极大促进了国内国产装备技术的提升，尽管在大型成套设备和关键设备核心技术方面还明显落后，但国产设备设计制造水平与国际先进水平的差距正在逐步缩小。目前部分非木纤维制浆成套装备技术具有国际先进水平，草类原料化学制浆或半化学制浆的国产横管式连续蒸煮和碱回收设备水平已领先于国外；日产600t的废箱纸板制浆造纸成套装备技术基本成熟，其中鼓式碎浆机、热分散器、脱墨装置等关键设备实现了国产化；国产鼓式真空洗浆机、双辊挤浆机、压力筛、大规格双盘磨、多圆盘过滤机等关键单机设备的性价比优势明显，已能替代进口同类产品配套于年产20万～30万t/a的浆纸生产线中；产学研联合开发设计的流浆箱、软压光、机内涂布设备、气垫干燥烘干、可控中高辊、上浆系统等新型设备正在中小型纸机上得到推广。从幅宽来看，国内已有能力生产幅宽为5.5 m的纸机；从车速来看，最高可达约1000m/min。国内已能生产15万t/a的箱纸板纸机、10万t/a涂布白纸板纸机和5万t/a的文化用纸纸机。

(四)制浆造纸化学品技术

高效和功能性化学品是制浆造纸过程节能降耗减排的重要技术手段,制浆造纸过程中使用着大量的各式各样专用化学品,在此技术领域的研究成果众多。

针对制浆和清洁漂白需求,改性蒽醌(AQ)类蒸煮助剂、四乙酰乙二胺(TAED)类氧漂活化剂和木质素过氧化物酶类生物酶漂剂的研究取得阶段性成果;研究开发了废纸脱墨用固体脱墨剂和高效的中性脱墨技术;二氧化氯制备技术与装置国产化研究开发已取得突破,拥有自主知识产权的技术成果成功应用于工业生产。

纸机抄造过程的高性能新型助留助滤剂、合成表面施胶剂、杀菌防腐剂等方面的研究较为深入,取得了一批新技术成果。

制浆造纸废水水处理化学品方面研究是目前的热点,深入研究开发了聚铝和聚铁类废水深度处理用高效混凝剂及其应用技术。

(五)污染治理技术

“十一五”期间,我国制浆造纸污染治理技术的研究与应用进入高速发展时期,废水的处理和固体废物的资源化利用技术成果大量涌现。

山东太阳纸业股份有限公司深入研究开发 PRC APMP 高得率制浆废液低能耗热泵蒸发浓缩和碱回收技术,克服了采用传统物化—生化处理方法难以达标排放的技术难题,初步建立了 APMP 制浆废液零排放技术。

为实现废纸制浆造纸过程废水超低排放或零排放目标,研究开发了多种多样的过程工艺用水封闭循环技术,部分企业采用短循环工艺或段间净化处理技术可基本达到废水零排放效果。华南理工大学万金泉等人研发的“废纸造纸废水资源化利用关键技术研发与应用”项目技术成果 2009 年获国家科学技术进步奖二等奖。

针对新颁布实施的制浆造纸工业水污染物排放标准(GB 3544—2008),开展了大量废水深度处理技术方面的研究,高级氧化法、生物滤池、超效浅层离子气浮净化等技术已呈现良好的 COD 深度降解及脱色效果。

制浆固体废弃物和水处理污泥的浓缩技术取得进展,高固含量的污泥可作为生物质燃料实现资源化利用目标。

四、本学科国内外研究进展比较

制浆技术方面,由于装备研发条件的优势,欧美等国家在高得率制浆技术和低能耗化学制浆新工艺方面的研发成效仍然领先于国内,溶剂法制浆、生物制浆、废纸生物脱墨等新技术也处于进展中。受新能源开发潮流的推动,国外研究的新热点是将传统单一的制浆造纸过程转化为能够同时生产纸浆和纸、高分子材料和化学品、生物能源的复合型生物质提炼过程。国内在吸收、跟踪、借鉴先进技术的同时,根据自身制浆纤维原料的特点进行了大量适应性和改良性研发应用,取得良好成效。特别是在麦草、竹材等非木材纤维原料清洁制浆和无元素氯漂白技术方面进展显著,自主创新性成果丰富,技术水平居国际领先。

造纸技术研究国外主要是由造纸设备公司推动,并通过新型设备予以承载和体现新

技术特点及优势。为改善纸和纸板产品品质和生产过程节能降耗，在节能磨浆工艺、新型稀释水流浆箱成形技术、靴式压榨技术、强化干燥技术等方面不断优化。同时，开发的帘式涂布和喷雾涂布等新一代机内涂布加工技术步入商业化应用阶段。国内在速生材高得率化学机械浆和低品质废纸浆扩展应用技术方面成果明显，起到了缓解国内优质纤维原料匮乏的成效。

在制浆造纸装备制造技术方面，尽管差距在逐步缩小，但总体上我国明显落后于国外。国内制浆造纸装备的技术研发和制造主要采取吸收、消化和再创新等措施，研究开发和升级了一批制浆造纸装备，但由于核心技术缺失、研发能力和集成能力相对薄弱，目前大型成套制浆造纸设备市场仍被国外跨国公司垄断。

制浆造纸化学品技术方面，国内外普遍注重功能性新产品的开发。在过程控制和功能性助剂领域，中性脱墨技术、微粒助留技术、聚氨酯和聚苯乙烯类高分子聚合物施胶技术等方面国内技术成果很多，但产业化和深入的应用技术研究相对薄弱。

污染治理技术方面，废水 COD、BOD 减排和固体废弃物资源化利用是国内外共同的研究重点。由于国内制浆造纸废水排放新标准(GB 3544—2008)的颁布实施，废水深度处理和回用技术成为研究热点。中小废纸制浆造纸企业采取强制封闭循环和内部净化处理相结合方式，在废水超低排放或零排放技术方面取得进展；非木材原料化学制浆黑液提取及碱回收技术趋于成熟；制浆和水处理污泥等固体废弃物的浓缩技术与生物质能源利用技术成果丰富。

我国制浆造纸学科技术尽管发展迅速，除了非木材制浆造纸技术等个别领域具有领先优势外，总体水平仍和国外存在一定的差距，其根源来自以下几方面：

(1)自主创新能力较弱。国内学科技术进步主要驱动力来自于市场需求和产业相关政策，主要通过引进、消化或模仿方式跟随国际技术前进，企业科技有效投入严重不足，技术自主创新发展明显滞后。

(2)工程技术开发能力和产业化能力不足。我国造纸技术研究开发主要来自于专业科研院校和企业技术中心，前者由于技术手段和设施条件的限制，往往以理论研究和应用基础研究形式为主，由于工程技术研发平台设施水平低、高水平工程技术人员缺少，自主创新技术的工程化技术开发能力严重不足；后者往往注重解决具体的生产技术问题，并由于商业竞争的原因，产业化技术推广应用动力不足，导致我国工程技术开发与集成能力薄弱、学科技术水平发展受限。

(3)新技术产业化难度大。我国由于原料结构中优质原料比例偏低，非木材纤维原料、废纸原料成为造纸的主体，在低质原料、高标准环保要求和企业的成本控制这三者制约下，新技术往往由于技术经济可行性的不确定性和风险性，使得新技术产业化难度极大，阻碍了行业自主创新技术的发展速度。

五、本学科发展趋势和对研究方向建议

(一)本学科发展目标和前景

近年来，中国造纸工业在高速、持续增长的过程中面临愈来愈严峻的压力和挑战，纤

维资源短缺、水资源匮乏、污染排放负荷高、重大技术装备依赖进口等问题越来越突出。由于原料结构复杂、中小企业众多、行业总体技术层次仍然相对低于国际先进水平，在纤维资源高效利用技术、清洁生产和污染减排技术、固体废弃物资源化利用技术、高性能纸基功能产品、大型成套技术装备等方面，具有迫切的技术和市场需求。

面对资源和环境制约，本学科技术的发展将以“资源低消耗、过程低排放、产品可再生、废弃物资源化”为目标，以发展循环经济、创新发展模式、建设资源节约型造纸工业为核心，重点开展资源的高效利用和循环利用、污染治理、节能减排技术与制浆造纸关键装备研究，促进造纸工业实现产业发展与环境、社会效益的完美统一。

（二）本学科未来发展趋势

针对我国造纸工业纤维资源的短缺、能源和水资源的匮乏，而环境保护要求日益严格的现状以及产业政策要求，制浆造纸学科技术必将依据我国造纸工业原料结构特点和企业技术水平的现状，进一步加大科学研究与技术开发力度，通过跟踪研究国际前沿技术，发展自主创新的先进技术，加快制浆造纸科技进步的步伐，促进我国制浆造纸工业的可持续发展。

本学科的研究成果的推广应用将推动制浆造纸生产线规模进一步扩大和工艺系统更加简化，促进纤维资源和能源的消耗指标进一步降低、污染负荷减少，使系统封闭将更加完善。

本学科技术将更多地引入现代生物科学、膜材料、木材化学、纳米等领域的先进技术，未来的制浆造纸厂将很可能是一个复合型的植物纤维原料生物提炼与利用企业，可得到纸浆、纸张、能源和多种化工产品。

制浆造纸学科的发展将为中国造纸工业发展成资源节约型、环境友好型的绿色产业提供有力的技术支撑。

（三）对本学科研究方向的建议

为加快制浆造纸科技进步的步伐，从我国造纸工业现状和发展需求以及行业政策导向出发，建议今后重点开展以下几个方面的科学研究和技术开发：

（1）纤维资源高效利用与循环利用技术。以废纸、速生材和非木材为主要对象，研究开发新型纤维分离技术和低品质纤维原料制浆造纸利用技术，提高纤维原料利用率，减少纸张回收和再生过程中的损耗和技术障碍，充分节约纤维资源。

（2）环境友好型制浆造纸关键技术。以制浆造纸过程清洁化技术为重点，研究开发生产过程污染减排先进适用技术、节水节能技术、造纸废水高效低成本处理技术和再生回用技术、固体废弃物资源化利用技术等，实现造纸工业的降耗、减排、节能目标。

（3）高性能纸基功能材料生产技术。开发高性能纸基功能材料重点产品，满足高技术领域对纸基功能材料的需求；拓展纸基材料技术含量和功能特征；丰富纸基产品的品种和应用范围。

（4）高度集成和性能明显提升的大型、先进、专用技术装备研制。以市场需求为导向，研制开发节能型清洁制浆成套设备；低能耗速生材高得率制浆成套设备；宽幅、高速先进

造纸机;高度集成的自动化制浆造纸生产线。

(5)高效、专一、功能性造纸化学品的开发应用。包括绿色化学品、生物质化学品、纳米材料的开发应用。

(6)造纸行业循环经济和低碳经济关键技术的开发。围绕纤维资源高效利用和废弃物资源化目标,开展生物处理技术、膜材料处理技术、生物质能源技术的应用研究与产业化实施,建立制浆造纸工业生产过程循环可持续和低碳化发展模式技术体系。

第十一节　食品科学技术

一、引　言

进入21世纪以来,我国食品工业在日益复杂的国际竞争环境下,持续保持强劲的发展势头,每年以20%以上的速度高速增长,已成为国民经济中增长最快、最具活力的支柱产业,并在生产、加工、销售过程中,带动了三大产业中其他相关行业的发展。食品学科作为集农业、制造业、现代流通服务业于一体的综合性学科,为食品及其他相关行业发展提供了人才、知识、技术等创新动力支持。因此,食品学科发展水平的高低,对我国食品工业优化产业结构、提升产业竞争力、实现持续包容性增长具有重大意义。

二、本学科发展概况

食品科学技术学科近几年在国内外的知名度与影响力日益提升,在学科方向特色、学术团队结构、科学研究水平、人才培养质量、社会服务等各个方面已经成为在国内外均具有较大影响力的学科。

(一)学科规模不断扩大、学术梯队显著优化

为尽快满足我国食品工业规模快速扩张对人才的需求,我国高校培养的食品专业人才数量快速上升,设立食品专业的高校也进一步增加。截至2010年,全国已有235余所高校设有食品类专业,比2008年新增30所高校。同时,我国食品类高校纷纷加大了领军人才建设。截至2010年9月,食品类高校中已有3人入选国家“千人计划”,在食品科学技术领域代表我国学术界最高荣誉的中国工程院院士有5位。同时,在“长江学者计划”等国家、省、市、各地人才计划的带动下,我国食品类高校师资队伍的规模、结构和质量不断优化,学术梯队快速组建。

(二)教学与改革不断推进、人才培养质量不断提高

各高校通过整合课程体系和改革教学内容、教学方法与教学手段,不断有效提高人才培养水平。国家精品课程和双语教学示范课程取得重大进展,2009～2010年共批准建设的食品类全国高等学校精品课程达18门,双语教学示范课程达5门。食品专业毕业生的质量也不断提升。2005～2010年,食品科学与工程专业获得全国优秀博士学位论文获奖

有 5 篇、提名 7 篇，其中 2010 年获奖论文 1 篇、提名论文 3 篇，为历年最多。

(三)理论与技术获得突破、科学研究水平持续提升

近年来，我国食品类高校的经费投入不断增多，如学生人均实验仪器设备价值由 2003 年的 2.3 万元增长到 2010 年的 5.3 万元。政府作为高校研究与开发的主要投入主体，也不断加大资金投入力度。以国家自然科学基金为例，2009 年与食品科学技术密切相关的科研项目有 200 余项获得资助。总资助经费额度达到 6262.5 万元，比 2007 年的 2440 万元增加了 156.7%。在政府不断支持下，食品学科在 2009～2010 年度培育孵化出一批高技术含量、高附加值的科研成果，并成功实现了科研成果在产业中的高效转化，大大提高了我国食品学科的科技水平和产品的国际竞争力，有效地推动了农产品的增值和农民的增收。2010 年，214 项国家科学技术进步奖奖项中有 9 项与食品科学技术直接相关，其中包括 1 项一等奖。高水平的论文产出也呈快速上升趋势，在全世界所发的食品科学技术领域的研究论文里，中国发表的论文所占比例从 2005 年的 3.71%提高到 2009 年的 7.75%。国内食品领域知识产权授权数也快速上升，我国食品学科不仅在科研和创新产出上取得可喜成绩，而且在推动产学研联盟、发挥高校科研优势、促进科研成果转化方面取得了一定的进展。此外，我国还建立了企业国家重点实验室和国家工程实验室，并已成为发展共性关键技术、增强高校技术辐射能力、推动产学研相结合的重要平台。

(四)食品学科发展不断促进食品工业发展

进入 21 世纪以来，我国的食品工业飞速发展，连续 20 年以超出 20%的年增长率高速增长。食品工业的高速发展背后，我国食品学科的支撑效应不可忽视。利用灰色关联度模型分析了食品工业发展水平与代表食品学科创新发展水平的主要因素之间的相关性，以量化分析食品学科发展对食品工业的促进作用。结果表明，在促进食品工业发展的各类要素中，食品学科经费投入、本专科学生招生人数以及发表的科技论文数量是最具影响力的三大要素。该模型为未来食品学科的发展指明了方向，即我国应大力加强食品学科的研发投入，进一步优化人才培养模式和提升创新型人才的培养力度，并引导科研人员更为积极地从事基础及应用基础方面的研究，在创新性上作出贡献，为食品产业的可持续发展提供动力。

三、本学科国内外比较分析

(一)国外优秀食品学科建设要素

国外优秀学科建设通常有着良好的政策引导和支持，充足的财政投入以及长期积累。以美国为例，美国政府高度重视农业和食品科技的投入，2011 年美国农业部国家食品和农业研究院(NIFA) 启动了“核心竞争力研究”计划，其中农业食品与研究启动项目(AFRI)投入 4.29 亿美元，相比 2010 年的 2.62 亿美元增长了 63%。近几十年内，欧美日等国也相继以政策立法形式保障本国学科发展的良好环境以及资金投入。正是这种长期支持以及学科发展的长期积累奠定了国外优势食品学科的基础，国外不少知名食品高等院

校都经过百年以上的累积才形成目前的优势地位。

(二)学科设置强调与食品工业发展的适应性

以美国为例,20 世纪 40～60 年代是美国新食品开发的繁荣时期,相应地美国食品科学研究也聚焦于新食品、新包装、新生产工艺的设计开发;从 60～80 年代,工业食品营养和安全得到重视,各高校中食品微生物、食品营养学、食品分析等新学科逐渐涌现;80 年代以后,转基因食品、功能性食品成为美国食品工业热点,因此食品生物技术、非热加工和分离提取技术研究迅速发展;进入 21 世纪后,学科的发展呈现超前工业的趋势,对工业发展和消费心态具有引导作用。

(三)基础研究和技术研究水准较高

国外,尤其是美国、欧洲、日本等国家,食品学科的学术研究水平较高。在 *Journal of Agricultural and Food Chemistry*、*Bioresource Technology*、*Food Chemistry*、*Journal of the Science of Food and Agriculture* 等 30 本权威食品科技类杂志中,在权威数据库 Chemical Abstracts Service, CAS 上检索,结果显示 2001～2009 年食品科学与技术领域发表的论文数共为 466583 篇,其中美国占 140201 篇(30%),位列第一,日本占 30 190 篇(6.5%),中国占 15744 篇(3.4%)。这与各国食品高等院校的数量、食品学科建设的总体质量的情况是相适应的,也显示了我国与国际水平的差距。

(四)食品学科与其他学科交叉水平比较高,国际化程度也比较高

国外食品学科设置往往与农业学科、生物技术学科等与食品密切相关领域实现交叉共建,多数著名食品高等院校均建立了工业中心或技术中试基地,与行业联系紧密。另外,国际优秀食品学科大多国际化程度比较高。例如美国诸多大学持续实施国际化战略,其国际影响力与声望是我国很多同类学科难以相比的。

(五)人才培养效果较好,服务社会能力较强

国外优秀食品学科的整个学科设置,包括课程设置、人才的培养模式和标准相对于不同阶段行业需求和国家需求不断进行调整。以美国食品学科建设的代表性标准,IFT "Education Standards for Degrees in Food Science"为例,自 1966 年首次制定最低标准以来,每 10 年修订一次。国外食品高等院校的课程设置各有特色,但都强调"以人为本,学以致用"的人才教育目的,且多学科交叉程度比较高。

(六)国内食品学科总体发展水平与国外依然有一定差距

尽管食品学科在最近两年取得了长足的进步,但是与发达国家先进学科相比,还存在着一定差距。在研究队伍方面,国内有博士学位的教师所占比例仍然偏低,教授和副教授趋于老龄化,例如 2008 年我国大学教师中获得博士学位的比例为 12.1%,而在美国的大学中具有博士学位教师的比例平均在 60%以上。国内师资力量和研究人才的培养机制和吸纳模式需要进一步改善;在人才培养方面,本科生和研究生的培养模式和标准差距比

较大，国内本科生以及研究生的社会服务能力相对比较弱；在基础研究和技术水准方面，国内的食品学科总体发展不均衡，总量和水平都有待提高；学科的国际影响力与美国日本等著名大学和著名学科相比，差距甚远。

四、本学科展望与发展对策

（一）本学科的发展趋势

随着世界多极化、经济全球化深入发展，各种形式的保护主义抬头，我国食品工业发展的外部环境更趋复杂，同时也面临了更多的发展机遇。国内政策环境的发展战略、食品行业发展的方向和步伐以及国际食品科学学科发展前沿将影响着我国食品学科以下的发展趋势。

1. 科技人才队伍不断壮大，培养水平进一步提升

“十二五”期间，我国食品学科将进一步培养造就规模宏大、结构优化、布局合理、素质优良的人才队伍；努力实现人才资源总量稳步增长、队伍规模不断壮大，人才素质大幅度提高、结构进一步优化，服务社会能力明显提高；为我国食品工业发展奠定坚实基础。

2. 专业结构趋于多样化，学科交叉性进一步提升

随着食品工业对人才的需求越来越多样化，食品专业的学科建设在巩固已有传统学科优势和特色的基础上，也逐渐从单纯的食品转变到与生物工程、生物技术和农业等专业的交叉，许多单一的专业向下发展了多个学科方向的分支，拓展到食品的几乎各个领域，逐渐形成学科群的模式，共同实现健康发展。

3. 以大项目为载体的平台建设不断增多，创新能力不断提高

在科学技术迅猛发展、各类资源快速流动的时代，一些重大研究活动是单个机构难以胜任的，只有跨越组织界限，通过众多研究主体要素的集成和合作，形成协作机制，才能真正实现科学技术的重大突破和创新。在未来发展中，我国食品学科建设将进一步加强重点学科平台建设的统筹规划，从而促进学科平台的共享与交流。随着食品学科的人才培养、科研和社会服务三大职能在创新中不断激活和强化，我国食品学科的创新能力与发达国家之间的差距将逐步缩小。

（二）本学科的发展对策

为实现我国“十二五”规划的宏远发展目标，特别是食品工业的包容性可持续增长，我国的食品学科的未来发展必须根据国家需求和行业需求、国际学科发展前沿，明确学科发展的方向和目标，进一步凝练大学精神、提高质量意识，提高教育质量、推进高水平学科建设，顺应科技发展趋势、强化学科创新能力，集聚优势资源、增强社会服务能力。具体应对措施如下。

1. 人才培养

高等教育应以学生在教育教学过程中各方面的发展作为评价教学质量的主要依据，除了要继续培养适应社会的人，也必须使他们能够面向未来，即培养具有创新精神的人

才。为回应高等教育的多样化及社会对人才的多样化需求，食品学科应实行多类型、多规格的人才培养模式，把培养具有社会责任感、全球视野和创新精神的高素质拔尖创新人才作为根本任务。

2. 优化学科队伍结构与学科建设环境

我国食品学科专任教师中拥有博士学历的教师比例大大低于美国，而且专任教师年龄偏大，要提高教育教学和科技研究的质量与水平，首要之举就是提高整个学科队伍的水平。以开放的姿态，优厚的待遇，采取特殊政策，通过有效的机制与制度保障，吸引和汇聚一批具有国际先进水平的食品科学与技术领域的学术大师和学科带头人，同时加大“内部培养”力度，从内部培养学科带头人和学术带头人，带动学科梯队建设，逐渐形成合理的年龄、职称、学历、学员、专业结构团队。

3. 产学研结合推动食品科技成果产业化

要促进高校食品科技成果转化，建议政府主导和市场配置相结合，同时加大科技投入，培育完善的科技成果转化服务体系，加强“官产学研”之间的结合。食品类高校应完善面向国民经济建设、面向企业市场需求的管理机制与考核机制，坚持基础研究与应用研究、科技成果推广相结合的原则，与企业建立紧密联系，充分发挥食品学科优势和科研资源。同时注重培养扶持科技创新团队，瞄准国民经济和社会发展的重点领域，加强基础科学和前沿技术研究，特别是交叉学科的研究，实施若干重大专项，实现跨越式发展，全面提高食品学科创新能力，为区域经济和社会发展做出贡献。

4. 经费投入

我国与发达国家在学科建设经费投入方面有较大差距，这严重制约了食品学科科技创新能力的提升与发展。因此，应保证政府在教育投入体制中的主渠道作用，加大财政投入，为建设高教强国提供保障。此外，积极拓宽教育投入渠道也是解决地方高校科技经费不足的途径之一。我国地方高校的科技工作要参与到本地企业科技活动中去，通过市场和企业来解决经费不足的问题。此外，也可学习美国等发达国家高校接受捐资办学的经验，鼓励社会各界人士对高校捐资助学。

5. 继续加大平台建设，强化资源整合能力

创新平台建设对推动学科发展、引导行业科技进步至关重要。因此，未来需要继续深入建设支撑食品学科创新发展与成果转化的平台，通过重点建设科研基地、科技创新公共服务平台、科技资源共享平台、科技成果转化与技术转移平台，完善孵化功能，实现科技成果转化和项目对接、同时辐射区域的科技创新集聚与扩散功能。在推进国际和国内跨省区的技术创新合作中，建立成果、专家、中介、需求数据库，积极参与国际间的技术引进和输出转移工作，为企业技术引进的消化吸收、开发创新提供全程服务。

6. 加强开放与交流，在交流中提高水平

我国食品科学的发展与创新要与世界同步，通过高水平国际合作与交流开拓人才培养和科学研究的全球视野。在提升国际影响与国际化程度方面，努力把食品类学校打造为国际交流、合作和创新的平台，从而提升食品学科的整体国际影响。

第十二节　粮油科学与技术

一、引　言

粮油科学与技术学科是研究粮食、油脂和油料在购销、储运、加工中的物理、生理和生化特性及控制技术的一门科学技术，它是一个以粮油为研究对象，涉及理、工、农、医（营养与健康）等跨领域、多学科渗透而又相对独立的综合性学科。粮油科学与技术学科涵盖了粮油产后的购销、储藏与物流、加工与综合利用、装备与自动化、质量安全与营养、信息网络与企业管理等专业。

粮油作为特殊重要商品，关系到军需民食、国计民生、社会安定。粮油科学与技术学科对推动现代粮油流通产业的发展、满足人民健康生活需求、保障国家粮食安全、建设和谐社会发挥着支撑作用，在我国国民经济发展中具有十分显著的地位。因此，备受党和国家的重视。

改革开放以来，粮油科学与技术学科的学科研究不断深入、学科建设快速发展、科技队伍日益壮大、科技创新硕果累累、粮油产业发生巨变，我国在粮油产后技术领域的国际地位显著提高。

二、近年来本学科主要研究进展

（一）学科研究水平空前提升

1. 粮食储藏

创立了具有中国特色的储粮生态系统理论体系，创新了低温储粮基础理论研究方法，创新了储粮通风技术基础理论，突破了储粮害虫抗药性基础研究瓶颈，完善了粮食干燥基础研究，夯实了粮食产后损失及减损关键技术理论基础。我国粮食储藏技术总体跃居国际先进地位，部分技术水平超过欧美等发达国家。

2. 粮食加工

建立了稻米与副产品深加工高效增值创新技术系统，稻米加工设备研究与制造基本达到世界先进水平；小麦制粉工艺处于国际先进水平，小麦制粉设备主机在性价比方面已超过外国公司；生物酶技术缩小了玉米深加工技术与国际水平差距，玉米生物转化技术的研究及应用进一步深化；特色杂粮生产及加工利用研究与技术开发取得进展。

3. 油脂加工

部分油脂设备技术性能指标接近或达到国际同类产品水平；开发出具有自主知识产权的系列磷脂产品，质量达国外同类产品指标；大豆分离蛋白、浓缩蛋白、组织蛋白产量已居世界前列。油脂加工节能减排技术、低溶剂消耗、低能量消耗以及热能回收等方面取得显著效果。

4.粮油检验

检验仪器开发水平与国际差距缩小,开发了自主知识产权的粮食新陈度快速检测方法及相关仪器等;食品安全评价技术研究系统化;标准体系建设快速发展;检验方法标准全面与ISO国际标准和发达国家标准相衔接。

5.粮食物流

初步形成粮食物流供应链系统理论;粮食流通的通道网络化、过程四散化、作业机械化、管理信息化方面已取得重大进展;研发出大型粮食装卸、输送、接受和散粮进出仓设备。

6.粮油营养

粮油营养理论研究受到重视,利用粮油中的营养素修饰基因表达或基因结构等方面取得一定进展。营养强化带动粮油食品开发,对强化面粉、强化食用油、强化大米及强化的米面制品已进行了工业化生产。

7.饲料加工

部分饲料产品和许多优质产品的饲料转化率都达到了国际先进水平;饲料加工工艺和设备制造技术接近国际先进水平;饲料设备制造成为世界最大的饲料装备生产国。

8.发酵面食

作为配料之一的活性干酵母研究取得突破性发展,达到了国际先进水平;形成班产1t、2.5t和5t的系列化馒头成套设备,馒头生产开始向现代化迈进。

(二)学科发展取得显著成就

1.科学研究成绩斐然

(1)创新成果丰硕。“十一五”期间,粮油科技创新使新技术、新设备、新成果层出不穷。“十一五”期间,粮油科技获得国家科技进步奖7项,其中一等奖是近20年首次获得,二等奖的数量也明显超过“十五”期间;获得国家发改委软科学奖3项、省部级奖励60多项、中国粮油学会科学技术奖147项,其他奖项近百余项。

2006~2009年,粮油科技项目共申请专利201项,其中申请发明专利60项、实际授权专利86项、授权发明专利36项。另外,2009年全国粮油工业企业获得专利1984项,其中发明专利528项。

目前,粮油科学与技术学科国内学术期刊共有11个,刊发的论文数量逐年增多、质量提高。其中《中国粮油学报》是全国食品工业类中文核心期刊,近5年来共发表论文1556篇。2006~2009年,粮油科技项目成果在国内外期刊上发表学术论文703篇,出版专著173万字。

“十一五”期间,正式颁布实施的制修订粮油国家标准和粮食行业标准共336项,其中国家标准248项、行业标准88项。

2006~2009年,共研制新产品104项、新装备1416台套、新材料4种、新工艺190个,进行中试和形成生产基地160个,示范基地321个。共完成成果转让166项,签订成

果转让合同 140 项，实际应用成果 221 项。

(2)实施重大科技专项。国家粮食局主持的国家“十一五”科技支撑计划项目共 4 个大项 14 个课题获得重大进展，取得了阶段性成果：①安全绿色储粮关键技术研究开发与示范项目；②粮食丰产科技工程(产后)课题；③粮食宏观调控信息保障关键技术研究与应用示范项目；④储备粮减损新技术研究与示范。

(3)科研平台全面建设。在国家有关部门的支持下，在不同的粮油技术应用领域、不同的地区建立国家工程技术(研究)中心、企业工程技术中心和国家(部门)重点实验室，为粮油流通科技水平的提升提供了平台。经国家发改委审批，3 个国家工程实验室建设已经立项，分别为国家粮食储运工程实验室、国家粮食深加工工程实验室、国家粮食加工装备工程实验室。国家粮食局组建了粮食储藏、粮食物流、粮油食品、粮油加工装备、粮油质量检验等 14 个国家粮食局工程技术研究中心。

2. 学科建设蓬勃发展

(1)学科教育。粮油科学与技术教育发展很快，学科分布逐步铺开，区域广阔，数量增多。截至 2010 年，全国开设有粮油科学与技术学科课程的高校有 140 多所，具有粮食油脂及植物蛋白工程硕士点的高校有 34 所，农产品加工及储藏工程硕士点的高校有 64 所，食品科学技术与工程专业博士学位授予权的高校有 15 所。以河南工业大学、江南大学、武汉工业学院、南京财经大学 4 所粮食院校为主，遍布全国 31 个省市食品学科院校中粮油学科专业本科和研究生教育的粮油科学与技术学科人才培养体系，业已形成。

(2)学会发展。近年来，中国粮油学会在组织开展学术交流，促进行业科技进步、发挥桥梁纽带作用、努力为粮油科技人员服务等方面发挥了积极作用：出版《中国粮油学报》，编辑出版学会会刊和专著文献，做好信息交流宣传平台；经国家奖励办批准，已连续 6 年开展了中国粮油学会科学技术奖的推荐与评审工作，在行业中具有较大的影响力和权威性；自 2003 年以来，在国家粮食局的领导下，学会每两年开展一次高级职称的评审工作，有力地推动了行业高级人才队伍建设；学会每年都深入企业、深入基层调研，为政府做好参谋和规划建言献策；随着学会专业领域拓展和工作面扩大，学会由原来的 5 个专业分会发展到 12 个专业分会，加强了自身组织建设，完善了发展机制，在国内外粮油科技界获得了较大的影响和较高的声誉。

(3)人才培养。目前，4 所粮食院校在校粮油本科生 5500 多人、硕士研究生 1100 多人和博士研究生 30 多人。多年来，为粮食行业培养和输送了大批高级专业人才，一批批毕业生活跃在国家机关、教育院校、科研院所、企事业单位的领导、管理、教学、科学研究、技术研发、产品营销与贸易等各类各级岗位上，为粮食行业的发展做出了突出的贡献。

截至 2010 年，基本完成了覆盖全国粮食行业的职业技能培训和鉴定网络，共组织鉴定 45075 人次，有 36163 人次取得了相应的国家职业技能资格证书，其中培训和鉴定的技师、高级技师已达到 510 人，一支具有粮食行业特点的职业技能人才队伍已初步形成。

(4)学术交流。近些年来，中国粮油学会广泛深入地开展国内外粮油科学与技术的学术交流。在国内交流方面：以总会、专业分会、专业学组、地方分会等层次主持或联合召开各种规模和不同形式的学术交流会、研讨会，不断将学术交流的平台做大、搞活、办实。在国际交流方面：参与了欧盟的“食品质量与安全(MoniQA)项目”的课题研究，将学术交流

构建为学科研究与国际接轨的桥梁，积极组织专家、学者出席国际学术交流活动；积极在华主办或承办较高层次和有影响的国际学术会议。

(5)科普宣传。国家粮食局自2006年开始连续举办了5届全国粮食科技活动周科普宣传活动，全国累计受众人数3 000万；中国粮油学会组织专家编辑出版了近10万字的《粮油食品营养与健康知识百问》科普读物，累计向社会发行10万册；近三年每年开展“爱粮节粮 科学储粮”科普系列活动；组织发酵面食科普宣传等专题活动。这些活动反响良好，受到中国科协的表彰。

(三)重大成果推动产业发展

“十一五”期间获得的国家科技进步奖和中国粮油学会科学技术奖等奖项，代表着我国粮油科学与技术学科创新的重大成果和研究水平，在粮油产业中得到推广应用，产生了巨大的经济效益。

获得2010年国家科学技术进步奖一等奖的粮食储备“四合一”新技术研究开发与集成创新项目，首创了以智能粮情检测、低剂量环流熏蒸、智能通风和高效谷物冷却四项技术为一体的“四合一”储粮新技术。成果应用到了全国31个省区市6000多万t仓容的中央和地方粮食储备库，取得290多亿元的经济效益。

获得2010年国家科学技术进步奖二等奖的大豆磷脂生产关键技术及产业化开发项目，以大豆油精炼的副产物水化油脚为原料，开发出食品、保健、医药等工业用系列磷脂产品，质量达国外同类产品指标，形成了具有我国知识产权的磷脂加工产业体系。在20家企业建立46条生产线，创经济效益20亿元。

获得2008～2010年中国粮油学会科学技术奖一等奖的大米产业链创新技术、高效节能与清洁安全小麦加工新技术研究与应用、馒头工业化生产关键技术集成创新研究与应用项目、特种水产饲料与特种水产品系统技术研究等13个项目的推广应用都取得了显著的经济效益和社会效益。

将科技成果向生产力转化，对促进粮油产业的技术进步和快速健康发展起到了重大作用。近年来，我国粮油产业发生了巨大变化，主要是：①初步形成了布局完整、结构合理、设施先进的现代粮食仓储体系，2009年全国仓房总仓容36424.3万t，比新中国成立初期扩大了20倍，国家和地方储备粮数量大大高于联合国粮农组织提出的粮食储备量不能低于年消费量17%(60天)的要求，为保障我国粮食安全和产品质量奠定了坚实的基础；②我国粮油工业已发展成为世界上最大的粮油加工产业，据不完全统计，2009年粮油加工业总产值达到11184.2亿元、利润总额312亿元，粮油产品品种和质量已跻身于国际先进行列，粮油机械远销国外；③在全国已经建立了200余家国家粮油质量监测中心，粮油质量安全监测体系初步建立；④以市场为导向的粮食物流体系基本形成，增强了国家对粮食市场的应急调控能力。

三、本学科国内外研究进展比较

国际粮油科学与技术学科发展日新月异：发达国家已形成了较为完整的粮食储藏生态学体系；对粮食资源的全利用技术使副产品综合利用的价值大幅提高；研发低热量油

脂；粮食物流实现“四散”化；新的粮油检验技术原创性强、方法针对性强，还有个性化粮油营养学的研究等方面，均值得我们很好地参考和借鉴。

我国粮油科学与技术学科发展取得了举世瞩目的成绩，但学科发展不平衡，即使是少数处于世界先进水平的技术，有些在全国范围内尚未广泛应用，因此，总体水平与发达国家相比还有一定差距。主要表现在：①系统的基础理论研究薄弱；②粮油科技对产业发展的支撑力不强；③粮食资源高效利用、综合利用研究水平偏低；④粮油加工工艺装备研究水平尚需进一步创新；⑤粮油产品安全质量标准和控制体系不够完善。

四、本学科的发展趋势及对策

（一）战略需求和发展对策

国家“十二五”发展规划所提出的战略要求，使我们粮油科学与技术学科面临新的形势和发展机遇：①国家粮食安全供求偏紧，令人忧虑；②公众对食品安全要求越来越高；③节能减排、绿色环保大势所趋；④外资企业在我国已从油脂加工领域向粮食加工领域进军，给我们带来新的挑战；⑤高新技术应用为粮油科技发展带来新的活力。

粮油科学与技术学科要采取坚持自主创新带动、关注市场需求拉动、依靠高新科技推动、利用产业更新促动、加强行业统筹联动等对策措施。要结合我国国情和粮食行业特点，走具有中国特色的粮油科技发展道路，力争在更多方面达到或超过世界粮油科技先进水平。

（二）发展方向及研发重点

紧紧围绕确保国家粮食安全和粮油食品安全与营养这个主线是粮油科学与技术学科的发展方向。依托高新技术改造传统粮油产业是粮油科学与技术学科的研究重点。

1. 粮食储藏

重点研发支撑害虫综合治理（IPM）策略的非化学防治，节能控温储藏，储粮害虫、储粮霉菌的生物防控，储粮信息在线检测及智能模型分析等技术；着重开展利用生物技术消解粮食中的化学药剂、真菌毒素研究等。

2. 粮食加工

重点开展粮食加工新产品与新型关键主机研制，大型粮食加工工艺与配套设备优化设计，加工过程控制技术和机电一体化装备开发，依托高新技术改造传统加工业，提高加工效能和产品质量、出品率等。

3. 油脂加工

重点推广应用油料低温或适温压榨制油技术，研究开发新型浸出溶剂，研究推广油脂适度精炼技术，开发研制大型化、机电一体化和智能化的油脂加工机械装备，研究油料蛋白资源和副产物的综合利用等。

4. 粮油检验

着力对粮食安全储存敏感指标、主要有害物质快速检验方法、中式蒸煮食品品质评价

等方面进行研究；重点开展近红外技术、图像处理技术、顶空分析技术以及粮食收购环节粮食质量快速检验仪器的研究等。

5. 粮食物流

重点研究粮食供应链体系构建与集成管理技术，仓型建筑合理化综合技术，物联网技术应用，公路、铁路及水运等多式联运技术，集装单元化运输体系，新型粮食物流技术与装备等。

6. 粮油营养

重点开展粮油产品中微量营养素及其他营养物质研究，粮油“小宗产品”及多种产品“复合”营养功能研究，粮油营养调整、改善功能的研究，原料成分与加工特性关系研究，减少加工环节对粮油营养成分损失的研究等。

7. 饲料加工

重点进行清洁饲料生产工艺设计研究，高效节能配料混合、粉碎、挤压膨化、干燥、智能化控制技术研究，利用生物技术提高饲料资源利用率研究，替代抗生素新型饲料及饲料添加剂研究等。

8. 发酵面食

重点开展馒头、冷冻食品等工业化生产研究，发酵面食冷冻和冷藏技术研究，基于生物酶技术的面团机理研究，发酵面食的标准及品质评价方法研究，发酵面食营养效价研究等。

第十三节　照明科学与技术

一、引　言

照明科学与技术学科是物理学、生理学、心理学、热工学、建筑学和艺术等学科的交叉学科。光源是照明系统的核心。1879 年爱迪生发明了白炽灯，由此进入了电气照明的时代。随着科学技术的发展，各种新光源又先后问世。电光源的发展为照明科技奠定了基础，随着相关学科的发展并与之结合，逐步形成了照明科学与技术学科。

我国是一个人口众多、人均资源相对不足的国家，照明用电在各个国家的总发电中占有很大的比例，我国照明用电大约占全国总发电量的 12%。我国政府对节约照明用电，一直十分重视。在现代化建设中必须实施资源开发和节约并举的策略，把节约放在重要位置，努力提高资源利用效率。推行绿色照明，倡导低碳生活，是节约能源、保护生态环境的重要措施。

二、近年来本学科的主要研究进展

(一)固态照明引发了一场照明科技革命

固态照明也称半导体照明，它是 LED(Light Emitting Diode)照明和 OLED(Organic

Light Emitting Diode)照明的总称。现在固态照明正引领着照明科技的一场革命。

最早的 LED 光源问世于 20 世纪 60 年代初。当时所用的材料是 GaAsP,发红光,在驱动电流为 20 mA 时,光效仅约 0.1 lm/W。20 世纪 90 年代初,两种新的 LED 发光材料体系被开发出来,即发红光、黄光的 GaAlInP 和发绿、蓝光的 GaInN。1993 年,日亚公司研制出第一支高亮度 GaN 基蓝光 LED,为发展白光照明技术奠定基础。目前大功率白光 LED 的光效产业化水平已达到 130 lm/W 以上,远超过普通照明白炽灯、卤钨灯等传统光源。

OLED 作为一种新型的漫射光源,也是近年来众所瞩目的焦点。OLED 应用于照明领域的技术研究始于 10 多年前,并且迅速发展成熟起来。

OLED 与 LED 是互补关系,两种技术有各自的优势。在未来照明中,OLED 和 LED 将各自在不同的应用领域担当着重要角色。

(二)第三感光细胞的发现,提高了对照明生物功能重要性的认识

长期以来,人们一直认为人眼视网膜上只有锥状细胞和杆状细胞,因而照明研究都是围绕这两种感光细胞的功能展开。2002 年在哺乳动物的视网膜上发现了第三种感光细胞。与前两种感光细胞不同,这种感光细胞与视觉并无关系。它不是连接到视神经,而是与人脑内的生物钟相连接,其接受的光信号抑制松果体分泌褪黑激素(也称为“睡觉的荷尔蒙”),从而影响人的生物功能。

人体生物节律周期的重要作用及其受光照的影响的关系,使人们在未来的多种光环境应用领域需要考虑其健康效应,例如研究光照对工人的生产效率的影响、对夜班工人身体健康的影响、对老年痴呆症和忧郁症患者的治疗作用以及色温、波长对体温变化的作用等。

(三)绿色照明工程取得重大成就

1996～2006 年,我国政府在全球环境基金(GEF)的支持下开展了两期绿色照明工程。通过这两期绿色照明工程的实施,照明电器产品的性能得到显著提高,高效照明电器产品大量推广应用。

2006 年 2 月在巴黎召开了“紧凑型荧光灯质量与逐步淘汰白炽灯战略”会议,2009 年我国政府与 GEF 和联合国开发计划署(UNDP)合作,开展“加速推广应用节能灯、逐步减少以致不用普通照明白炽灯”的项目。我国将增加节能照明的投入,进一步提高国产节能照明产品的质量;通过政策扶持,加速用节能灯替代普通照明白炽灯的进程;提高控制污染物质的能力(减少荧光灯中汞的用量),并进行废弃照明产品的处理和再生利用。

(四)光度学和色度学基础和测量技术正在产生大的变革

现行的光度学基础建立于 20 世纪初,现行的色度学基础则始于 20 世纪 30 年代。目前广泛采用的传统光度学和色度学主要建立于以白炽灯等连续光谱为视觉目标或环境的基础之上。随着新光源特别是白光 LED 的出现,传统的光度学和色度学受到了极大的挑战,并引发了至少以下三个大的变革:①针对 LED 等窄光束分布的光源,由于传统的照度

与距离的平方反比定律不再成立，新的光度测量方法和仪器正在建立；②由于陶瓷金卤灯和白光 LED 等富含短波段光源越来越多被使用于室外，特别是道路照明，CIE 于 2010 年新发布的基于视觉工效实验的 MES2 中间视觉系统，引发了道路照明等中间视觉场所的具体设计和测量的新一轮研究热潮；③针对白光 LED 和荧光灯等合成白光，传统的 CIE 的显色指数的准确性受到质疑，正在开展新的关于显色系统如 CQS 等的研究；基于视觉评估的照明质量评价体系成为趋势。

（五）重视光辐射安全标准的修订

我国已成为国际上重要的紫外线杀菌灯、保健用近紫外灯的制造基地。我国专家参与了 IEC（国际电工委员会）62471/CIE S009 国际标准修订工作，并对评估方法提出了重要的建议。2009 年，国际照明委员会成立了 CIE R2－46“照明产品的光生物辐射安全测量”项目，并由我国专家担任研究的负责人。2010 年，在美国西雅图国际标准化 IEC 年度会议上，由我国专家提出的“灯和灯系统的光生物安全测量方法”获得确认。我国参与了 LED 光辐射安全的测试比对，在该领域处于国际前列水平。

（六）传统光源技术继续进步

电光源学科研究的内容包括各种光源的发光机理、光效的提高、器件的实现和参数优化等。目前国内电光源研究开发的热点有：① 荧光灯整体性能的继续提高，包括光效、显色性、光通维持率、寿命的提高和固态汞填充；②陶瓷金卤灯的国产化，通过自主研发已形成批量生产。

金卤灯在体育场馆中得到了大规模应用。小功率陶瓷金卤灯成为商场中重点照明的主要光源，中功率陶瓷金卤灯开始在道路照明方面推广。高压钠灯仍是道路照明中应用最广的光源，以后可能逐渐替换为白光光源（如陶瓷金卤灯和 LED）。

2010 年，我国已成为世界最大的电光源节能产品生产基地和销售中心，制造了全球 80％以上的紧凑型荧光灯，从而促进了荧光灯产业的繁荣和技术进步。

三、本学科国内外发展状况比较

（一）固态照明的开发和应用

世界许多发达国家的政府将固态照明看成是具有战略意义的新兴产业，给予财政支持和优惠政策，飞利浦（Philips）、通用电气（GE）、欧司朗（Osram）、Cree 和日亚（Nichia）等公司都投入了大量人力和财力，开展从芯片到照明应用的研究。它们在固态照明的高端技术方面有很多核心专利。美国 Cree 公司公布的大功率白光 LED 实验室光效已达到 208 lm/W，日本日亚公司的小功率白光 LED 实验室光效已达到 249 lm/W。

我国政府对发展固态照明也非常重视，2003 年科技部启动了中国半导体照明工程，通过“十五”的攻关计划、“十一五”的“863 计划”对我国半导体照明核心技术的突破和产业化关键技术的攻关等进行了全产业链部署。2009 年 10 月，发改委等六部委发布《半导体照明节能产业发展意见》，以引导半导体照明产业健康发展。2010 年 9 月，国务院召开

常务会议，审议并原则通过了《国务院关于加快培育和发展战略性新兴产业的决定》，确定战略性新兴产业将成为我国国民经济的先导产业和支柱产业，半导体照明也被纳入其中。

我国目前在前沿性技术探索和装备开发方面取得阶段性进展；在 LED 外延材料、芯片制造、器件封装、荧光粉、功能性照明应用等方面均已掌握自主知识产权的单元技术，且部分核心技术具有原创性。但是，目前我国关键技术主要以跟踪国际上主要研发方向为主，总体上自主创新能力不足，还没有形成产业化的优势技术。

随着 LED 光效的提升和成本的下降，我国半导体照明系统集成技术开发与市场应用走在国际前列。LED 照明技术和与之相配合的智能化控制技术的推广，使得以“多彩、多变”动态城市景观照明在我国得到迅速发展。我国是最早推广 LED 交通信号灯的国家，既节能，又保证了交通的安全通畅。中大尺寸 LED 背光源的技术日趋成熟，市场占有率逐步提高。LED 在通用照明领域刚刚起步，处于试点示范阶段。通过广泛试验，取得了很多经验和教训。经过实验研究和现场试验，对照明质量要求很高的电视演播室也正逐步推广 LED 照明，并取得显著的节能效果。此外，医疗、农业等特殊领域的半导体照明技术方兴未艾。

（二）天然采光和智能照明控制系统

在建筑环境中利用天然光，不仅节能、环保，又能创造健康、有效的工作和居住空间。在我国《建筑采光设计标准》GB/T 50033—2001 中规定了对工业和民用建筑天然采光的数量和质量要求，但是该标准未能在建筑设计和照明设计中得到认真实施执行。天然采光已应用于北京奥运中心区地下车库和上海世博会的阳光谷，并取得良好的效果。但就整体而言，我国天然采光的应用还远远不够。

美国绿色建筑先锋奖评判条例要求 90％以上的使用者能够单独或分组调光，以适应个人的照明需求和爱好。相比之下，我国的室内照明控制技术和设备还比较落后，目前除了部分公共空间设有声控、光控或红外线控制的照明开关外，绝大部分的建筑照明还是手动开关。在这些方面，我国有待于加强研究和提高技术水平。

（三）体育照明

我国从 1985 年开始正式开展专业的有电视转播的体育照明，经过全国运动会、两届亚运会和奥运会等重大赛事的检验，不论是照明设计理念应用的光源、灯具和体育照明标准，还是体育照明设计水平及最后的体育照明现场效果及电视转播效果，或是对整个赛事转播的照明支持，体育照明水平已经处于世界先进行列，不少场馆的照明设备和照明效果代表了当今国际最高水平。

（四）光度、色度的视觉基础研究和应用

针对 LED、无极灯和陶瓷金卤灯等新光源的大量应用，我国学者开展了对室内外光环境的颜色、色觉表观、眩光的评估和视觉舒适度的研究，并创造性地开展了室内空间的视觉舒适度和人眼视觉疲劳、近视眼发展等的关系研究。在以道路照明为应用环境，基于视觉工效学的中间视觉光度学系统研究方面，我国学者在以视觉任务的完成、识别、探测、

反应时间等来建立光谱灵敏函数的研究和道路照明的评估方面已经处于国际先进水平。

(五)传统光源和灯具

国外陶瓷金卤灯研发的突出进展是:①Ir－Al2O3 匹配封接的非饱和陶瓷金卤灯,光效 120Lm/W,显色指数 98,寿命 20kh,寿命期间参数的稳定性达到了气体放电光源的最高水平;②基于 TmⅠ3 的填充系(Xe－TlⅠ－AlⅠ3－TmⅠ3),该填充系不仅无汞,而且其分子辐射使光源参数比较理想(光效 90Lm/W,显色指数 90,色温 3420K,灯电压 70V)。我国小功率陶瓷金卤灯与国际水平尚有一定差距,需要继续优化设计、改进工艺水平。

国外 T8 直管荧光灯的寿命已达 46kh,且 2kh 光通维持率高达 95%;而我国 T8 灯的寿命仅 10kh,且 2kh 光通维持率小于 90%,与国外先进技术相比,我国紧凑型荧光灯的光效普遍要低 10%～24%,寿命和光通维持率均低于国外水平,原因是荧光粉的质量、保护膜涂敷工艺还有所不足。

在办公室照明中使用最多的格栅灯具,国外采用高反射率白色涂料和高反射率镜面铝,灯具效率高达 80%。我国仍普遍使用一般的白色涂料和一般的镜面材料,灯具效率只有 70%。

四、对本学科发展的展望与建议

(一)固态照明将加快进入通用照明的步伐

伴随着白光 LED 的发明,以及近十年来其功率、光效的飞速增高和成本的快速下降,白光 LED 正在逐步进入通用照明领域。白光 LED 不仅能够取代普通照明白炽灯和卤钨灯这类光效较低的光源,而且有取代紧凑型荧光灯甚至荧光灯的趋势。我国亟须实现工程化的集成创新,解决核心器件的可靠性和成本的问题,开展灯具散热结构的设计与散热材料选择、光学设计、驱动电源标准化等系统集成技术研究,开发出替代传统照明光源与灯具的规格化、标准化 LED 照明产品。

OLED 要大规模进入通用照明应用领域,面临的主要问题包括光效、寿命和成本。OLED 将来可望在面光源领域扮演杰出的角色,我国应在 OLED 产业尚未成熟时加大研发投入,帮助我国企业和研发机构掌握更多的自主知识产权。

LED 照明目前还处于发展阶段,缺少科学的标准和测量方法。市场上 LED 产品质量良莠不齐,市场秩序较为混乱,严重影响了用户信心。因此,在固态照明逐步进入通用照明市场的过程中,必须高度重视建立各种相关的标准,完善检测方法和设备,权威检测和认证机构要加强对 LED 产品的质量监督。

(二)重视天然采光和智能化照明控制的研究及产品开发

天然采光和智能化照明控制不仅能节约电能,更重要的是能够提高照明质量,有利于提高工作效率和人的身心健康。在这一方面我们有很多工作要做,要加大投入,加强基础研究,并努力开发相应的产品,推广应用。

(三)关注传统光源生产和使用过程中的环保问题

照明产品在生产和使用过程中的环保问题日益引起人们的普遍关注。其中,最引人注目的是气体放电灯中填充的汞对环境的污染和危害。近年来通过采用固态汞替代液态汞,减少灯管中的充汞量,大幅度降低了汞污染。另外废弃含汞灯管的回收处理工作有了一定进展,部分企业引进国外先进的处理设备,对生产过程中的废弃灯管进行回收处理。此外,国外十分重视无汞放电灯的研发,我国也应加强这方面的研究。

(四)重视光辐射安全和植物光生物学的研究

应重视紫外和红外辐射对视觉的伤害机理的研究。LED 过强的 460nm 左右的蓝光辐射将对人眼视网膜产生光化学危害,应迅速加强光生物安全性检测及光生物效应的辐射剂量标准的制定,推动我国的光生物辐射安全标准体系的建立。在植物光生物学方面,支持 280～1100nm 波段对植物的一般作用光谱的研究。

(五)重视光度学、色度学和生物效应健康照明的基础研究

由于新光源和新技术的出现,传统光度学、色度学正面临着新一轮的变革,对照明效果考虑光色效果和生物效应的双重评价标准体系正在建立。我国人口约占世界人口的 1/5,也是全球最大的照明产品生产和消费大国,开展以中国人为受测者的视觉和非视觉生物效应的基础研究是十分必要的,是改变传统光度学、色度学系统中缺乏中国人为观测者这一状况的必经之路。

(六)继续提高气体放电灯的性能

荧光灯性能需要从以下几方面提高:①延长寿命,直管灯 20～30kh,紧凑型灯 15～20kh;②提高光效,直管灯 110lm/W,紧凑型灯 85lm/W;③研究新型氧化物保护膜材料和工艺,提高光通维持率;④减少充汞量,实现直管灯充汞 3mg,紧凑型灯充汞 1～1.5mg。

非饱和式陶瓷金卤灯光效更高,颜色一致性更好,国家应大力支持其研究开发。无汞陶瓷金卤灯既能达到含汞陶瓷金卤灯的性能,又消除了汞污染,是未来高强度气体放电(HID)光源的发展方向。

第十四节　动力机械工程

一、引　言

动力机械工程学科是现代科学技术发展的基础学科,动力机械及其系统构成了国民经济发展、人民生活水平提高和国防工业现代化的重要技术和物质基础,是一个国家生产力和竞争力的主要体现。

动力机械及其系统技术的发展促使全球经济得到迅速发展。现代工业、农业、交通运输以及国防等各个部门无不以动力为先行，没有现代动力机械的大量生产和各种动力机械的广泛应用，就谈不上现代工业、现代农业、现代国防和现代科学技术的发展。

二、近年来本学科的主要研究进展

(一)锅炉研究及技术进展

锅炉研究需要建立完整的将气固两相流动与燃烧、气液两相流动与传热和金属材料三位一体、多学科交叉、有机结合的锅炉科技研究体系，实现材料与受热面内、外部系统环境的协调优化。

在锅炉设计技术方面，成功掌握了具有塔式和π型布置的螺旋管圈和垂直管圈的超超临界锅炉水冷壁结构设计和制造技术，对超超临界锅炉水冷壁水动力、流动和传热特性进行了试验研究和工程验证设计，开发了锅炉热力计算、强度与应力分析、水动力计算、启动特性计算程序，形成了具有完全自主知识产权的结构设计技术基础。

我国在引进、消化和吸收国外燃烧技术的基础上，各高等院校、研究院所和生产企业相继建立了多台架的煤粉燃烧、流化床燃烧、煤气化的大型试验研究平台，相继研发了适合烟煤、贫煤和褐煤的四角切圆、旋流对冲煤粉燃烧技术，适合难燃无烟煤的“W火焰”煤粉燃烧技术，煤粉和生物质混合燃烧技术，燃用劣质煤的循环流化床燃烧技术，煤粉气化技术，水煤浆气化技术等。与此同时，我国学术界和工业界已开展了纯氧燃烧、化学链燃烧及催化燃烧技术基础理论研究、实验研究和中试研究工作。

在锅炉材料研究开发方面，通过我国冶金行业、发电设备制造行业、电力行业产学研合作攻关，已经基本实现了600～1000MW、600℃/600℃的超超临界电站锅炉钢管、管道材料供应的国产化，为更高参数锅炉技术发展奠定基础。

我国制造企业已掌握了300MW、600MW亚临界、600MW超临界锅炉设计、制造技术，机组经济性、可靠性、自动化等技术水平已接近国外先进水平。在相继引进660～1000MW超超临界锅炉设计和制造技术的基础上，已实现1000MW超超临界锅炉的完全国产化批量供货。目前，我国制造和建成的600～1000MW、600℃/600℃的超超临界发电机组占据世界首位。

我国制造企业已掌握了电除尘、布袋除尘以及电袋复合除尘成套设计、制造技术，完成了30mg/m^{3}烟尘排放改造技术设计和示范工程；完全掌握了石灰石—石膏湿法、循环流化床半干法、氨法、海水法、液幕法以及活性焦等脱硫技术的设计、制造技术，掌握了低NO_x分级燃烧、SCR脱硝催化剂、SCR脱硝装置成套设计和制造技术，进一步完成了200mg/m^{3}低NO_x排放的改造技术设计和示范工程；开展了多种污染物联合脱除技术的研究工作并进行了大量的工程应用；建成了在烟气中实施CO_2捕集、合成共聚物等再利用技术的示范工程。

目前，我国引进型和经过优化创新的、完善提高的自主型的300MW循环流化床锅炉产品已实现批量供货，并组织开展了600MW超临界循环流化床锅炉的关键技术研究开发工作，首台600MW超临界循环流化床锅炉已在生产制造之中，有望在2011年投产运

行。“十五”期间，完成 IGCC 设计和动态特性“863”课题研究工作；2005 年 12 月，IGCC 发电技术可行性研究通过国家科技部验收；2009 年 5 月，国家发改委核准华能天津 IGCC 示范项目，将成为 IGCC 商业化试验示范工程的典范。

（二）蒸汽轮机械研究及技术进展

蒸汽轮机是将工质为水蒸气的热能转换成机械功的旋转式动力机械，汽轮机是发电用的原动机。蒸汽轮机械研究主要包括通流技术、结构及可靠性、防止汽流激振、防止固体微粒侵蚀、高温部件冷却技术、大型铸锻件毛坯设计制造技术等。

我国制造企业在通流部分计算中已普遍采用以计算流体动力学为基础的辅助全三维成型的弯扭动、静叶片结构及通流设计技术，开展了迷宫汽封汽流激振的数值计算研究，并对汽轮机转子、叶轮、汽缸、阀壳等重要部件的温度场、机械应力和热应力场进行了有限元分析和计算；在气动试验研究方开展了平面叶栅吹风试验、叶片的环形叶栅吹风试验、阀门试验等；在末级长叶片的开发方面，已研制成功最长的 1200mm 钢制叶片；成功研发并应用了多种新型汽封结构；在强度及寿命设计方面，开展了高温部件与大尺寸部件强度设计共性技术研究，开展了汽轮机关键部件状态评定、寿命评估和寿命预测技术研究。这些研究奠定了汽轮机工程应用的基础。

目前，我国汽轮机制造企业已掌握了 300MW、600MW 亚临界，600MW 超临界汽轮机设计、制造技术。其中 300MW、600MW 亚临界汽轮机经济性、可靠性、自动化等技术水平已接近国外先进水平。在相继引进 660～1000MW 超超临界汽轮机设计和制造技术的基础上，除部分大型锻件毛坯外，已实现 1000MW 超超临界汽轮机的国产化批量供货。截至 2010 年年底，我国汽轮机制造厂生产并投运的超临界、超超临界 600MW、1000MW 的机组约有 250 台。不仅如此，我国汽轮机制造厂还在引进 300MW、600MW 火电汽轮机的设计技术基础上，按核电要求完成秦山核电厂的 300MW 汽轮机改型设计和 600MW 汽轮机自主设计。

（三）燃气轮机械研究及技术进展

燃气轮机是一种高速旋转的叶轮机械。燃气轮机械研究主要包括通流技术、结构及可靠性、防止汽流激振、防止固体微粒侵蚀、透平叶片冷却技术、大型铸锻件毛坯设计制造技术、整体系统设计及优化技术等。

我国燃气轮机关键技术研究具备一定实力，在传热学和燃烧学基础理论研究方面具有较强基础，航空和舰用燃气轮机的研发和应用已达到接近当代先进水平。自 2003 年 3 月起，国家发改委组织了 3 次 F 等级和 E 等级燃气轮机的捆绑招标工作，引进了国外先进的燃气轮机设备制造技术，但没有引进设计技术，目前正在努力自行开发燃气轮机的设计、试验研究平台；已开始开展耐热腐蚀定向、单晶合金材料研究工作，争取在材料研究和制造工艺方面也有所突破，为今后在合金、复杂型芯制备及大尺寸定向成型、复合热障涂层等方面打下一定基础。

“十五”期间的“863 计划”中燃气轮机重大专项中重型燃气轮机的研发目标是消化和吸收国外重型燃气轮机的设计思想，设计、研制具有自主知识产权的、功率为 110MW、技

术水平相当于E级以上的重型燃气轮机样机，并为“十一五”期间开发F级（200～250MW）的重型燃气轮机打下基础。

“十一五”期间的“863计划”重型燃气轮机重大项目设置了“中低热值燃料R0110燃气轮机研制及其在IGCC电站中的工程应用示范”课题，该课题对R0110燃气轮机进行了深入研究和发展，所研制的R0110燃气轮机设计成熟、性能优越、结构紧凑先进，具有同等功率等级燃气轮机世界先进水平。

与国外发达国家相比，我国燃气轮机技术研究发展起步不晚，但研究工作多限于理论和数值分析，加之实验设备和测试手段相对落后，理论和数值计算的研究成果无法进行试验验证。尽管已经基本掌握E级燃气轮机的制造技术，但至今不掌握重型燃气轮机整体系统设计及优化技术，还不能制造大型燃气轮机的核心部件，先进的燃气轮机的核心技术研究开发尚处于初级阶段，缺乏整体系统集成与优化的实践经历，不具备设计制造大型高性能、重型燃气轮机的能力，在重型燃气轮机整体设计和制造方面和国际水平存在较大差距。

（四）水轮机械研究及技术进展

水轮机械研究包括水力研究和机械研究。目前，我国已经开展了现有产品的水力设计、CFD分析、模型制造和模型试验研究工作，并具有进行原型设计、工艺设计、产品制造、设备现场安装、控制、调试、运行等工程化能力。目前，CFD技术已应用于水轮机的水力优化设计及性能预估中，并在三峡、水布垭、小湾、溪洛渡等一些大型电站的水力设计中得到了广泛应用。

我国有近十座高水头试验台，通过国内外试验台（包括中立台）的互校，试验能力、精度等水轮机试验水平达到国际先进水平。但相对国外而言，国内企业的试验台数量仍显不足，尤其是专业试验台，如贯流台、冲击台等；没有真水头、水泵、水轮机试验台，影响了这类产品的研究开发工作的不断深入。

我国已能够自行研发、设计、制造、安装各种类型水轮发电机组，以满足大规模水电开发的需要。我国的造坝技术也居世界先进水平。目前已能独立设计制造和安装直径超过10m的三峡右岸混流式水轮机转轮和成套水轮机设备，已能批量生产制造700MW级水轮机，达到世界先进水平。单机容量770MW的溪洛渡水轮机和单机容量为800MW向家坝水轮机已完成科研，正在制造中。已基本完成1000MW级水轮机的研制的前期科研工作。

三峡右岸转轮是我国在大型水电设备研制上具有自主知识产权的核心技术，是引进技术消化吸收再创新的典范。不仅效率高于左岸，而且在稳定性方面也有了很大的突破，在整个运行区域内消除了高负荷压力脉动，解决了困扰水电行业的世界性技术难题。

通过三峡技术引进后消化吸收再创新，我国在混流式水轮机的研究、制造、安装上已达到国际先进水平，具备与国外最先进的水轮机制造厂商同台竞争的水平。在一些领域，尤其是机组的稳定性，也达到了国际领先水平。

国外水轮机技术有100多年的发展历史，我国只有60年。通过60年的发展，特别是最近10年的快速发展，我国水轮机技术总体上已接近目前国际先进水平，在某些领域已

经达到国际领先水平。

三、本学科的发展趋势和展望

(一)高效清洁燃煤发电技术

“十二五”期间,随着燃煤发电机组向着更高参数方向发展,国内制造企业将进一步完成 1200MW 等级 610℃/625℃超超临界火电机组的自主化设计和工程示范。同时,根据我国未来的能源战略发展规划,国家能源局于 2010 年 7 月正式组建和启动了国家 700℃超超临界燃煤发电技术创新联盟,希望借此整合研究开发资源,实现 700℃超超临界锅炉和汽轮机技术的自主化设计生产。

在 2015 年前,国家计划完成华能天津 250MW 级 IGCC 机组试验示范工程;预计到 2020 年,完成 400MW 级 IGCC 试验示范工程,实现生产制造 2000t/d 级干法、湿法气化炉,有自主设计和生产 3000t/d 级气化炉的能力,形成 IGCC 技术的设计、制造、运行、维护经验并开始逐步应用。

为实现我国未来燃煤发电技术低碳排放、减少温室气体对气候的影响,应积极推进纯氧燃烧、化学链燃烧和催化燃烧技术的工程化,积极研发和储备燃煤电厂的 CO_2 捕集和储存技术(CCS)。

(二)重型燃气轮机发电技术

燃气轮机的技术发展水平比较集中地反映了一个国家在工程热物理、信息电子、材料冶金、机械制造以及自动控制等多学科和多工程领域科技发展的综合水平,已经成为一个国家科技水平、军事实力甚至综合国力的重要标志之一。为攻克重型燃气轮机整体系统设计和制造技术,必须动员全社会的力量进行科技攻关、优化资源配置、加大科技研发和重型制造技术投入、加速人才队伍的培养;尽早形成自主开发先进重型燃气轮机的能力。

(三)水轮机械发电技术

大容量、高效率是未来水轮机发展的主要方向,应积极推进单机容量为 1000MW 的混流式水轮机技术的工程化研究;研发功率 250MW 级的轴流式水轮机;促进 75MW 级贯流式水轮机的完善化;研发高水头、多喷嘴、巨型化的冲击式水轮机;设计开发 300MW 等级及以上水泵水轮机技术(抽水蓄能机组);在研发新产品的基础上按照再制造的理念开展老水电站的技术改造。为配合新产品开发,我国需要开展水轮机的空蚀、稳定性、泥沙磨蚀机理研究,开展流固耦合 CFD 计算分析研究以及模型试验技术研究。

(四)核能发电技术

预计到 2020 年,我国核电的比重将由“十一五”末期的 1.4%上升到约 5%。我国已引进第三代 AP1000 核电技术,通过引进第三代 AP1000 核电技术并加以消化吸收,研制出具有自主知识产权的第三代先进核电技术,将进一步提高我国设计、装备制造水平,加快核电技术进步的步伐。与此同时,以快堆、高温气冷堆技术为基础,国内正在开展第四

代核电技术的研发工作。为尽快将快堆技术推向商用，我国应在实验快堆建成后尽快建设快堆示范电站，使我国核电设计、制造和运行技术实现跨越式发展，进入核电技术先进国家行列。

(五)可再生能源发电技术

风力发电方面，国家需要培育出国内具有自主知识产权的3MW级及以上风电机组及零部件品牌，使风电技术水平和装备能力达到国际先进水平，并建立具有技术研发、装备检测认证、试验测试等功能的技术及产业服务体系，进一步提高风电建设运营中各项技术经济指标，增强风电市场竞争力。

太阳能发电方面，积极推进太阳能光伏发电和太阳能集热发电技术。可以预计，国家在2015年前后将建成10万kW的太阳能热发电示范电站，2020年前后建成30万kW荒漠地区实用热发电示范电站。

生物质发电方面，应积极推进大容量生物质和煤粉混烧发电技术以及生物质气化、裂解、生物转化后的分布式发电技术。

(六)构建智能电网技术

智能调度、智能变电站、智能小区、大容量储能、智能电气及电动汽车将是未来智能电网发展的重点。可以设想，未来中国智能电网将覆盖发、输、配、用的全过程，实现从发电到用电所有环节的智能控制。

第十五节　农业科学(基础农学)

一、引　言

农业是国民经济的基础，而基础农学学科发展又是农业科技进步、发展的基础。当前，我国正处在以城带乡、以工促农的历史阶段，促进农业发展方式转变已经成为我国重要的战略选择。随着我国经济社会的快速发展，基础农学在发展现代农业、建设中国特色农业现代化中的重要作用日益凸显。

“2010～2011年基础农学学科发展研究”是在“2006～2007年基础农学学科发展研究”、“2008～2009基础农学学科发展研究”基础上进行的，根据基础农学学科及其分支领域的进展实际以及未来发展的引领作用，确定了农业生物技术、植物营养、灌溉排水、耕作学与农作制度、农业环境、农业信息、农产品贮藏与加工、农产品质量安全、农业资源与区划9大分支领域进行专题研究。是近年基础农学学科发展提高的体现。连续开展基础农学学科发展研究，一方面表明了基础农学在我国农业科技中具有基础性、全局性、前瞻性的重要作用，反映了基础农学近年来受到科技界高度重视、学术活跃和学科快速发展的状况；另一方面，也表明了基础农学的内涵丰富、领域众多与博大精深，需要根据现代农业科技发展不断地去研究、去拓展、去创新。

“2010～2011 年基础农学学科发展研究”在研究过程中，注重分析基础农学及其分支领域的最新研究进展、重大成果与应用，科学把握本学科发展的现状、动态，全面开展国内外研究与应用比较，准确判断学科未来的战略需求和发展趋势，合理提出加快基础农学发展的政策建议。从这 3 次基础农学学科发展研究来看，其中 2 次选择了农业生物技术、植物营养、农业信息、农业资源、农业环境、作物遗传等最为活跃、进展最快、最为亟须的分支领域作为研究专题；而农产品质量安全、农产品贮藏与加工、农业资源环境这 3 个分支领域是近年来农业科学中的热点、难点和焦点问题，与农业可持续发展和城乡居民健康生活息息相关，引起了全社会的普遍关注；另外，灌溉排水、耕作学与农作制度这两个分支领域既是传统的命题，也是当前现代农业的热点课题，需要赋予新的内容和新的使命。

二、本学科的发展概况

基础农学学科是农业科学技术的基础。它不仅可以促进农业科技进步和创新，而且可以推动农业和农村经济持续稳定发展。基础农学是基础研究在农业领域中的应用和体现，包括农业基础研究和农业应用基础研究两个方面。基础农学是农业应用研究和开发研究的基石，是农业高新技术产生和发展的源泉。因此，基础农学学科发展在一定程度上决定着农业科技以及农业发展方式的走势和未来。

基础农学学科是生物学的一个分支学科，是认识与农业有关的自然现象、揭示农业客观规律及其原理、研究农业生产体系中的自然现象及其现象本质的学科，其目的是为充分开发利用和保护农业自然资源、协调农业生产与环境之间的关系、防止有害生物和不良环境对农业的破坏，以期获得农业生产的最佳组合、提高农产品的产量和品质及其生产效率，促进高产、优质、高效、生态、安全农业的发展，有效保障国家食物安全、生态安全，持续增加农民收入，提高农产品的国际竞争力。

基础农学学科是一个综合、动态、发展的概念，随着经济和科技的发展，在不同历史时期有着不同的内涵。早在几千年前，人类在进行农耕、放牧的实践中，通过观察、描述、认识、总结，积累了有关植物、动物、微生物的丰富知识。我国的《诗经》、《齐民要术》记载了大量的草木鸟虫鱼的名称及其实际应用。人类生产、生活实践，催生了传统农学的形成、发展。进入 19 世纪，受物理学、化学、生物学等基础科学发展的影响，特别是受近年来生物技术、信息技术的影响，基础农学及其相关分支领域开始形成并得到了迅速发展，从此跨入了现代科学的行列。20 世纪 90 年代以来，随着现代科学技术的迅猛发展，特别是数、理、化、天、地、生等基础科学对农业科学的渗透以及物联网、云计算技术等信息技术手段的应用，基础农学学科研究出现了新特点、新趋势。即与农业科技、生产结合越来越密切，正在走向一体化和综合化；对农业基础研究的渗透日趋明显，不断产生新的边缘学科、交叉学科和综合学科；向微观和宏观两个方向发展，既结合又促进，加快了科研进展与突破；借助现代实验工具和理论方法，实现了试验研究手段的现代化；国际竞争与合作、交流与限制并存，形成了十分复杂的态势。随着基础农学研究及其成果转化与推广，必将为解决全球人口高峰期的食物安全问题做出新的贡献。

我国从 19 世纪引进基础农学，历经清王朝、北洋政府和国民党政府三个时期，学科发展一直停滞不前。1986 年，基础农学学科发展进入改革与发展阶段，通过实施一系列的

改革与发展措施，基础农学学科发展与农业生产相脱离问题有所好转，一批学科研究成果实现了商品化、产业化，学科结构调整进一步优化，自主创新能力显著提升。

三、近年来本学科若干分支领域的重要进展

近年来，我国高度重视基础农学学科建设，取得了基础农学研究和应用的累累硕果。

（一）农业生物技术领域

抗虫棉是我国独立开展转基因育种、打破跨国公司垄断、抢占国际生物技术制高点的成功范例。1991 年，“863 计划”启动转基因抗虫棉研究项目，仅用 5 年时间成功研制出拥有自主知识产权的转基因抗虫棉，使我国成为世界上第二个拥有抗虫棉自主知识产权的国家。10 多年来，我国先后成功研制了单价、双价转基因抗虫棉，创造了巨大的经济、社会和生态效益。截至 2009 年，Bt 棉花的种植面积已达 400 万 hm^2，占棉花种植总面积的 75%；国产抗虫棉累计推广面积 846.67 万 hm^2 以上，增收节支约 338 亿元人民币。2009 年，转基因植酸酶玉米获得了在山东省生产应用的安全证书。我国拥有转基因植酸酶玉米的全部知识产权，转植酸酶基因玉米是全球第一例通过绿色农业生产模式替代工业生产模式来生产植酸酶，堪称低碳农业的典范。

（二）灌溉排水领域

在节水农业基础理论方面，初步建立了抗旱节水型作物鉴定评价技术，筛选出一批抗旱节水新材料和新品种，提出了水分亏缺补偿响应机制的节水高产与营养补偿技术，为大面积提高植物水分利用效率和建立高效农田灌溉系统提供了理论与技术支撑。确定了华北和西北地区主要农作物非充分灌溉模式和关键技术，建立了主要作物调亏灌溉、控制性分根交替灌溉等技术，对于指导我国农田灌溉实践起到了重要作用。研发了激光控制平地铲运设备和相应的液压升降控制系统，使灌水均匀度提高 20%～30%，灌溉水利用率提高 30%～40%。

在节水产品创制方面，研发了一批环保高效低成本的雨水集蓄新材料。研制出 SWR－4型管式土壤剖面水分传感器实验样机，可替代进口 TDR/FDR 同类仪器。开发的 PY 系列、ZY 系列和 GJY 系列喷头，性能达到国际先进水平。研发出具有防鼠、防虫、防根系入侵的地下滴灌专用灌水器，以及随土壤干湿自动启闭的自适应式地下灌水器。研制了一种抗拉、抗爆破、抗穿刺的薄壁滴灌带材料配方和滴灌带成型工艺，加快了微压滴灌系统研制进程。我国在重点缺水地区建立了现代节水农业技术集成示范区，大田棉花膜下滴灌、旱作雨水集蓄高效利用和行走式蓄水保墒抗旱灌溉等综合节水技术的应用面积达到世界之最。

（三）农业资源与区划领域

丰富和发展了土壤质量内涵，拓展了农业土壤功能；研发了缓解水资源胁迫、应对气候变化的抗旱节水技术，以及增强农业水资源生产效率技术；研究发展了农业气候资源区划、调控理论和灾害防御技术；加强了农业微生物菌种资源收集和保藏，数量显著增加；研

发了一系列的高效施肥技术及新型肥料；探索形成了农业废弃物资源高附加值化利用技术；强化了农业资源监测技术研发与应用；完善农产品产业带理论，加强了农业功能区划研究。围绕农产品产业带发展，农业部先后颁布实施了《优势农产品区域布局规划（2003～2007 年）（2008～2015 年）》和《特色农产品区域布局规划（2006～2015 年）》，经过建设和发展，初步形成了一批国内外较为知名的优势区，资金、技术、劳动力、管理等现代生产要素加速向优势区集约，加工、储运和营销等农产品关联产业加速向优势区聚集，优势农产品产业带建设和农业地域分工加速推进，现代农业产业体系和农业生产力布局逐步优化，为现代农业建设奠定了重要的地域空间基础。

（四）农业环境领域

尤其是设施农业工程方向，通过有关课题攻关，揭示了农业环境要素与农业生物间的相互作用规律，阐明了农业环境控制机理，实现了可控环境农业系统模拟，研发了现代植物、动物设施环境控制关键设备，提出了保障动植物生长环境的工程措施和环境安全生产技术。此外，生猪垫料养殖技术得到应用；植物工厂技术获得突破，已开发出国内第一批用于植物工厂育苗和蔬菜生产用的红蓝 LED 光环境控制装置，并在此基础上开发成功 LED 节能植物工厂和家庭用智能箱式植物工厂生产系统；日光温室最近十多年来在三北地区得到了快速发展，区域范围已扩展到北纬 32°～48°，为解决北方地区的反季节蔬菜供应、增加农民收入做出了重要贡献。据农业部统计，2007 年全国日光温室面积已达 70 万 hm^2，2010 年达到 78 万 hm^2。

（五）农业信息领域

农业信息智能服务技术取得了重大突破。农业信息智能服务技术包括农情精准获取技术、数据自动处理技术和信息推送应用技术三个方面。在农情精准获取技术方面的农情数据采集标准技术、多源异构农情信息自动采集技术；在数据自动处理技术方面的作物生长模拟技术、农产品信息智能分析预警技术、农业数据建模工具技术、农业信息数据融合技术；在信息推送应用技术方面的农业生产适用技术个性化推送服务技术、作物品种优化布局辅助决策服务技术、农业信息智能服务技术平台建设技术等，不仅取得了重大研究进展，而且得到了广泛的推广应用，产生了良好的经济效益、社会效益和生态效益。

四、本学科的发展趋势和展望

随着知识经济、市场经济的发展，第一产业在 GDP 中的比例越来越小，但农业的功能不仅没有减弱，而且得到了进一步加强。与此相适应，农业基础研究的地位与作用将日益凸显，主要体现在：农业基础研究是衡量国家农业科研水平的重要标志；农业基础研究提出的新概念、新理论、新方法是推动农业科技进步和创新的动力；农业基础研究定位观察和基础数据积累是国家农业宏观决策重要的科学依据；农业基础研究的成果转化与推广应用，可以促进农业和农村经济持续稳定发展。

目前，我国基础农学学科及各分支领域逐步发展起来，形成了门类比较齐全的学科体系，并获得了重要进展与突破，产生了一批新理论、新方法、新技术，涌现出一些新思路、新

见解、新观点，某些领域已接近或达到世界先进水平。但是，我国基础农学学科起步晚、发展滞后，同发达国家比较，还存在较大差距。我们要按照“自主创新，重点跨越，支撑发展，引领未来”的要求，密切联系我国农业、农村、农民实际，充分认识加强基础农学发展的战略需求，加快改革和发展，完善体制机制，加大投入力度，加强国际交流与合作，以人才建设为核心组织精干高效的科研队伍，选择有基础、有优势的国际学科前沿以及影响国计民生、具有全局性的重点领域和亟须服务“三农”的重大理论、技术问题，联合攻关，实现跨越式发展，为发展现代农业奠定坚实的技术基础。

第十六节　土壤学

一、引　言

目前，全球所面临的粮食安全和环境污染等方面的问题以及节能减排和生态保护等方面的要求促使土壤学各分支学科的研究不断向前推进。在这样的背景下，总结近年来我国科学家在该领域所取得的研究成果，并通过和国际同行间的比较，找出我国土壤学发展中存在的问题，分析学科发展趋势，提出近期研究的重点领域、发展的措施和展望，促进土壤、环境和生态学的交叉、融合，把握学科发展方向，紧跟学科发展前沿，对促进土壤学科发展，促进国家科技进步与经济可持续发展具有重要意义。

二、本学科近年来的研究进展

我国的土壤科学虽然起步较晚，但近年来发展极为迅速。在土壤学的某些分支，如土壤系统分类、表面化学、土壤温室气体排放和面源污染控制、土壤水肥管理、长效肥的研制、土壤—植物营养、土壤污染修复和土壤微生物等方面的研究均有长足发展。我国的土壤系统分类研究逐步与美国系统接轨，中国土壤分类系统已经成为国际四大分类体系之一。其中，有关人为土纲的分类研究在世界处于领先水平；在土壤化学方面系统地开展了土壤胶体化学、土壤界面化学、土壤养分化学、土壤污染化学等方面的研究，其中以土壤胶体和界面化学的研究较为系统和深入，也取得了很好的研究结果；在污染土壤修复方面系统地开展了土壤污染调查、污染过程与机制研究、污染效应风险评价、污染土壤修复管理研究，基于污染物界面过程的效应评价模型已经达到国际水平；在土壤环境方面开展了温室气体排放调控和农业非点源污染控制的系统研究，稻田 CH_4 和 N_2O 排放规律和稻麦系统 CO_2 倍增生态效应的 FACE 研究达到国际先进水平；土壤—植物营养学方面已形成以植物—土壤互作的根际理论为核心，以作物高产、资源高效和环境保护为目标，综合利用生物调控及养分管理技术来实现作物高产高效的研究体系，形成以植物营养生理与遗传、土壤—植物互作与调控、养分资源管理、污染物控制和治理等主要研究领域的系统学科；土壤物理学与土壤矿物学研究在土壤水文学、土壤力学、矿物界面反应分子机制以及矿物界面反应过程与化学动力学等领域也已接近国际前沿。此外，我国的古土壤研究、(数字)土壤制图研究、土壤质量研究、土壤退化机理研究等基本与国际同步。

在面对国家需求、解决生产实际问题的同时土壤学的学科建设也得到了极大发展，相继建立了土壤地理学、土壤化学、土壤物理学、土壤生物学等各分支学科，出版了《中国土壤》、《中国水稻土》、《土壤发生与系统分类》、《中国农业土壤志》、《中国土壤质量》、《中国红壤》、《红壤物质循环与调控》等一系列专（编）著，提出了土壤圈物质循环的重要研究内涵，建立了具有中国特色的土壤学理论，中国土壤学已经形成了阵容较大的研究队伍和较为完整的学科体系，在国际上已具有一定特色和地位。

三、本学科发展趋势

土壤学的研究成果在解决全球资源紧张、环境污染、气候变化以及保障人类社会可持续发展等问题中发挥了巨大作用。目前，该学科正在经历从传统土壤学向现代土壤学的过渡，具体可归结为三方面的转变：①研究目标的转变，即从土壤的发生分布更多地转向与人类活动密切相关的农业、资源和环境方面的研究；②研究时空尺度的拓展和融合，土壤研究在宏观（全球、区域、流域）、中观（土链、田块、颗粒、结构、表面）和微观（分子、原子、离子和电子）尺度上相互融合，在短时间（秒、分）和长时间（年、世纪）尺度上相互结合；③研究手段的不断提升，借助于现代高技术不断走向信息化、数字化、网络化、集成化，建立从实验室模拟、机制模型到田间模式、示范模区的综合体系。经过 160 多年的发展，土壤科学已发展成以系统观测与定量实验为基础，以多组分、多形态和多尺度物质性质、分异与变化为中心，以土壤过程和功能为重点的土壤学学科理论、研究方法及相应技术体系的综合性学科。近年来，国内外土壤学的发展呈现如下发展态势。

（一）新技术、新方法的应用以及长期定位试验成为土壤学发展的重要手段

当前国际土壤学研究，由于广泛借助地球系统科学新思维、物质科学新技术和地球过程监测新装备等现代科学技术而获得空前发展。技术进步将在未来相当长的一段时期内继续推动土壤学的认知水平和分析能力，从而提升土壤学研究的整体水平。这些技术包括：应用同位素的生物地球化学法元素识别技术、同步光谱显微技术、同步辐射技术等对土壤物质形态和性质的研究；应用红外发射光谱法、发射性反射光谱法和光栅分类法等技术进行的遥感遥测与制图技术；应用现代分子微生态技术（例如 FISH 和 CARD－FISH 技术）和 DNA 同位素探针技术（13C DNA probing），生物化学同位素质谱探针耦联技术（例如 PLFA－GC－MS）进行界面及其相互作用研究；应用磷脂脂肪酸（PLFA）、脂肪酸甲酯（FAME）、限制性片段长度多态性（RFLP）、DGGE /TGGE 等方法进行分子生物学和分子生态学研究；应用基因芯片（又称 DNA 微阵列）与高通量 DNA 测序技术进行基因组学研究；借助通量观测系统、水分—温度—电位的现代传感器系统、数据自动存储和远程传输系统进行长期定位观测和联网试验研究等。

（二）基础理论创新、技术进步与产业开发相结合成为现代土壤科学发展的战略途径

土壤科学正在向农业和环境问题的结合研究发展，（有机）碳—氮—磷的土壤和生态系统循环再度成为土壤学研究重点和热点。环境污染和全球变化下生态系统 C－N 耦

合、P 的活化及其在土壤—植物—水体系统转移与富营养化形成机理成为土壤学解决农业和环境问题的焦点；土壤中痕量元素的生物有效性与环境效应研究朝着食物安全和生物修复方向不断深化；土壤环境污染表征、界面过程与生物效应研究成为新热点，土壤环境污染修复技术向通过化学—生物联合方法降低重金属对作物的生物有效性以及提高富集植物的生物提取效率两个方向发展。上述动态说明，当前国际土壤学研究已在基础理论创新上有所突破，并不断地推进农业和环境技术体系与产业发展进步。

（三）多学科交叉综合与集成研究是提升和发展现代土壤学的新趋势

新兴土壤学研究方向及分支学科的诞生和涌现得益于与土壤学内部分支学科的融合和土壤学与其他基础科学的渗透融合。例如，生物学参与土壤物质和过程的研究，衍生出土壤生物物理研究分支学科；微生物学、微形态学和土壤颗粒与土壤结构的交叉研究派生出土壤微生境和微生态研究方向；突飞猛进的生物学特别是分子生物学技术与土壤学的交叉发展了分子土壤学研究；化学结构、化学计量与土壤颗粒基本物质分子组成的交叉和综合形成了分子模拟（molecular modeling）方向；数学、地统计学和土壤学的交叉形成了土壤计量学（pedometrics）；数字技术、信息技术的发展使得土壤信息系统研究和数字土壤研究成为现实，改变了传统土壤学分析的模糊和定性的形象。特别是在土壤的环境研究上，土壤学与生态毒理、环境毒理和化学毒理与风险管理学等学科的交叉融合奠定了土壤环境与健康风险的活跃的研究领域方向。而临界带（critical zone）土壤的研究，则是整合了微生物学、水文学、生态学、环境科学、地球化学、地质学、大气科学的知识和技术，在考虑土壤过程、功能及服务上与地球系统科学表层过程研究接轨，使得土壤学在解决地球各圈层交互作用以及诸如农业与面源污染、土壤与全球变化、跨界面和跨流域环境污染与控制等问题上的能力大为提高。

（四）社会与公众需求成为土壤科学发展的推动力

全球社会可持续发展面临的挑战极大地推动了土壤学的发展。不断增长的人口对粮食的需求成为农业土壤学尤其是土壤肥力和生产力研究的持续动力；气候变化及其应对的挑战，催生了土壤碳循环与固碳土壤学在全球的兴起；环境污染的全球化和 POPs 控制的国际公约推动了土壤环境与污染控制和修复成为全球环境科学的热点领域。科学研究的全球合作和重大国际科学研究计划，也推动了土壤学的全球对比与网络化。随着国际地圈生物圈计划（IGBP）等全球变化研究的需要，构成了国际有机质研究网络（SOMNET）和全球土壤变化与长期试验网络（LTES）的跨地域和国家的整合研究。为了全球土壤信息化对比，在 ISRIC（International Soil Reference and Information Centre）基础上，正在开展国际土壤分类系统的全球合作研究。随着全球对社会可持续发展科学的需求，土壤学在各个领域的全球对比和网络化研究必将得到进一步的推进。

四、本学科研究展望及建议

今后我国土壤学的发展必须首先面临全球能源、资源、生态、环境、农业、全球变化、自然灾害、经济危机及人类生命健康等八大问题的挑战。目前我国面临的土壤学问题主要

是如何进一步提高土壤生产力和可持续利用能力，满足人口不断增加对粮食和其他农产品的需求；如何提高农用化学品和水资源利用率，减少环境污染；最大限度地开发土壤的环境保护功能，缓解区域和全球环境向不利方面发展。针对这些问题在未来几年土壤科学应该优先发展的重要领域如下。

(一)土壤发育与土壤信息

研究大空间和精细时间尺度土壤演化速率、影响因素和过程模拟，特别是全球环境变化背景下风化和土壤(如冻土)形成过程与全球生物地球化学循环，以及地学定年为基础的古土壤与环境演变和近代人为活动的土壤学记录；深入研究以基层分类为主要内容的土壤系统分类，以国际上统一分类为导向开展分类参比研究；研究土壤遥感与信息技术中土壤学、农学、地学等的机理，构建标准光谱库；发展土壤遥感图像处理与自动分类技术，多元、多维复合分析的智能化处理，以及新型传感器数据分析处理技术；实现土壤数字制图和土壤数据库的数据标准化，开发“3S”一体化技术。

(二)土壤资源和土壤质量演变

系统观测和联网研究高强度利用条件下土壤质量，特别是环境和健康质量的演变规律与机制；研究土壤退化的景观生态学机制和预测预报，自然作用和人为活动共同影响下土壤侵蚀的形成过程、机理及其调控机制，跨尺度土壤侵蚀研究方法综合集成和预测模型，径流—泥沙(土)—面源污染物相互作用机制，盐渍土土壤质量演变规律与机制，高效评估方法、盐渍化防控机理和修复技术，酸沉降和人为活动共同影响下的红壤加速酸化机制及其生物调控技术。

(三)土壤性质与多界面过程

研究土壤特性和生物物理过程演变的定量描述方法和监测方法；研究土壤物理过程和化学、生物过程的耦合机制和模拟模型，建立土壤基本特性与土壤水、盐、溶质(包括养分和污染物)、热、气迁移特性的内在定量关系；研究土壤水—盐—肥耦合调控的机理和措施；基于现代光谱技术研究土壤胶体的结构、亚结构及特性，以及纳米相界面反应和纳米颗粒相互作用的机理；开展纳米微域中养分和污染物的土壤固定与液体流动态监测，研制相应的非均质体系模型；研究土壤组分与有机物/微生物作用的界面过程、分子机制及分子模拟；研究土壤矿物表面铁循环与物质转化的化学过程、生物起源的矿物形成过程和形成机制及其在污染物迁移中的作用。

(四)土壤分子生物学与蛋白组学

以土壤微生物群落的遗传信息为研究对象，采用先进的分子生物学手段，构建土壤微生物环境基因组学和蛋白组学库；研究土壤生物代谢过程及其影响因素和产物；研究炭黑形成的生物化学过程与机理，土壤生物氧化还原过程及其作用机制；研究极端环境、微域空间与根际界面土壤生物驱动过程、互作方式及其调节机制；研究复杂群落及食物网水平土壤生物的相互作用、进化机制及其生态功能。

(五)土壤利用与全球变化及生态系统

通过多目标、多类型(农田、森林、草地、湿地等)的长期野外观察网络,研究不同生态系统土壤碳汇提高和稳定的机制,全球变化下土壤生态过程的响应与反馈过程和机理,特别是土壤碳、氮循环与温室气体产生和释放的关键过程和因素作用,以及全球变化背景下不同类型生态系统土壤碳动态的模型模拟和准确预测;研究脆弱和退化农业生态系统中土壤—生物—植被交互作用机制,以及生态系统服务功能恢复过程中土壤生物多样性与植物多样性的协同机制及其反馈;研究污染退化土壤的土壤植物—微生物强化修复机理。

(六)土壤养分、肥力与生产力

研究农田生态系统内源有机质转化途径及其关键生物群落与功能,有机质积累、转化的环境因素与调控机制,土壤有机质提高对高生产力条件下生态系统稳定性的影响机制;研究土壤多养分转化的生物学过程和机制,如土壤有机碳耦合条件下氮磷在土—水界面的生物学过程及其机制,土壤碳氮共济的关键生物过程、制约条件及潜力;研究土壤根际过程与养分资源高效利用机制,主要包括作物根系诱导的根际养分活化过程及其分子机制、根际微生物与根际养分转化过程、根系与水分养分时空耦合的作物根层水肥调控机制;建立不同尺度土壤肥力及可持续性评价的方法与指标体系,研究不同生态区域土壤肥力的演变规律与主要驱动因子及机制;研究高生产力条件下养分资源综合管理理论与技术。

(七)生态高值农业的土壤学基础研究

研究耕地质量的定向培育与耕地资源集约利用、水肥耦合管理与流域水资源保护利用、农业面源污染控制与农业清洁生产、应对全球变化的农田增汇减排体系;研究现代农业条件下,主要土壤障碍形成机制与调控技术;研究连作障碍的生态过程与调控、精准农业和信息化农业科技发展技术,建立土壤质量标准体系;研究土壤环境污染防治与修复技术体系。

面对这些艰巨的任务,我们应该清楚地看到存在的不足。首先,我国教育体制限制了多学科综合人才的培养。由农业大学培养的土壤学基础人才在数学、物理学和哲学等基础学科的知识和技能上明显逊于国外,使得从事土壤科学研究的科研人员知识面单一,应用其他自然科学的最新进展严重滞后,从而影响其创新能力。其次,对于土壤学观测、监测和实验分析的仪器设备研制方面的支持不够,生态环境长期定位监测网络的自动化水平低,制约了土壤学研究水平的提升,导致尖端仪器设备以及相关信息产品(如高精度卫星遥感数据)的土壤学研究工作始终滞后于国际先进水平。第三,部门分割导致土壤学研究资源分散,利用效率低,共享程度差。高水平研究平台、国家信息数据、土壤调查和长期试验资料分别掌握在不同的部门和研究单位,由于管理体制问题,对这些资源很难做到完全共享,制约着整体土壤学研究水平的提高。

综上所述,土壤学发展面临着前所未有的机遇与挑战,特别是随着全球生态环境的急

剧变化，人类将遭受难以预测的突发性灾害。因此，现代土壤学研究的任务，首先必须从战略的高度、从系统角度出发研究土壤的结构、过程和功能的演变规律和机制，准确把握土壤演变的未来发展趋势，提出应对策略和措施；同时，现代土壤学的研究必须与社会需求和社会变革相适应，以解决全球土壤变化和生态环境对社会经济与人类健康影响等方面的关键性问题。只有不断发展现代土壤学，才能为实现人口、资源、环境和社会可持续发展的前景提供必不可少的保障。

第十七节　植物保护学

一、引　言

植物保护学是属于农学学科门类之中的一级学科，是研究植物病害、虫害、杂草、鼠害等有害生物的生物学特性和发生危害规律及其与环境因子的互作机制，以及监测预警和防控技术的一门综合性学科。

在深入贯彻落实科学发展观和“自主创新，重点跨越，支撑发展，引领未来”科技方针的指导下，我国植物保护科技工作者紧紧围绕严重制约农业可持续发展的粮食安全、生态安全、农业增产、农民增收和农业现代化建设的战略需求，瞄准世界科技前沿，发扬传统，开拓创新，协作攻关，通过不同学科的交叉与融合，不断革新研究技术与手段，在国家加强对植物保护领域基础和应用基础研究、高新技术研发和应用技术研究的支持下，近两年来，植物保护学学科研究、学科建设、人才队伍培养、科研平台等方面得到了快速发展，取得了一批重大研究成果和突破性研究进展，显著提升了我国植物保护学科的研究总体水平和防御生物灾害的能力。

二、近年来本学科的主要研究进展

(一)植物病理学

植物与真菌互作机理研究，证明 3 -磷酸磷脂酰肌醇(PI3P)分子在植物和动物细胞表面广泛存在，是真菌效应蛋白进入动、植物寄主细胞的一种普遍机理。该研究对于通过阻断和破坏真菌与寄主细胞分子的结合、开发有效的药物和杀菌剂具有开拓性的意义。病原物致病机理研究，从油菜菌核病菌致病力衰退的菌株中发现了一种可寄生植物病原真菌的新的 DNA 病毒，解开了多年来真菌中是否存在 DNA 病毒的谜团，是国际上首次有关真菌 DNA 病毒的报道。病害流行学研究，进一步探明了我国陇南小麦条锈病菌源区的扩大范围，发现小麦条锈菌在菌源基地存在遗传重组现象及新的高毒力致病型。揭示了小麦赤霉病菌致病机理以及寄主植物的防卫反应。利用地理信息系统(GIS)对小麦白粉病越夏、越冬进行区划，将高光谱、无人机低空遥感及病菌孢子捕捉器等新技术应用于小麦白粉病监测预警研究，在小麦白粉病流行监测中发挥了重要作用。

(二)农业昆虫学

昆虫生理生化与分子生物学研究,揭示了昆虫发育与变态的相关基因及内分泌调控机理、作物—害虫—天敌互作生理基础、昆虫生殖生理与抗逆生理机理;建立了昆虫转基因技术体系,并就害虫转基因方法进行了探索。昆虫化学生态学研究,阐明了植物化学信息分子的基因调控和气味信息分子对昆虫行为的调控机理以及昆虫感知化学信息物质的分子机制。迁飞昆虫学研究,初步阐明了草地螟、褐飞虱、白背飞虱等重大害虫的迁飞行为、迁飞轨迹和虫源性质;组建了毫米波扫描昆虫雷达、垂直监测昆虫雷达、收发分置的多普勒昆虫雷达和厘米波旋转极化垂直监测昆虫雷达,有 7 台昆虫雷达分布于我国具有代表性的观测地点,形成了一个小型的昆虫雷达观测网。昆虫对 Bt 和化学农药抗性机制研究,探明了棉铃虫对 Bt 棉花抗性的形成、遗传与演化机制和多种农业昆虫对化学农药的抗性机制。

(三)杂草学

杂草生物学研究,发现辽宁杂草稻具有较高的遗传多样性、群体间遗传分化较大、遗传差异明显;探明了黄顶菊在中国的潜在适生区域;明确了播娘蒿的抗药性水平和重要抗药性杂草的交互抗药性以及抗药性分子机制。微生物除草剂研究,提取分离出 AAC-Toxin、小菌核菌(*Sclerotium rolfsii*)、放线菌等除草活性菌株。植物化感作用研究,明确了我国化感水稻产生的化感物质及其抑草机理,并在获得具有化感作用新品种的基础上,开展了确定与水稻化感活性相关的基因标记工作;揭示了外来杂草释放化感物质的途径和环境响应机制。应用技术研究,创建了生态控草与化学除草相结合的油菜田杂草综合治理技术体系;构建了以除草剂减量使用技术为核心的小麦—玉米两熟农田除草剂安全高效技术体系;应用 GPS 定位手机平台,研发出田间杂草分布采样系统和精量喷药自控系统。

(四)生物防治学

害虫生物防治研究,明确了菜蛾盘绒茧蜂等多种重要容性寄生蜂的寄生机理;探明了寄生性天敌可利用相同或相近的挥发物谱对不同的植食者进行寄主定位,以及植食者诱导的挥发物调控寄生性天敌与捕食性天敌间的相互作用;通过对部分天敌昆虫的滞育研究,表明利用昆虫本身固有的滞育遗传性,可实现对天敌昆虫产品发育进度的调控。植物病害生物防治研究,从渤海潮间带植物盐地碱蓬根内分离到 1 株海洋芽孢杆菌 B-9987(*Bacillus marinus*, CGMCC 号:2095),并已创制出首个海洋微生物农药——10 亿 CFU/g海洋芽孢杆菌可湿性粉剂(简称海洋 WP),建立了中试生产线,对多种蔬菜土传病害和叶面病害均有良好防效。发现海泥的地衣芽孢杆菌 BAC-9912 控制真菌病害的主要活性物质为脂肽,并分离鉴定出其中一个活性组分为 surfactins 系列化合物,开发出宁康霉素生物农药。在木霉菌多功能性研究中,开发出多种新型生物防治菌剂及环境生物修复剂。

(五)农药学

农药创制基础研究,建立了基于密度泛函的 QSAR 理论(DFT/QSAR)和基于分子聚集态的 QSAR 理论(QAAR);建立了以顺式硝基烯为代表的基于新靶位的反抗性杀虫剂创制方法,发现了系列超高活性的化合物;从分子水平上阐述了新型除草剂单嘧磺隆的作用机制;提出了基于阻碍病毒颗粒组装的抗植物病毒新作用机制;通过仿生合成方法合成系列含氟含杂环的氨基膦酸酯化合物,并借助于芯片技术等研究手段和酶生物化学技术,发现高活性抗病毒化合物——毒氟磷。

农药新品种开发,在"973"农药创制工程中,共有 33 个具有自主知识产权的创制品种取得农药登记进入产业化开发,并获得国内外发明专利 64 项,其中国内 58 项、国外 6 项。农药环境安全评价与环境行为研究,建立了我国农药环境行为、环境毒理试验方法 21 项,明确了 10 多种手性农药在土壤、水、植物(多种蔬菜、农作物)样本中和兔、鼠等动物体内的残留、降解、代谢等环境行为。

农药残留分析方法研究,系统建立了己唑醇等 20 余种手性农药在土壤、水、多种植物体、动物组织中的残留分析方法。农药残留标准研究,建立了涉及 178 种农药在 92 种(类)作物的农药残留限量标准 807 项,制定了 500 多种农药在农产品、环境中残留量检测的国家标准和行业标准方法 232 项,以及农药合理使用准则、残留田间试验准则等技术规程 39 项。

(六)入侵生物学

基础与应用基础研究,围绕紫茎泽兰和烟粉虱的种群形成与扩张机制、松材线虫入侵种群致病作用与遗传分化机制、紫茎泽兰和烟粉虱的适应性与进化、松材线虫入侵的生态适应机制、大豆疫霉毒性因子与寄主的协同进化、紫茎泽兰和烟粉虱等重要入侵物种对土著种的竞争排斥机制与置换效应以及生物入侵对特定生态系统结构与功能的影响等,开展了较为系统的深层次研究,解析了一些外来有害生物入侵的生态学现象与过程,提出了一些新的观点和理论,为制定防控对策与技术提供了科学依据。

外来入侵物种的风险评估与早期预警技术研究,建立了部分重要入侵物种的远程鉴定系统和图像识别系统以及一套具备地理数据的创建、提取、管理能力的外来有害生物大尺度生物—环境关系分析平台;建立了外来入侵物种适生性风险分析评估技术体系;完成了对 40 种局部入侵物种的适生性风险分析,并制定了 15 种外来入侵物种的紧急控制预案;建立了入侵物种特异性的分子检测技术及早期诊断技术。

(七)转基因生物安全学

经过近几年的努力,在转基因抗虫水稻和植酸酶玉米的生物安全潜在风险的系统评价、转基因抗虫棉对棉铃虫调控作用的系统监测、抗虫棉种植后盲椿象灾变原因及控制技术、棉铃虫对抗虫棉抗性风险评估与预防性治理技术等项研究中,取得了突出的进展,为转基因新品系的安全管理、转基因新品种的产业化和持续应用提供了坚实的科学基础或关键性的技术支撑。"转基因抗虫棉对棉铃虫调控作用的系统监测"、"Bt 棉花种植对盲

椿象种群区域性灾变影响机制”两篇研究论文在国际著名杂志《科学》上发表后，受到国内外媒体的普遍关注。前文被两院院士推选为2008年度国内十大科技进展新闻之一。

(八)鼠害防治学

通过气候、植被等环境因子对害鼠种群波动的研究，揭示了气候及其影响下的食物、植被等因素对鼠类种群暴发的影响；提出厄尔尼诺—南方涛动(ENSO)可能是鼠类种群暴发的重要启动因子；构建了鼠害区域性暴发的计算机数值模拟；在网络建设的基础上组建了鼠害暴发预警系统。研究中阐明了鼠类生殖期的免疫功能、BAT(棕色脂肪组织)产热与免疫功能的关系，揭示了低温驯化和IBAT(肩胛间棕色脂肪组织)切除对免疫指标的影响、血清瘦素在布氏田鼠妊娠期和哺乳期对能量摄入和产热调节的不同作用；明确了鼠类群体的遗传多态性与鼠群体数量的暴发成正相关，光照因子是决定布氏田鼠遗传表达的最重要因子之一；发现食物中的单宁酸对小家鼠的蛋白质代谢有抑制作用，添加单宁不仅会降低其免疫功能而且可抑制鼠的繁殖能力。

三、本学科的学术建制、人才培养及科研平台建设

(一)学术建制

近年来，随着生命科学和生物技术的发展以及新原理、新方法的不断渗透、交叉与融合，植物保护学科形成了分支学科比较齐全、基础和应用基础研究以及高新技术研究和传统技术相协调的植保科技创新体系，有15个分支学科，其中植物病理学、农业昆虫与害虫防治、农药学这三个分支学科也是教育部学科分类系统的重要二级学科。学科发展以国际植保科技前沿和国家重大需求为目标，着力推进原始和自主创新能力，围绕农作物重要有害生物的灾变规律、成灾机理、监测预警的理论和技术以及有害生物控制的理论和技术等进行系统、全面的研究，为实现有害生物可持续控制和农业可持续发展以及培养高学历、高素质、高水平的专业人才做出新的贡献。

(二)人才培养

通过国家及省、部有关人才计划以及“973计划”、“863计划”、科技支撑计划、自然科学基金、科技基础条件平台建设和政策引导类科技计划及专项、农业部公益性行业科研专项等，对植物保护学科予以大力支持。据不完全统计，近几年有近万名中青年科技工作者和研究生参加了上述研究计划，加速培育了一批中青年学科带头人，特别对研究团队与领军人物的培养发挥了更为重要的作用，提高了我国植物保护领域的整体学术水平。

(三)科研平台

目前我国已建成较完善的植物保护学科研究平台，有依托在中国农业科学院植物保护研究所的国家农业生物安全科学中心和依托在科研院所、高等院校的“植物病虫害生物学”、“农业虫害鼠害综合治理”等7个国家重点实验室以及依托在中国农业科学院植物保护研究所的农业部作物有害生物综合治理重点实验室，该重点实验室下设15个专业性或

区域性实验室，包括农业昆虫学重点实验室、植保生物技术重点实验室、植物病理学重点实验室以及分布在全国各大区的作物有害生物综合治理重点实验室，成为我国植物保护科技创新研究基地；同时该重点实验室在全国各地设有 29 个作物有害生物综合治理科学观测实验站，作为作物有害生物监测和防控试验示范基地。上述平台建设为植物保护学科发展提供了有力的条件保障。

四、本学科国内外发展状况比较

近几年，我国植物保护科技工作者以提高自主创新能力为核心，刻苦钻研、辛勤努力，取得了显著的研究进展，涌现出一批研究成果，某些成果达到国际领先水平，缩短了与国际先进水平的差距。但是，我国植物保护学科研究总体水平与国际先进水平相比，还有较大差距，主要表现在原创性研究不足、基础研究和高新技术研究仍较薄弱。

植物病理学在病原菌侵染及其病害的灾变分子机理、病原菌致病性与毒性及其变异的分子机理、植物持久抗病性分子机理、病原菌与植物寄主互作机制等研究方面，尚有较大的差距。

农业昆虫学对转基因昆虫、昆虫功能基因组、害虫与寄主植物的协同进化、农田生态系统食物网、转基因作物利用等领域的研究工作还有待加强；3S 技术和计算机网络技术亟待进一步发展，以提高对害虫种群的监测预警能力和水平。

杂草学在杂草致灾生物学的遗传学基础、杂草与农作物的互作机制、除草剂作用机理以及抗药性杂草的抗性分子机制、抗药性水平检测和杂草治理专家支持系统等方面，与发达国家相比差距较大。在生态控草技术、3S 技术、杂草抗药性治理、除草剂对作物的安全性、除草剂药害预防与修复等方面均有待加强和提高。

植物病害生物防治缺乏生态学研究，在生防菌功能发展物质、定殖规律和作用机理等方面与发达国家相比存在一定差距。害虫生物防治在天敌与害虫互作机制、农田食物网作物—害虫—天敌间的信息网与通讯机制、天敌昆虫人工繁育的营养学与生理学基础、害虫及其天敌的种群波动机制、天敌控害作用的评价方法、天敌引种的基础理论研究及风险评估、新的生物技术开发改良等方面与发达国家相比也有较大差距。

农药学研究与先进国家相比，主要差距是农药创制处在“追踪世界先进水平的阶段”，不但创制的品种少、所占份额低，且主要源于跟踪创新。

入侵生物学在应用基础和应用技术研究方面还相当薄弱，检测和监测手段还比较落后，无法实现对入侵物种的远程实时监测及其识别与诊断。对相当数量的高度危险的潜在外来有害生物甚至还没有基本的检测方法和标准，已有的检测方法也还存在检测时间过长或敏感性不够的缺陷，不能满足维护国家安全的实际需求，使大量外来疫情不能得到及时、准确鉴定，无法组织对国内突发以及尚未定殖的外来有害生物进行监测、调查和封锁控制。在对国内外疫情调查和风险分析、疫情数据库信息管理系统的建立与实时更新，以及快速的信息沟通与反应机制等研究均存在较大的差距。此外，入侵物种的转基因控制技术研究尚属空白。

转基因生物安全学研究与美、欧先进国家相比差距较大，许多国家对风险评价、风险管理和风险交流 3 种技术研究同期开展、同步推进。我国转基因生物安全技术研究按照

差距由小到大的顺序，依次为风险评价技术＜风险管理技术＜风险交流技术。其中，室内风险评价技术的差距大于田间风险评价，尚无产品应用的风险管理技术差距大于已有产业化应用的。

鼠害防治学研究，发达国家当前都在积极研究、发展生态治理技术。欧美国家根据鼠类生活习性，通过大规模清理农田，在易于发生鼠害的农田尽可能把鼠类适宜的栖息地改造成不适栖息地，并采取同种作物大面积连片种植的方式降低鼠类栖息的机会。相比之下，我国虽然也有类似的研究，但农田改造的强度和实际鼠害控制效果均有一定的差距。

五、本学科的发展趋势与展望

（一）植物病理学

应对全球气候变化和种植结构调整，强化重大病害发生规律的基础研究。发挥生物芯片、DNA 条码等技术在植物病害监测与诊断中的应用；发挥网络和信息系统的作用，建立各级网络化诊断、监测和预警体系和平台，提高应对突发事件的能力；加强危险性入侵植物病害的监测预警与应急防控技术的储备研究。在防控策略上朝着有害生物的系统管理（SPM）、生态治理（EPM）和持续治理（SPM）方向发展。

（二）农业昆虫学

选择我国重大农业害虫及其天敌，系统开展分子生物学基础研究，为揭示害虫成灾机制以及害虫控制与天敌利用提供理论依据。加强迁飞性害虫境外虫源性质、间歇性猖獗的宏观和微观机制和传毒虫媒生物学、生态学及植物病毒病流行学的研究。进一步研究昆虫抗药性分子机制，深入研究气候变化及农药使用对害虫种群发生的影响效应。运用生物技术，开展新生代抗虫转复合基因植物培育、转基因昆虫、基因工程微生物杀虫制剂、害虫关键功能基因干扰、天敌基因修饰改良等研究。探索害虫控制与天敌利用的新方法、新技术，寻求害虫可持续控制的新途径。

（三）杂草学

运用分子生物学技术，研究重要杂草的生态适应性与致害、恶化机制，杂草—作物—除草剂—环境间的互作机制，抗药性杂草发生发展的生态适应性和抗药性机制，为杂草治理奠定理论与技术基础。在杂草治理研究方面，探索以生态控草为核心，以生物防治、精准施药为基础的杂草治理新方法和关键技术，将是我国杂草治理技术研究的重点。

（四）生物防治学

害虫生物防治研究：进一步加强天敌昆虫资源及其控害作用特征、天敌与害虫互作分子机制、天敌昆虫种质选育与人工繁育、病原性天敌培养的营养学和生理学基础、农田食物网作物—害虫—天敌间的化学信息网与通讯机制、生物多样性对天敌控害功能的作用、天敌应用或引进、基因工程生物防治制剂以及抗虫转基因植物的环境安全性评价、植物害虫生物防治新方法和新技术等研究。

植物病害生物防治研究：创建生物药物及基因靶标设计和高效筛选技术，研究或挖掘农业生物药物资源，设计具有高效农业生物药物活性的分子，研究生防微生物次生代谢生物药物相关基因的时空表达，构建重大农用抗生素品种的高效遗传菌株，进行农用抗生素生物合成关键酶基因的克隆及功能鉴定，建立农用抗生素的安全性评价和质量标准鉴定体系。

（五）农药学

新农药创制，加强新的作用靶标的研究和绿色生态农药和生物源农药的研发，以及手性农药高活性异构体的研究开发；对各类手性农药的环境行为和毒性进行系统研究；尽快完善农药残留标准制定和风险评估的管理法规，建立我国农药风险评估技术体系。

（六）入侵生物学

加强重要入侵物种的适应性与进化、重要入侵物种对土著种的竞争排斥机制与置换效应、入侵生物对生态系统结构与功能的影响、重要入侵物种预警和控制技术基础，以及外来入侵物种的风险评估与早期预警技术研究。

（七）转基因生物安全学

深入开展靶标害虫对转基因抗虫作物的抗性机制与抗性治理研究，有助于对主要害虫的持续控制。继续加强新型外源基因以及转基因作物的安全性评价研究，为转基因生物安全学科发展带来新的机遇。

（八）鼠害防治学

研究不同生态系统中鼠类对极端气候条件变化的生理生态学响应、害鼠生殖调控相关重要功能基因的作用机制及其与环境变化的关系以及害鼠生殖的生理学、遗传学调控机制，为鼠类种群的生殖调控提供理论基础；分析害鼠迁移路线，揭示全球气候变化—害鼠迁移为害—害鼠适应性的机制；研究植物—害鼠—天敌互作及调控机制，为鼠类生物控制以及生态调控措施的制定提供理论基础；研发适宜于不同农业生态系统、不同鼠种的以TBS为代表的各类绿色防控技术；开展害鼠抗药性监测及其机制研究。

第十八节　药　学

一、引　言

药品是人类用于预防、治疗、诊断疾病的特殊商品，和公众生命健康紧密相连。进入新的历史时期，党和国家强调要把改善民生作为科技工作的出发点和落脚点，并已经明确将生物医药产业培育成高技术支柱产业。2009年4月国务院关于深化医药卫生体制改革的意见，体现了党和政府对人民身体健康的高度重视。医改方案提出把医药卫生科技

创新作为国家科技发展的重点，要加大医学科研投入、整合优势科研资源、鼓励自主创新、加强对重大疾病防治技术和新药研制关键技术等的研究。我国医药卫生事业面临着前所未有的发展机遇。

二、本学科最新研究进展

目前，我国医药行业总体保持快速增长，规模不断壮大。随着生命科学和生物技术的迅速发展，分子生物学、分子药理学、功能基因组、蛋白质科学、理论和结构生物学、信息和计算机科学等学科与药学学科的交叉、渗透与结合日益加强，我国药学科技工作者利用其他学科的技术及研究方法服务于新药研发，发现了一批针对重大疾病的先导化合物和候选药物，在药物作用机理的基础研究方面，取得了国际先进水平的研究成果，重大疾病相关基因及蛋白功能转化领域取得了新进展。我国现代化创新药物研究的学科领域框架和技术平台体系已经基本构筑，显著提高了我国创新药物的基础和应用基础研究水平，为我国创新药物的前期基础性研究快速走向国际前沿提供了基础。

(一)生化与生物技术药物

以基因工程药物为核心的生物制药工业蓬勃发展，并成为新药开发的重要发展方向。世界上销售前 10 位的生物技术药物，我国已能生产 8 种，已有多种具有自主知识产权的生物技术药物和疫苗获得新药证书，表明我国生物技术药物研究已步入自主创新开发的新阶段。生物技术药物的发展已进入蛋白质工程药物新时期，第一代重组生物技术药物逐渐被第二代蛋白质工程药物所取代。新型生物技术药物的近期发展重点有 5 个类型：单克隆抗体(包括鼠源抗体、嵌合抗体和人源化抗体)、反义药物、基因治疗剂、可溶性治疗蛋白药物和疫苗。正在研究开发的品种中以疫苗为最多，多达 98 种，主要用于防治肿瘤、呼吸道疾病、AIDS/HIV 疫苗和感染性疾病治疗。现代生物制药主要依靠两种技术：重组 DNA 技术和单克隆抗体技术。

(二)药剂

我国在新型药物递送系统研究方面取得了很大成绩，紧跟国际先进水平，成为新药研发热点。药剂学总体上向着更微观、跨学科以及更多地与生物学相结合的三个方向发展。生物学的发展不仅为新药设计提供了明确的靶点，也为药物输送提供了有用的信息，故受体介导、转运体介导等的新型药物递送系统研究成为热点。目前，药剂学研究的前沿主要集中在新型靶向给药系统、载体给药系统、口服缓控释给药系统、新型黏膜给药系统、生物技术药物的新型药物递送系统以及生物药剂学等方面，预计分子药剂学(及分子生物药剂学)将成为未来药剂学的一个重要科研方向。纳米给药系统和纳米药物制剂作为新型药物递送系统已取得了显著的成绩，纳米粒或其降解产物的细胞毒性仍是一个主要问题，在未来研究中重点关注改善其生物相容性。目前国家对创新制剂研究的重视程度和扶持力度正在加大。“重大新药创制”科技重大专项中设置了“新制剂与新释药系统技术平台”，通过评审，北京大学药学院、四川大学华西药学院等 7 家单位分别承担了此项专业技术平台的建设任务。

(三)海洋药物

我国已成为国际上制备新颖结构海洋天然产物最多的国家。海洋微生物是近年刚发展起来的具有发展药物先导化合物潜力的海洋生物群。我国科学家已从不同海洋微生物菌株中获得一系列具有新颖骨架结构的活性化合物，为微生物天然产物及其药物先导化合物的深入研究开拓了方向。此外，在国际上率先开展了深海和极端微生物中天然产物的化学和药理学研究，并取得初步的成果。我国海洋药物研究逐渐形成以生物小分子为先导化合物的药物候选物研究。目前一批海洋候选新药正在进行临床前研究和临床研究，一些项目取得了可喜的成效。我国已初步掌握近海海洋生物的天然产物结构类别，为进一步开发我国海洋生物药源提供大量的模式结构和物质基础。由中国海洋大学管华诗院士领衔、历时 5 年整编而成的海洋生物巨著《中华海洋本草》，为现代海洋药物的研究开发提供了基础性科学资料。

(四)药物化学

近两年我国的药物化学学科取得了新的成绩，分离和合成了数以万计的新化学实体，许多具有自主产权的新药研究进展顺利，同时出现了一些新的观点以及化学生物学、化学信息学等新学科。通过研究，发现了一批针对重大疾病的先导化合物和候选药物，其中一些已进入临床前和临床研究，展示出鼓舞人心的发展前景。针对重大疾病相关基因，利用有效靶标的发现技术和功能验证技术，从基因组学等信息资源中寻找药物发现的关键靶标分子，目前已经得到国内药物研究者的重视并取得了新进展。在我国目前的情况下，制药工艺研究仍然是国内药物化学工作者关注的热点。

(五)药物分析

目前，药物分析从分析对象来看，除了传统意义上的药品质量控制方法研究以外，对生物标志物及体内代谢物的分析也逐渐成为研究热点。从分析方法来看，仪器分析技术在药物分析领域得到了广泛的应用，先进的仪器分析技术，如近红外光谱、质谱、核磁共振光谱、X－射线衍射、毛细管电泳、气相色谱—质谱(GC－MS)、液相色谱—质谱(LC－MS)和液相色谱—核磁共振光谱(LC－NMR)等联用技术，在药物物质基础和作用机理研究，药品质量标准研究，药物体内吸收、分布、代谢和排泄规律的研究，手性药物色谱分析以及药品生产过程中的过程控制技术等方面均取得了长足的进步。这对于进一步了解生命过程和药物的作用以及在保障药品质量、提高药品疗效等方面发挥了积极的推动作用。

(六)抗生素

近两年来，我国在微生物药物筛选研究方面也取得了显著进步。由中国医学科学院医药生物技术研究所牵头的“创新微生物药物高效筛选与发现技术平台”，已经建立起 3.5 万多株筛选用微生物菌种库；微生物产物样品库有 3.5 万个样品，可供抗感染等药物活性筛选的天然与合成品纯品库也已达到 4.5 万个样品。近年来建立了 40 多种针对病毒感染、结核杆菌感染与持留、耐药细菌感染、恶性肿瘤发生与发展以及动脉粥样硬化发

生发展等新药物靶标的新型药物筛选模型。中国科学院微生物研究所2009年以来选择部分西藏冬虫夏草定殖真菌、植物与地衣内生真菌和低温真菌等特殊资源进行了系列的化学研究，共分离微生物产物350个，其中发现约150个新结构次生代谢产物，部分化合物具有新颖骨架类型或显著的药理活性。我国在高效抗肿瘤抗生素力达霉素和加里奇霉素的研究，特别是力达霉素抗体靶向肿瘤治疗研究方面取得显著的进展。

(七)中药与天然药物

当前，加强中药药效物质基础研究，借鉴运用各领域的先进技术和方法提高中药的安全性、有效性和质量稳定性是中药现代化的必然之路。2009年在国家发改委的中药现代化专项及“重大新药创制”科技重大专项的中药大品种二次开发支持下，中药生产过程控制技术得到了较快的发展。据《中国药典》2010年版(一部)记载：我国积极采用新技术、新方法，使得部分药品标准已达到或超越国际同类标准水平，中药标准有了实质性的突破和提高，完善了饮片国家标准体系，强化了符合中药特点的专属性鉴别。目前，中药炮制研究正在由单一的注重化学成分变化逐步转向全方位的注重化学和药理共同作用的研究模式，从单一药效指标评价逐步转向多项药效指标的综合评价模式上。国家食品药品监督管理局(SFDA)颁布了《中药注射剂安全性再评价相关技术评价指导原则》，对上市后中药注射剂的药物组成、安全性、制备工艺、质量标准、功能疗效等各个环节进行再评价，以保障临床用药的安全。

(八)医院药学

近两年，随着医药卫生体制改革的不断深化，我国医院药学学科发展迅速，医院药学的工作模式开始由简单的保障药品供应型向综合药学服务的方向转变。临床药师的需求日趋旺盛，卫生部临床药师培训基地已经启动并招生。卫生部出台多项制度，促进合理用药，保障医疗安全，促进医院药学发展。2009年8月，我国建立国家基本药物制度工作正式实施，已公布的《国家基本药物目录(基层版)(2009版)》，包括化学药品、中成药共307个药品品种。2010年2月发布《中国国家处方集(化学药品与生物制品卷)(2010年版)》，为规范医疗行为、提高临床药物应用水平等工作奠定了重要基础。卫生部组织制定了《医院处方点评管理规范(试行)》和22个专业112个病种临床路径，在规范医院处方点评工作，提高处方质量，促进合理用药，保障医疗安全等方面，临床药师作用不可替代。随着信息化和智能化加速发展，电子处方和单剂量分包装机开始在我国使用，医院药学信息系统建设受到重视。

(九)药物毒理学

近年来，我国药物毒理学研究取得丰硕的研究成果，在实验动物的管理、专业的药物毒理学研究机构建设、毒性病理学诊断技术、新技术新方法的应用等方面均取得长足的进步。到目前为止，我国共有27家机构已通过国际实验动物评估和认可管理委员会的正式认证，其中的绝大多数机构均从事新药非临床安全性评价与研究。我国在生殖器官的固定、包埋等组织处理程序，生精小管分期及组织病理学检查，计算机辅助精子分析

(CASA),以及卵巢、子宫、阴道等病理学检查细则等方面也取得重要的进展。

(十)药物临床评价研究

国家对于药物临床评价研究学科建设和发展支持力度很大,“重大新药创制”科技重大专项中“新药临床评价研究技术平台”资助了 26 家大型综合性医院的药物临床试验机构药品临床试验管理规范(GCP)平台建设。一批药物临床试验关键技术,如重大疾病相关创新药物临床基因组学研究技术平台、创新药物 PK/PD 评价技术平台研究、创新药物群体药代动力学评价技术平台研究,以及创新药物临床评价新指标研究方面取得了可喜的成绩,建立了抗菌药物临床评价新指标、心血管疾病治疗药物临床评价新指标、脑血管疾病治疗药物临床评价新指标等,为我国医药产业战略性调整提供了科技支撑和技术保障。

(十一)老年药学

目前以纳米技术制备的纳米药物对药物的药代动力学及药效动力学的影响已引起老年药学界的高度重视。应用生物化学技术研究老年病药物比传统的化学方法更经济、合理、作用好、疗效确切、效果明显、治疗周期短,尤其适合老年人。人工神经网络在老年药学研究的众多领域中广泛应用,并显示出其独特的优越性。器官水平微循环动态观察技术、细胞水平微循环动态观察技术及微透析技术等在老年药学研究领域受到重视并取得了可喜的成果。

(十二)药物流行病学

国内加强了对药品不良反应(ADR)危害程度的定量评价研究,既为药品监管部门加强对 ADR 严重程度较高的药物的监管提供决策信息,同时又为医生及患者合理地选择药物提供定量化的参考依据。目前我国 ADR 病例报告数据增长迅速,如何快速准确发现安全信号已成为难点问题,不少学者开展了药品不良反应信号检测方法的研究。此外,药物基因组学在药物安全领域得到进一步应用,“常见重大疾病全基因组关联分析和药物基因组学研究”重点课题业已立项,此项计划实施必将推动我国药物基因组学的研究,为患者个性化治疗和安全合理用药奠定理论和技术基础。医疗器械不良反应监测和上市中药淘汰管理工作得到进一步重视,骨科植入物是我国医疗器械不良事件监测的重点。

(十三)药物经济学

当前,我国的医药体制改革方案、发改委的药品价格管理办法和人保部的基本医疗保险药品目录(2009 版)对药物经济学的研究和应用产生了迫切需求,药物经济学在宏观药品政策,如药品的价格管制、药品补偿机制、基本药物及医疗保险药品目录的制定、新药审评标准等方面研究不断深入,药物经济学广泛应用于政府和企业等多个层面,为相关政策的制定者和决策者提供可靠的参考依据。药物经济学评价方法在我国的应用逐步由成本—效果分析向成本—效用和成本—效益过渡。近两年,药物经济学研究大多集中在健康相关生命质量量表的验证、对中国特定疾病人群的生命质量测量,以及完整的经济评估

等方面。中国药学会与中国医师协会组织相关药物经济学专家完成了《中国药物经济学评价指南》初稿的撰写工作。

(十四)医药知识产权

生物医药技术对知识产权保护的依赖性强,且与国计民生息息相关,故成为国内学者研究重点。《专利法》的第三次修改,立足于鼓励技术创新,为医药知识产权保护提供了法律保障。此外,国家还制定了一系列的激励政策,如财政支持政策、专利药品定价政策、药品知识产权保护政策等,分别从医药知识产权的创造、利用、管理、保护四个方面不断丰富和完善我国医药知识产权保护体系。2009 年 8 月 SFDA 颁布实施了《药品技术转让注册管理规定》,在《规定》的影响下,我国明显加快了专利实施转化的力度,未来我国专利药品的产业化程度将得到进一步的提高。

(十五)药事管理

随着医疗保障制度逐步完善、医药经济的快速发展,使得药事管理理论与实践的研究领域有了进一步扩展的空间,特别是医药卫生改革中遇到的有关药事管理的理论和实践问题,如医疗保险用药、药品价格控制、药品集中招标采购、国家基本药物政策等,不仅成为国家政策重点,也成为社会关注的热点。执业药师资格制度的实施推动了药事管理学科的发展。现代科学技术在医药领域的应用,对药事管理学科产生了重要影响,全球医药物流、供应链管理、医药电子商务、医疗机构零库存等新技术、新方法、新模式正影响和改变着传统的药品管理规范。

(十六)军事药学

“十二五”计划即将启动,军事药学专业从“保打赢”转变为“应对多种安全威胁,执行多样化军事任务医学科技发展的战略需求”,反恐维稳、应急处突等非战争军事行动的药材保障需求加强。在药物设计合成、药用高分子材料、核酸化学研究系统以及小分子药物设计等方面成为军事药学工作者关注重点。在长期低剂量辐射、微波、电力辐射防治药品制剂,抗高原反应药品制剂,二炮、核潜艇等战略军兵种部队特殊军事环境防治药材,核、生、化及新概念武器的致伤防护及救治药材,飞行等特勤人员的职业病防治及医疗保健药物,坑道卫生、皮肤病防治药物方面的研究均取得可喜成果。在现代战争、战场环境对参战人员心理及多种身心疾病干预药物制剂与服务方法方面也获得一定成果。国内在长效、强效、低成瘾性的镇痛药候选化合物、抗运动病药物、抗疲劳药物研究上也取得进展。

三、本学科国内外发展状况比较

在国家高度关注民生、深入推进医药卫生体制改革、逐渐加大对医药卫生领域科研资金投入的良好背景下,我国医药产业快速增长,医药工业集中度进一步提高,医药企业的销售规模也逐步加大,市场竞争能力增强。2009 年 5 月,“重大新药创制”科技重大专项正式启动,这对于提升我国医药产业的创新水平起到重大的推动作用,专项给予重点支持的幽门螺杆菌(Hp)疫苗等 3 个新药已经取得新药证书,左旋奥硝唑等 10 个新药已经完

成全部研究工作，抗肿瘤药海姆泊芬等 43 个新药正在进行Ⅲ期临床试验，中科院上海药物所经过 16 年研制的抗菌药盐酸安妥沙星 2009 年 4 月 15 日获得一类新药证书。已有 6 个 GLP 通过了国际 AAALAC 认证，国家成都中药安全性评价中心通过了美国 NIHOLAW 认证，中科院上海药物所安评中心/阿斯利康生物技术安评中心完成建设，建立了系列分子毒理模型。专项支持 26 个新药临床研究平台也取得了较快进展，部分机构已经得到国际互认、开始承担国际多中心研究工作。全国医药园区建设力度明显加强，医药产业的布局出现可喜局面。

但是，国际医药形势表明，我国医药行业的整体水平与发达国家相比，还有较大的差距：药品创新能力和潜力不足，自主知识产权药品严重缺乏，极大制约了国内医药工业向高技术、高附加值的下游深加工领域延伸；产品更新换代缓慢，无法及时跟上和满足市场需求的变化，在国际医药分工中一直处于低端，不但国际市场占有率低，国内高端医药市场也主要被进口或合资产品占据，我国医药卫生领域迫切需要药物创新。另外，在思路策略、研究方法、研究手段、学科交叉、人才培养、成果转化等方面也需要不断改进和提高。

四、本学科发展趋势和展望

现代生物学取得突飞猛进的进展，深刻影响着药物研发的策略与研究模式，并推动药物发现进入了一个革命性变化的新时代。2009 年 6 月，国务院出台了《促进生物产业加快发展的若干政策》，提出将生物产业培育成为我国高技术领域的支柱产业。我国目前重点发展人源化治疗抗体等生物技术药物，力争在生物技术药物研究领域取得多点突破，接近或达到世界先进水平。

随着全球细胞和分子生物学、化学基因组学、蛋白质组学等研究不断取得进展，对于疾病病理机制的认识和研究已经达到很高的水准。针对重大疾病相关基因，利用有效靶标的发现技术和功能验证技术，从基因组学等信息资源中寻找药物发现的关键靶标分子，目前已经得到国内药物研究者的重视并取得了新进展。借助化学和生命科学学科交叉的手段，针对生命体系信号转导过程中的重要分子事件，以小分子化合物为探针，在分子和细胞水平上开展小分子化合物对生物体系的调控、对生物体系信号传导的影响，揭示信号转导的调控规律，在此基础上发现新的药物作用靶点、设计和研究新的先导结构分子，这已成为创新药物研究的一个新的研究动向。要全力推进化学药研究开发，实现跨越发展，使化学药研究开发的综合能力和水平接近国际先进水平。合成药物仍然是 21 世纪重点开发的新药的领域。

传承中医药优势和特色，加速中医药现代化的进程，使我国创新中药研究居于国际领先水平；加强地道中药材优良品种的选育和规范化、标准化、规模化种植；在继承和发展中医药理论的基础上，阐明中药作用的物质基础和作用机理，建立具有中医药特色的中药药效与安全性评价体系，根据中药复合成分的特点建立科学的中药制剂质量控制系统；在继承和发扬中医药优势和特色的基础上，充分利用现代科学技术的方法和手段，借鉴国际通行的药品标准和规范，研究开发能够进入国际医药市场的中药产品，提高中药在国际市场的竞争能力。

从天然产物中发现新的先导化合物，对先导化合物进行结构修饰和改造或全合成研

究仍是21世纪新药发现的重要途径。随着国家对创新药物研发投入的加大，我国药学学科的发展前景将更加美好。

第十九节　生理学

一、引　言

生理学作为一门经典的学科有着悠久的历史，在现代医学与现代生物学的发展中起到了重要作用。中国的生理学诞生距今已经有80多年的历史。由于国家科技投入的增加和科技政策的保障、国内年轻人才的成长和国际高水平人才的回归、国家重大需求和人民健康需求等因素，中国生理学在“十一五”期间有了飞速发展，形成了多专业领域百花齐放的局面。

二、近年来本学科在科学研究、学科建设等方面的进展

(一)有关科学研究的进展

1.神经系统生理

整体上，我国感觉系统的研究与国外差距不大，某些领域处于国际先进水平，尤其以视觉、痛觉和听觉的研究较为突出。痛觉近年来的研究主要集中在病理性疼痛，即炎性痛和神经病理性疼痛方面。视觉研究在视网膜信号转导和视觉皮层可塑性的研究提供了新认识。听觉系统研究在听觉与视觉的交互作用和蛙类超声听觉有了新的发现。嗅觉的研究在哺乳动物对CO_2检测的分子机制方面也有了一定的进展。对AD和PD的病因、发病机理、早期诊断和治疗策略进行了较系统研究。确立了国人脑卒中发病的遗传和环境危险因素并提出了防治的新策略。癫痫的机制研究与临床利用电刺激预防和治疗癫痫也取得一定成果。脑胶质瘤主要集中于抑制肿瘤的生长通路和血管生成治疗。

2.循环生理学

循环生理学的转化医学研究对HHcy可通过血管炎症免疫反应促进动脉粥样硬化的机制做了深入探讨。发现层流可以通过调节花生四烯酸、激活PPARγ、上调硬脂酰去饱和酶改善内皮细胞的脂质代谢。揭示了microRNA在机械生物信号传导中的重要作用。关于核受体LXR、FXR与脂质代谢调节的研究也发表在国际权威杂志。严重高甘油三酯基因突变、动物模型、氧化损伤机制与调脂新药的研发也推进到一个新高度。证实房颤时KChIP2和minK表达量下调。发现许多血管活性物质对BKCa通道存在直接或间接的调控作用。我国的PGE2系统的研究处于国际领先水平，发表了一系列高水平的研究论文。在国际上最早发现并提出H_2S是心血管调节的新型气体信号分子，其对整个心血管稳态调节作用具有普遍性意义。证明了κ-阿片受体兴奋后对心血管系统的活动具有明确的调节作用，这些作用的信号机制涉及阿片受体/酪氨酸蛋白激酶/PKC/KATP

等途径。

3. 生殖生理

男性生殖健康研究包括异嗜性抗原溶脲脲原体免疫节育疫苗、隐睾不育的分子基础及寻找新一代男性避孕靶点、生殖道微生物组学等课题。女性生殖健康研究重点关注卵母细胞发生过程中减数分裂发生或染色体分离异常，大幅度提高了 PGC 体外分化卵母细胞的减数分裂成熟能力。初步证明 cyclin G1 对子宫内膜上皮细胞增殖的负调控作用可能通过 PP2A 改变 Rb 磷酸化而实现。筛选到一批在胚胎着床位点上调和下调的 microRNA。揭示了血管发生相关的分子基础及其在卵巢功能中的作用，为从血管新生角度深入研究围绝经期卵巢衰老机制提供了新的思路。阐明了调节胎盘 CRH 合成和分泌的关键环节及其相关的分子机制，揭示了胎盘内分泌网络在妊娠维持、诊分娩启动中的重要作用。为早期预测子痫前期提供了新的靶分子，同时为“胎盘功能障碍导致子痫前期发病”这一理论提供了新的依据。

4. 内分泌生理

率先提出了糖皮质激素非基因组作用及其膜受体假说，发现糖皮质激素可以通过非基因组作用抑制 NR2A 介导的 ERK1/2 的激活从而增强 NMDA 导致的神经元损伤。发现甾体类激素—受体复合物、PKC 信号通路、雌激素可通过 CRE 调节靶基因的效应。以神经肽 CRF 和 CRF 受体为中心，研究其在低氧损伤和适应中的系统调节作用。发现高原动物 CRFR1 型受体和 HPA 轴低氧反应和细胞保护呈“多模式”化，提出 CRFR1 作为低氧损伤预警信号和干预靶点的观点。

5. 呼吸生理

初步阐明了神经肽对气道微环境稳态的调控作用和相互关系。发现中枢组胺 H_3 受体和 P 物质、VEGF、NGF 和 GDNF 对哮喘神经源性炎症具有调控作用；香烟提取物可引起气道平滑肌大电导的钙活化钾通道和电压依赖性钾通道 Kv1.5 表达下调，PKCε、η、θ 参与其信号转导过程；哮喘小鼠肺组织中 AQP5 表达明显降低可能与气道 MUC5AC 表达的升高有关，地塞米松可以上调 AQP3 和 AQP5 的表达。发现 NO、5－羟色胺 2A 受体、多巴胺 D1 受体、酸敏感离子通道（ASICs）的亚型对吸气中止和呼吸幅度具有调节作用，表明 BKca 通道可介导 CO 的中枢性呼吸调控作用。发现慢性间歇性缺氧通过窦神经传入可上调大鼠延髓胱硫醚—合酶（CBS）的表达，使延髓 H_2S 的含量增加，参与对呼吸中枢的保护作用。提出 TRPC1/SOCC 表达和功能的上调是慢性缺氧和野百合碱引起肺动脉高压发病机制的共同通路，TRPC1/SOCC 表达和功能在肺动脉高压早期均发生显著变化。首次在整体水平证实谷氨酸是新的肺损伤因子。发现 H_2S 调节大鼠高血流性肺血管重构的机制与 MAPK/ERK 信号通路有关。发现肺内 VIP、P 物质、CGRP、ET－1等感觉神经肽在肺脏应激、炎症、损伤时对气道上皮细胞功能的调控作用。

6. 消化生理学

发现在基础和刺激条件下末段结肠粘膜上皮主要表现为 HCO_3^- 的分泌和 Cl^- 的吸收，为该部位的微环境 pH 调节发挥着一定的作用。首次提出黏膜下神经丛 5－HT_3 受

体参与结肠粘膜离子转运的抑制性调节。发现 6－OHDA 在黑质(SN)和消化道对 TH 和 DAT 免疫阳性细胞影响不同。提出了下丘脑的室旁核(PVN)和下丘脑的外侧区(LHA)在胃缺血—再灌注损伤中的作用,阐明了电刺激 PVN 对胃黏膜缺血—再灌注损伤具有显著保护作用的细胞分子机制。提出了牵张刺激可以通过毒蕈碱受体、Cajal 间质细胞膜电位去极化参与牵张引起平滑肌收缩过程。证实了心房利尿钠肽(ANP)、NO、缩宫素受体(OTR)等调控胃肠平滑肌运动。提出了小肠传入神经按电生理学特征可区分为低阈值,高阈值和广泛动力三种类型。发现了 TRPV1、SST2、ASICs、TRPM8 和 TRPA1 等是肠道传入神经重要的信号转导蛋白。

7.运动生理

提出 NO 诱导的线粒体生物合成的一个重要内容是新产生的线粒体有能力与呼吸偶联,并导致 ATP 通过氧化磷酸化路径生成。证明损伤后骨骼肌的组织和形态学变化主要发生在肌浆膜、收缩蛋白和结构蛋白三方面。发现骨骼肌微损伤的同时也伴随着力的损失;成肌调节因子在运动及低氧导致的骨骼肌损伤及修复中起着重要作用。探讨了中药组分促进损伤骨骼肌愈合的作用及其相关机制。发现丝裂素活化蛋白激酶在运动性心肌肥大中重要的信号介导作用。发现不同强度运动训练可使心脏功能、胆碱能神经和 M2 受体发生不同程度的改变,适宜运动训练可以降低心理应激反应程度。发现体质水平与人体适应能力之间存在低度正相关关系、太极拳锻炼对地震灾后老年人的身心康复具有较显著的效果等。

在奥运会重点项目上,进行运动体能监测和训练方法评价领域进一步扩大、方法多样、评价科学。发现力量训练与场地训练两种手段有叠加作用,力量训练课较场地训练对肌肉的刺激更大。提出了机体核心力量的新见解。发现训练负荷周的血清 CK 和 BU 平均值与调整周相比有不同的特点。

8.中西医结合基础(生理)学科

建立了基于人体生理、病理指标数字化、量化技术中医健康状态识别平台,创立了针对人体整体功能状态对人群进行分类辨识的方法,并已在国内得到较广泛的应用,实现了对中医体质分类的计算机辅助诊断及可视化模拟。开展了中医四诊研究,形成了获 sFDA 批准的专业中医诊断设备——便携式四诊合参辅助诊疗仪。通过人体和动物试验,模拟出包括涩脉在内的迟、数、滑、弦、洪、浮、沉等十几种脉象,建立了脉诊教学模型。探讨了中药在脐部神阙穴、脚心涌泉穴经皮给药疗效的机制和适应证。开展了中药微乳载药体系关键技术及中药方剂配伍规律研究。创建并应用“优化拆方—数据挖掘—知识发现”(OD－DM－KD)模式,从整体角度阐释了中药复方中君臣佐使、类方差异、药味药量与药效关系以及药性理论的配伍规律。研发了多种突破传统组方的新药组方。依据中医理论研发了有效的心肌细胞保存液。

9.应用生理与比较生理

极端温度生理提出并初步证明了中暑的炎症因子风暴假说,研发了针对性的防护药物。提出了血管内皮细胞是低温损伤靶点的观点并研发了药物。极地生理系统观察了南极考察队员越冬时神经内分泌的变化。水下生理深入开展了减压理论、减压病发病机制、

不同类型潜水生理变化的理论与技术的研究，实现了国际一流的 480m 的深潜模拟训练。航空生理在高 G、爆炸性减压、噪声、热负荷、冲击力、眩光失能等方面开展了大量工作，对国产新型战机研发与航母舰载机飞行员训练意义重大。航天生理在失重心血管、骨骼、肌肉生理、晕动病、脑功能、＋Gx 作用等方面开展了广泛研究，为载人航天、出舱活动和 MARS500 等提供了医学支持，正在开展长期在轨飞行相关研究。高原生理方面的自然基金重大项目和“973”项目均以“优秀”结题，在低氧适应的多途径诱导与多方向转归方面有了一系列发现，有关藏族低氧适应基因的研究发表在《科学》；系列干预措施在青藏铁路、援藏干部保障、玉树地震等高原地区重大需求方面发挥了作用。

（二）学科建设工作

1. 教学工作

中国生理学会一贯注重生理学的教学工作，于 2002 年设立教育工作委员会，负责组织全国性的生理学教学研讨工作，推进生理学教学工作的发展。教育工作委员会以每两年一次的频率连续举办全国性学术交流。主要集中在生理学理论课教学内容和教学方法的探讨、国外生理学教学和教材的介绍与比较、生理学双语教学的探讨、PBL（problem based learning）教学法、精品课程建设、生理学多媒体课件的建设和生理学教学仪器的发展等方面。学会重视了生理学教材的编写和出版，目前。国内生理学教材大都由中国生理学会会员主编。最近还组织翻译出版了《Berne & Levy 生理学原理》。展望生理学教学和教学研究的发展，将来的主要方向是如何搞好精品课程、双语教学；同时，要结合目前电子化和网络化教学的发展，加强生理学课程的网站建设。

2. 学会工作

中国生理学会努力推动学术交流、继续教育、科普等诸项工作，促进学科发展。“走向国际”是近年来学会提出方向和目标。为促进学术交流，学会召开了 40 余个学术会议，并在比较生理、体育生理、基因进化、神经科学等方面组织了国际会议。2008 北京国际生理学学术大会有 35 个不同国家及地区近 700 人参加，取得了圆满成功。学会重视组织中国学者出国参会，如 IUPS 第 37 届的与会中国生理学工作者达到 170 余人，我国学者还当选为 IUPS 副主席。

人才培养上，张锡钧青年基金评选、青年工作委员会等均为生理学会首先开展并为多个兄弟学会效仿；在院士候选人、创新群体推荐等高端人才选拔上也做出了努力。积极推动学术期刊的运行，其中《生理学报》荣获“新中国 60 年有影响力的期刊”称号。

三、本学科在经济建设、产业发展和国防建设中的重大应用

生理学是一门基础性的学科，多年来在医学生物学教育与人才培养方面做了大量的工作，特别是全国 200 多所医学院校均有生理教学的任务。可以说，生理学教育是我国医学生物学大厦的重要基石。

不仅如此，在生理学学科中偏重应用研究的领域，如运动生理、中医生理和应用与比较生理不仅加强了基础研究，还重视了满足国家重大需求方面的工作。运动生理工作者

在多年的全民健康运动和我国成为体育大国的征程中发挥了重要的作用。特别在2008北京奥运会的准备、实施中为我国体育健儿提供了巨大的科技支持，为奥运火炬珠峰传递提供了医学保障，为扬我国威做出了贡献。中医生理工作者多年来在国民健康保障方面做了大量的工作，在我国人均预期寿命不断增长、中华民族彻底摘掉“东亚病夫”的帽子方面起到了重要的作用。现在又抓住“人口与健康2020规划”提出前移下移战略的机遇，积极研发贴近实际、贴近社区的医疗与保健设备和训练方案，进一步发挥更大的作用。

我国的应用生理与比较生理在国防建设和经济建设方面，在高原医学、极地医学、航天医学、航海医学、航空医学、劳动作业医学等领域，紧密结合我国实际，为我国在这些领域冲击世界先进行列保驾护航。如青藏铁路、玉树地震救援、南极DOME A观测、480米模拟深潜、新型战机、航母、长期载人航天等计划的实施，都对生理学提出了新的挑战。作为医学生物学的重要基础学科，中国生理学必将在我国的国防建设、经济建设和人民健康保障中继续发挥重要的作用。

四、本学科国内外研究比较

生理学作为一门经典的学科有着悠久的历史，在现代医学与现代生物学的发展中起到了不可磨灭的作用。近些年分子、细胞水平研究的深入以及系统科学学术思想、方法论及技术的引入，又为生理学的发展注入了新的生机。

就目前而言，我国生理学研究在整体上与国际研究基本保持同步发展。在循环、生殖和神经等我国传统的优势领域中，部分研究成果进入到了国际领先或先进行列。在比较生理、运动生理和环境生理等方面，由于国家需求，近年来发展较快。在个别拥有特色资源的方向上，已在国际同领域达到领先水平。

五、本学科发展趋势及展望

从今后的战略需求、研究方向的分析，可以看出有以下机遇与挑战。

(一)各种组学发展带来的机遇

随着各种组学的发展，产生了海量信息。但是，如果不能阐明这些分子事件的功能意义，所有的信息只能变为尘封的资料。因此，生理学面临着巨大的机遇，需要突破以往的技术方法，采用高通量技术发掘有用的资料。

(二)整合生物学对生理学的挑战

随着人们对生物体多层次、多方位的深入认识，有可能在研究模式上改变多个世纪以来的还原论方式，全方位地从整体上认识生命的本质。而生物体的两个基本方面——形态(组织解剖)和功能(生理)，无疑后者将面临更大的挑战。今后的发展不仅需要技术的不断更新，更需要创新的研究模式。

(三)转化医学对生理学的需求

历史上，生理学在现代医学与现代生物学的发展中起到了不可磨灭的作用。生理学

是医学之母，同时生理学又是正常与疾病中间的桥梁、转化医学的 B to B、重大新药创制的新靶点、人们健康保障的前移下移等等新的理念，都需要生理学的发展给予保障。

如果在国家已经制定的中长期发展规划(2020 年)基础上讨论生理学学科发展目标、前景和在我国未来的发展趋势，大体上可以用一句话表述：我国生理学今后发展的关键是如何实现顶天立地。即在科学前沿上引入高技术、新思维，形成能够在国际上一定范围内起到引领作用的工作，并在国际生命领域高端刊物上发表(顶天)；同时，紧密结合国家需求、发现需求、创造需求、引领需求、满足需求，为国家的经济、国防建设和产业化发展起到推动作用(立地)。

特别是在国际生物医学强调“转化医学”的今天，生理学作为基础研究和临床医学的重要桥梁，必将发挥更大的作用，迎来第二个学科发展的春天。

第二十节　药 理 学

一、引　言

药理学是生命科学领域中的一门重要学科，是连接药学和医学、基础医学和临床医学、基础科学与应用科学、生命科学与化学以及其他多学科与医药科学的桥梁学科，药理学科的发展与医学科学的进步、药学科学的发展和人类防病治病维护健康的关系密切，与社会发展和经济建设密切相关，在现代科学进步和社会发展中发挥着重要作用。

中国药理学学科经过历代药理学家的艰苦努力，从无到有，从小到大，不断发展进步，成为医药科学领域的重要学科，不仅促进了我国临床医学、制药工业、生命科学的发展，而且在国际上产生了重要的影响。

我国药理学发展的重要标志之一是 2006 年第十五届世界药理学大会在北京成功举行，让全世界药理学工作者认识了中国药理学的成就。这次大会的圆满成功，促进了我国药理学界与国际药理学界的交流，全面提高了我国药理学会和药理学家在国际学术领域的地位和声誉，为我国药理学的持续稳定发展奠定了新的基础。

药理学研究的内容非常广泛，归纳起来主要有两个方面：一是药物对机体的作用，即药物效应动力学；二是机体对药物的作用，即药物代谢动力学。但由于药物种类繁多和作用的复杂性，实际研究的内容是非常广泛的。这两个主要方面的内容是认识药物作用和作用机理的关键。通过这两个方面的研究，可促进药理学的发展和进步，完成药理学发展的任务。

药理学科是基础科学与应用科学的桥梁科学，社会的需求是药理学学科发展的动力，我国药理学能够在不同的时期取得进步和发展，与我国药理学家将社会需求融入药理学研究密切相关，正是由于药理学的研究任务适应了社会需求，才促进了学科的发展。

药理学学科发展的任务是与社会的需求不可分割的，主要表现在以下三个方面。

(1)药理学学科发展的任务之一是认识药物作用机理，指导临床合理用药。通过研究药物作用的机制和特点，评价药物作用的效果和安全性，指导临床合理用药，充分发挥药

物的药理作用，从而达到最佳治疗效果是药理学研究重要内容之一。药理学发展的水平，直接关系到临床用药的科学性和合理性，关系到临床医疗水平的提高。因此，药物的药理作用、作用机制、不良反应的研究与实验治疗学的研究是重要的研究内容。

(2)药理学科发展的任务之二是新药发现和新药作用评价，开发新型药物。新药发现和新药研发是药理学研究另一重要内容。采用药理学研究的技术方法，评价可以作为药用的物质，发现新的具有药理作用的药用物质，是新药发现的重要途径之一；根据研究认识的药理学知识和药物作用机制，形成疾病治疗的药物作用新策略，通过筛选能够影响药物作用靶点的物质，发现新的具有药理作用的药物，是现代药物发现的重要策略。在新药发现的基础上，对发现的具有药理作用的物质进行系统的药物作用机制、药物体内过程和药物安全性的评价，进行药物的临床前研究，为新药的临床研究和应用提供实验依据。

(3)药理学科发展的任务之三是探索生命科学的机制，促进生命科学发展。药理学是生命科学的重要组成部分，通过药理学的研究，发现人类生命过程中的重要生理病理机制，提高对生命过程的认识，促进生命科学的发展。药理学发展的历史证明，大量对生命活动的机制认识，是在药理学研究过程中发现的，利用药理学多学科交叉的优势，可以深入认识人类生命过程。

二、近两年本学科最新研究进展

(一)总体进展概况

随着我国经济建设的发展和社会的进步，我国对人民健康极为重视。由于药物引起的不良反应和不良事件频繁发生，使人们更加重视药物的应用；医药卫生体制的改革方案的启动，对临床合理、科学、安全的应用药物提出了新的要求；药物在经济建设的重要作用，促进了我国对生物医药产业的重视；特别是国家科技重大专项“重大新药创制”的启动，推动了我国创新药物的研究，新药发现、新药临床前研究以及药物的临床研究，都是药理学研究的核心内容。上述因素的存在，为我国药理学发展提供了有利条件，同时也为药理学的发展发挥了重要的促进作用。

围绕药物靶点和药物作用机制开展的基础研究取得重要进步。最近两年中，我国药理学家紧紧围绕药物作用相关的药物靶点进行了药物靶点的发现和确证研究工作，发现了一些具有药物靶点特征的功能蛋白质，围绕一批具有良好表现的生物大分子进行了深入研究，证明了一些生物大分子作为药物靶点的可能性。此外对于药物作用机制进行了比较深入的研究，提出了疾病过程中药物多靶点相互作用和药物治疗作用的多靶点模式，为新药的发现和开发提出了新的思路和策略，不仅有利于我国新药的研发，而且有利于指导临床用药。

围绕临床药物治疗学进行的临床药理学研究、新药临床评价研究、药物相互作用研究和药物不良反应研究均取得积极进展，针对药物作用和我国人群的特点，开展了基因组药理学研究，为我国人民科学合理用药奠定了实验和理论基础。围绕我国新药研究发展的现状，临床药理学的研究得到快速发展，不仅研究能力和条件有了大幅提高，而且一些研究已经达到国际先进水平；药物的临床合理应用和药物治疗学研究逐渐受到重视，具有重

要临床使用价值的研究成果不断出现。

围绕新药发现和新药研发开展的临床药理学研究在国家重大科技专项的带动下，发展迅速，新理论、新技术、新方法不断出现，形成了药理学研究的新的高潮。围绕新药的药物评价模型研究、药物作用机制研究、新的药物作用理论和药物安全性评价等方面，开展了大量的研究并取得重要进展。我国在新药发现、新药药效评价和安全性研究方面均取得积极进展，药物代谢研究在技术水平和创新能力上有了大幅提高，尤其是对一些具有显著特点的药物代谢评价，如晶型药物、生物技术药物以及新型制剂的药物，都取得重大进展，达到国际先进水平并逐渐与国际标准接轨。

中药药理学发展迅速，为传统药物的现代化研究、临床合理用药和新药开发提供了重要的实验基础，为传统药物的开发利用提供了技术方法和科学理论的支撑。针对中药注射剂开展的安全性研究，为中药注射剂的合理应用提供了实验基础；在国家自然科学基金委支持下进行的中药复方代谢研究，在代谢机制、相互作用、多成分代谢特点和方法学方面均取得进展；中药与系统生物学、基因组学、代谢组学和蛋白质组学的结合，扩展了中药尤其是中药复方研究的思路；中药作用的理论研究和应用研究有了密切结合，使新的理论和药物研发同步前进，组分中药、有效成分组等新的概念和相关药物研究均取得重要进展。

(二)中国药理学分支学科发展

1. 神经精神药理学

神经精神药理学是一门跨学科的科学，涉及神经药理学、精神药理学以及基础神经科学，研究的范畴包括神经传递/受体活动、中枢生物化学过程、神经环路、药物怎样影响脑的功能和心理活动等。神经精神药理学的发展直接影响到对焦虑、情感性疾病、神经退行性疾病、摄食、睡眠、药物依赖性及成瘾等的研究和相关疾病、症状的治疗。

近年来，基因组学、蛋白质组学、神经干细胞、RNA 干扰、基因治疗等的发展，促进了在疾病网络机制这个更高层次上对神经精神系统疾病发病机制的研究，从多个靶点影响疾病过程的网络药理学应运而生，由此思路研发的药物将有可能提高对神经精神系统疾病的治疗效果。神经干细胞、广义的基因治疗等技术方法则可能对一些实质损害性神经精神疾病的治疗起到革命性的作用。

2. 心血管药理学

针对我国心血管病发病和防控现状，心血管药理学的研究对于防治心血管疾病发挥了积极作用，实施“从实验至临床至社区”的转化医学理念，积极宣传心血管疾病的预防措施和理念，提高预防心血管疾病的认识。围绕明确的目标组成多学科团队，形成协作体，顺应了当前学术发展趋势，体现了多学科交叉的需求。

哈尔滨医科大学药理实验室近年来在小 RNA 与心肌缺血、心律失常研究方面取得重大进展：①发现微小 RNA 是调控心律失常的重要靶点，并揭示了该靶点的作用及机制，*Nature Medicine* 杂志同期发表评述认为该研究“为心源性猝死患者的防治研究带来希望”；②发现微小 RNA－1 和微小 RNA－133 是调控心肌细胞凋亡和心肌保护的靶点，

二者对心肌细胞凋亡的作用截然相反；③提出微小 RNA 多靶点沉默技术，该技术通过组合多个微小 RNA 反义寡核苷酸于一体而起到多个微小 RNA 沉默的作用；④发现了微小 RNA 是传统的 β 受体阻滞剂防治心源性猝死的新靶点，并明确了普萘洛尔调节 microRNA－1 的信号通路；⑤通过离体、在体动物实验和临床观察最终确定微小核苷酸－328 为心房颤动发生的关键调控分子，从微小核苷酸分子水平上阐明心房颤动的发生机制，寻找到治疗房颤的新靶点，并为心脏疾病的预防、诊断、治疗以及生物医药产业的发展起到积极推动作用。

3. 肿瘤药理学

目前，恶性肿瘤是当今世界严重威胁人类生命健康的常见疾病之一，且发病率逐年上升。随着人们对肿瘤发生机制越来越深入的研究与探索、各学科间知识与技术的交叉和融汇以及新技术新理论的引入与应用，近年来人们对抗肿瘤药物的研究思路也不断地发生着新的变化。利用现代药理学技术及方法，结合肿瘤分子生物学的基本理论知识，从传统的筛选药物到定向筛选、从全身化疗到局部靶向化疗、从细胞毒药物杀伤肿瘤细胞到基因治疗诱导其逆转、从整体治疗到生物治疗，越来越多的新型抗肿瘤药物陆续出现。近来尤以肿瘤的生物治疗备受人们的关注。肿瘤的生物治疗研究范围非常广泛，主要包括基因治疗、靶向治疗（蛋白酪氨酸激酶抑制剂等）、免疫治疗（过继免疫治疗、疫苗治疗、抗体治疗、细胞因子治疗等）、抗血管生成治疗、诱导细胞分化及凋亡治疗等。

4. 临床药理学

临床药理学是研究药物与人体相互作用及其规律的一门学科，是医学和药学密切结合的重要学科。我国临床药理学在教材、期刊、基地建设和临床药理学专业人才的培养以及新药的临床研究、创新药物平台建设等方面取得了明显成绩，尤其是近年来在新药临床研究的科学性、规范性等方面不断完善，水平不断提高，为推动我国新药创制做出了重要贡献。在遗传药理学和药物基因组学、临床合理用药和个体化用药、药物不良反应监测、临床药效和不良反应的机制研究等方面也做出了显著成绩，产生了明显影响。积极加强国内外学术交流，中国药理学会临床药理学专业委员会自 20 世纪 80 年代初至今已召开了 12 次全国性学术大会，并积极参加国际学术会议，大力开展国际学术交流和人才培养，为推动我国临床药理学的发展发挥了重要作用。

5. 中药药理学

中药药理学是药理学的一个分支学科，是中医药走向世界的重要学科，也是新药发现和创制的重要学科。许多新药如麻黄素、黄连素、青蒿素等，就是通过中药药理研究从中药中发掘出来的。2009 年中国药科大学研究项目“基于中医药特点的中药体内外药效物质组生物/化学集成表征新方法”获得国家科技进步二等奖。近五年来一些中药研究取得了重要的进展，如复方青黛片及砒石、雄黄所含的三氧化二砷治疗急性早幼粒细胞白血病的分子机制；复方丹参滴丸、丹参及其成分丹酚酸抗心脑缺血；人参及人参皂苷 Rg1 防治应激智力及性行为低下；六味地黄汤调药免疫功能，炙甘草汤抗心肌触发活动。中药药动学、中药毒理学正在兴起，对雷公藤、关木通等中药的毒性研究也已引起高度重视。

6. 数学药理学

数学药理学(又称定量药理学)是运用数学手段定量研究药理作用规律的一门分支学科。近年来,该学科发展迅速,国内学者做了大量工作,在药代动力学和药效动力学定量研究、药动学—药效学模型、群体药动学—药效学、临床试验模拟及计算机仿真技术、中药定量药理学、定量药理软件编制等领域取得了很多重要研究成果,解决了大量基础药理学、临床药物治疗、新药研发中的实际问题,推动了相关学科的发展。

7. 抗炎免疫药理学

抗炎免疫药理学学科是我国创立,经过近 30 年的发展,已成为一门较完善的、具有推动理论和应用研究重大意义的新的专门学科。近年来,抗炎免疫药理学工作者大力开展研究,在以下四方面取得了明显进展:①炎症免疫病的发病机制研究;②抗炎免疫药物的作用和机制研究、应用研究以及成果转化;③新型免疫治疗方法研究;④抗炎免疫药理学新技术和新方法研究等。

8. 生化与分子药理学

生化和分子药理学学科是药理学的一个重要分支。20 世纪 40 年代,该学科还只在整体、器官和组织的水平上研究药物与机体相互作用。随着生物化学和分子生物学等新理论、新技术的融入,生化和分子药理学得到了迅速发展,神经递质、受体、多肽、酶、代谢等的研究取得了可喜的成果,药物作用机理的研究也深入到分子水平,亦为新药设计提供了重要的依据。特别是受体学说,它诠释了细胞识别、接受和传递信息,产生药理作用和生命活动的机理,使原属于药理学的概念,或只被药理学家应用和发展的学说,成为现代生物医学科学的极为重要的带有根本意义的理论。近年来,现代生物学理论和技术的发展更是促进了生化和分子药理学的进步,在自身发展的同时,也促进了其他学科的发展。

9. 药物代谢药理学

药物代谢动力学是研究机体对药物的作用规律的学科。它应用动力学原理与数学模型,定量地描述药物在机体内的吸收、分布、代谢和排泄过程。在初期,药物代谢动力学研究主要集中在对已进入临床研究阶段的候选药物的体内药动学过程评价上,进入 20 世纪 90 年代之后,发达国家开始重视药动学研究在创新药物研发中的早期与长期介入。进入 21 世纪以来,药物代谢动力学更是得到飞速的发展:新型的体外及体内模型为研究药物在体内的转运机制提供了有效的手段;计算机模拟技术、药物基因组学、表观遗传学在药物代谢酶及转运体的结构及功能研究以及个体化用药研究等方面发挥了十分重要的作用。

10. 药检药理学

药检药理学是采用药理学的知识和技术方法,以药品质量控制为目的,开展药品有效性和安全性技术研究的学术领域,是药理学科中一支重要的技术力量,并为我国公众的用药安全起到了重要的技术保障。

11. 抗衰老与神经退行性疾病药理学

我国在天然药物、中药治疗帕金森病的研究方面取得了巨大的进展。中国医学科学

院药物研究所国家药物筛选中心在神经退行性疾病的研究中，围绕神经细胞保护和中枢神经递质平衡理论，筛选发现并研发了治疗帕金森病的国家1.1类化学新药百可利，目前已完成临床前研究，可有效缓解帕金森病人的震颤症状，而且副作用较小，有望成为新一代治疗帕金森病的新药物。

12.生殖药理学

生殖药理学是药理学和生殖医学的交叉学科，是药理学中探讨生殖系统药物作用机制及其作用规律性的一门重要分支学科。经过60年的发展，生殖药理学所涵盖的内容已不单纯局限于生育调节药药理，而是扩展到了生殖健康用药；其研究领域也从避孕药的研究，延伸到对生殖系统常见疾病及激素依赖性肿瘤药的药理研究。

三、本学科国内外研究进展比较

近年来我国药理学研究水平整体提高。基础理论研究和药物作用机制研究逐渐接近国际先进水平，有些研究成果一定程度上达到国际领先水平，学术论文数量快速增长，在世界上展示出中国药理学研究的学术地位。

特别是现代生物医学领域，国外已建立并应用的新技术新方法有基因修饰动物技术、表观遗传修饰及芯片技术、计算机虚拟筛选技术、模式生物斑马鱼毒性检测技术、干细胞毒性检测技术、毒理基因组学、蛋白质组学和代谢组学技术，并得到了广泛应用。我国在这方面处在探索与起步阶段，部分新技术已在应用于新药研发中。

我国新药研究的模式基本上遵循国际新药研发的策略和途径，但近年的发展现状使国际药物研究机构均认识到目前正面临着严重的困扰，传统成功的道路已经出现局限性并受到制约，新药研发正处在新的探索时期，引领国际新药研发方向的探索性研究已经成为药理学家面临的重要任务。

四、本学科发展趋势和展望

经过几代人数十年的努力，我国药理学发展到了新的阶段，也存在着新的机遇和挑战，在新的形势下，探索新的研究方向成为药理学研究重要任务。

首先基础科学研究需要加强创新。随着研究条件的改善和追赶国际水平的目标逐渐接近，在我国强化创新性研究成为我们面临的重要任务，也是药理学基础理论研究重要方向。

其次临床药理学研究亟待加强。由于多种因素的影响，药理学在临床用药中的指导作用亟待加强，尤其是针对临床用药所需的研究工作，急需深入广泛的研究，同时药理学知识的交流和传播，药理学教育（包括继续教育和再教育）亟待加强，药理学科普工作也需要进行认真的研究。

创新药物研究是长期的任务，新理论新方法是研究的重点。现代药学经过百余年的发展，已经进入新的调整时期，新理论新方法正在孕育之中，中国药理学家应该认真研究新药研发的趋势，探索引领国际新药研发方向的新的理论和策略。

中药研究需要交叉、融合、交流和整理。通过对研究成果的分析和整理，发现、肯定、推广已经形成的研究成果，形成系统的新的中药药理学理论，促进中药学和中药药理学的

全面发展。

在新时期，我国药理学家肩负着艰巨的任务，经过艰苦的创新性研究和广泛的合作，实现我国药理学的全面发展，使我国药理学研究符合药物发展的方向，在国际药学和药理学发展中，早日进入引领发展方向的先进行列。

第二十一节　麻风病学

一、引　言

麻风病是由麻风分枝杆菌引起的最古老的疾病之一，在世界范围内流行极广，在我国也有 2500 多年的流行史。医学界曾将麻风、梅毒、结核并列为世界三大慢性传染病，对人类的身心健康构成严重的威胁。为此，世界卫生组织将麻风病列为全球重点防治的疾病。

麻风病学是医学科学的一个重要分支，它涉及麻风的历史、病因、发病机制、传染与流行、临床表现、组织病理、免疫反应、检验技术、诊断方法、畸残康复与社会康复、防治措施、健康教育以及社会医学等诸多方面。至今，麻风病的传播途径尚未被最后确认，但普遍认为是在和未接受治疗并且有传染性的病人近距离频繁接触时，通过上呼吸道飞沫传播或破损皮肤黏膜的直接接触可能是麻风传播的最主要方式。自然人群中只有极少数易感者感染麻风菌后可以发病。麻风病发病隐匿、潜伏期长，主要临床特点是侵犯皮肤和周围神经。周围神经损害可导致不可逆性畸残，给患者及其家庭带来严重的精神和经济压力以及一系列的社会问题。因此麻风病不但是一个医学问题，也是一个社会问题，引起流行国家政府的高度重视，我国政府也将麻风病列为重点救治的疾病。

二、本学科发展现状

20 世纪 80 年代初，全球估计有麻风患者 1200 万，随着联合化疗的推广和应用，麻风病的流行得到了有效遏制，患病率有了大幅度下降。为了激励全球各国共同努力，WHO 提出要在 20 世纪末全球在国家水平将麻风作为公共卫生问题加以消除，即将患病率控制在 1/1 万以下。其基本理论是——人是麻风杆菌唯一的宿主，联合化疗可以迅速杀灭人体内的致病菌，当麻风病患病率控制在 1/1 万以下时，便会自然中断传播链，最终逐渐自行消亡，而不会有大规模流行的危险。经过世界各国近 30 年的努力，麻风患病率下降了 90%，取得了巨大成效。尽管如此，从现已报告的流行状况来看，麻风病仍在不少国家和地区中流行。2009 年全球 141 个国家和地区共报告了 244796 名新发病人，主要集中在东南亚、非洲、大多数中东国家、中南美洲和西太平洋区。其中以东南亚流行最为严重，患病率为 9.31/10 万人。

新中国成立以来，经过几十年的努力我国麻风防治取得了巨大成绩，全国麻风流行区域缩小，患病率和发现率（发病率）均下降了 95%以上，并在 1998 年以省为单位，达到了世界卫生组织“基本消灭麻风病”的目标。近十几年来每年新报告病例数维持在 1600 例左右。但我国麻风的流行不平衡，到 2010 年底全国尚有 279 个县尚未达到中国（患病率

≤1/10 万)基本消灭指标,其中 46 个县尚未达到 WHO(患病率≤1/1 万)基本消灭指标。大多数分布在云、贵、川、藏、湘等西部和边疆少数民族地区。为了加速我国麻风控制规划的实现,中央不断加大了对高流行地区的支持力度,开展了麻风消除运动。这不仅最大限度发现了潜在病人、减少了传染源,还提高了高、中流行地区政府的重视程度,普及了麻风病科普知识,降低了社会对麻风患者的歧视,创造了社会关爱麻风患者的氛围。

自 2004 年以来,中央通过转移支付资金项目以及实施《"十一五"麻风防治规划(2006—2010)》,对加速消灭麻风进程和麻风防治可持续发展发挥了重要作用。但因至今麻风防治没有一级预防疫苗,麻风病不可能在预期的时间内完全消灭。

早发现、早治疗是麻风防治的重要策略。过度诊断会给患者带来巨大的精神压力,误诊和漏诊不仅会使传染源持续存在,而且会延长病期、增加患者发生周围神经损害导致畸残的危险性。尽管近年来在麻风病的血清学试验和生物学分子诊断方面有了一些进展,但目前仍然主要依靠临床麻木性皮损、周围神经粗大/损害和皮肤查菌三大主征确诊麻风病人。皮肤感觉检查有很强的主观性,早期瘤型麻风和面部皮损感觉障碍往往不明显,部分病人可以没有周围神经粗大。皮肤组织液涂片抗酸菌检查需要质控。通常综合医疗机构缺乏麻风抗酸菌检查必需的试剂和技术。所有这些问题限制了这三大主征在麻风早期诊断中的应用价值。此外,部分病人由于社会歧视或缺乏对麻风病的认知等原因而延迟就医。以上因素综合作用的结果导致了我国麻风病人的诊断延迟期长和较高的畸残率。目前我国新发病人 WHOⅡ级畸残率在 20%以上(是全球 4%的 5 倍以上),部分低流行省份甚至高达 40%～50%,表明我国麻风早期诊断水平仍需提高。

20 世纪 80 年代,世界卫生组织推荐了治疗麻风的联合化疗方案,使得全球的麻风患病率大幅度下降,被称为麻风防治史上的一个里程碑,大大加速了全球控制麻风的步伐。为了在不增加复发危险的前提下,最大限度增加联合化疗的覆盖率和节约治疗成本、降低麻风防治负担,世界卫生组织提出将 2 年疗程进一步缩短疗程为 1 年,并逐渐在全球推广。2002 年 WHO 又试用统一联合化疗方案(不论多菌型和少菌型均应用 WHO 三联化疗治疗 6 个月)。初步结果显示,对大多数多菌型病人来说疗效与 2 年疗程方案大体相当,但对含菌量较高的少数病人仍需长期观察对复发率的影响。由于到目前为止,利福平是最重要的杀菌药物,保护利福平的有效性对麻风化疗至关重要,因此,全球正在合作开展对利福平的耐药监测。目前,从我国有限的检测来看,尚未发现利福平耐药菌株。

麻风病是一种复杂性疾病,不仅损害患者的躯体,而且也摧残患者的精神,并给患者及其家庭造成巨大的社会和经济影响。因此,麻风病的防治一方面要通过早发现、早治疗,终止传播链,控制麻风的流行;另一方面,还要对畸残者进行躯体的、精神的和社会的康复。我国 1990 年开始,通过与国际麻风救济会合作开展了麻风畸残防治项目,并在社会和经济康复方面进行了试点,取得了一些成效,丰富了我国麻风防治内涵和提升了防治水平。

三、本学科最新进展

(一)麻风控制指标的进展

鉴于麻风所致的周围神经损害对患者社会和经济的影响,2010 年 WHO 提出将新发

现病人中的Ⅱ级畸残率作为控制麻风的重要指标。到 2020 年在全球水平上将新发麻风病人中 WHO Ⅱ级畸残率降到 1/(100 万)，近期目标是到 2015 年将新发病人中 WHO II 级畸残率减少 35％，要求各麻风流行国家积极努力为实现这一目标做出贡献。同时，还要求在低流行状态下，保持麻风防治的可持续性和提高防治服务质量，保障麻风病人的人权以及减少对患者及其家庭造成的歧视。

我国“十一五麻风防治规划”已于 2010 年结束，基本达到了规划的要求，2010 年卫生部已组织专家编写了“中国消除麻风危害行动计划(2011－2020)”，着重强调了麻风病的早期发现和提高麻风服务质量。该规划的内容与 WHO 的要求相一致。随着 2011 年“中国消除麻风危害行动计划(2011－2020)”的实施，必将进一步提高我国麻风病的防治水平。

(二)麻风基础研究进展

自 1873 年挪威科学家 Hansen 发现了麻风病的病原体——麻风分枝杆菌以来，人们对麻风病的研究从未停止过。特别是近 5 年来，分子生物学的发展和人类基因组学数据库的完成，为麻风分子生物学和分子遗传学等方面的研究提供了平台，也取得了一些重大进展。如利用麻风菌基因组学，揭示了麻风菌株间基因序列的差异很小、相对稳定，麻风菌在进化中处于退化状态，对简明麻风菌严格的细胞内寄生性和临床较长的潜伏期提供了理论依据。从麻风菌基因组中确立的麻风菌株分型标记物已成为麻风分子流行病学研究的工具。麻风研究的另一个重要进展是运用麻风菌基因组学建立了包括利福平在内的耐药菌株检测，与传统的鼠足垫接种相比，具有操作简便、快速和低成本的优点，现已成为检测麻风耐药菌株突变的主要手段。

从理论上推测，基因型一致或高度相似的菌株，被认为是来自同一个传播链或同一传染源；如果在特定地区内，基因型一致的菌株在近期内不断出现，提示传播仍在进行。结合病原菌基因系统进化与其它信息的分析，有助于了解疾病的传播，如菌株基因型是否与地理分布相关，即是否应比地理位置距离远的菌株关系更密切等。近年来，麻风菌株基因分型，揭示了许多有益的信息。中国科学家对来自西南、华中、华东、华南的 130 个麻风菌株，经 18 个位点的 VNTR 与 SNP 分型研究发现：我国西南、中原等地菌株基因型相似。但我国华东菌株与日本菌株一致，华南菌株与东南亚国家一致，提示我国沿海地区麻风菌传播与海上贸易或“海上丝绸之路”有关，而“丝绸之路”对西南等地的传播有影响，这为研究麻风病在中国与全球的传播史提供了佐证。

对麻风易感性的研究也是目前全球麻风研究的热点之一。麻风菌具有高感染低发病的特点，感染麻风菌后是否发病，发病后呈现何种表型均与宿主对麻风菌的免疫反应有关。但麻风病的易感基因定位一直是困扰着这一领域研究的难题，随着全基因组关联分析技术的应用，我国科学家开展了国内外大合作，成功地在 706 名麻风个体和 1225 名正常对照中发现了位于 6 号染色体 MHC 区域上的 7 个麻风易感基因，其中 6 个基因构成了一个固有免疫通道，很好地解释了麻风病发病的两阶段学说。该研究不仅使我国在该领域的研究处于国际领先地位，而且为今后国际合作和阐明麻风病的发病机理及相关研究，如麻风基因型和表型间的关系、麻风反应和神经炎等的易感性，提供了新的研究思路。

(三)麻风防治策略进展

随着麻风流行的控制,很多国家和地区已处于低流行状态,但仍需要维持一个有效的麻风防治体系,以满足麻风防治项目和新发及畸残病人的需求。从长远角度出发,将麻风防治纳入综合卫生服务体系(简称一体化),不仅可体现对麻风患者服务的均等化和使麻风防治更具有可持续性,而且有助于消除麻风歧视和节约防治成本。这种服务体系应包括:①易于获得;②提供联合化疗;③处理麻风并发症和药物不良反应;④提供畸残防治和重症病人的处理;⑤根据麻风防治的需要,在一定水平上建立有效的转诊系统和专业服务,为基层防治提供技术支持;⑥对大众进行麻风知识的宣传和健康促进,降低社会对麻风病人的歧视,并对基层医务人员进行基本知识培训,以提高早期诊断能力。

我国麻风防治一体化进展缓慢,虽然做了一些尝试、取得了一些经验,但麻风防治一体化是一个极为复杂的过程,运行良好的卫生服务网络和足够的政府投入是两个基本条件。当前,我国卫生体制正处于转型期,政府对公共卫生服务的投入仍然不足,一体化的进程不可能在短时期内完成。

自 20 世纪 90 年代以来,我国通过与国际组织合作,开展了麻风畸残防治项目,逐渐引进了现代麻风畸残防治和社会经济康复的概念,通过试点取得了一定的成效和培养了一批骨干,为麻风病的综合防治奠定了一定基础。但也应看到我国的麻风防治仍然主要停留在以控制麻风流行为主要目标上,麻风的问题还远远没有解决,现有的麻风防治理念和能力还远远不能满足麻风防治工作和任务的要求,麻风防治水平和麻风防治质量需要进一步提高;即使在低流行状态下,潜在和新发的病人仍需要早期发现,神经炎和麻风反应需要监测和处理,已发生畸残者需要采取以自我护理为重要内容的畸残防治和社会及经济的康复,残老病人(很多是无家可归或有家不能归者)需要社会的关爱、照料和赡养。因此,麻风病防治项目是综合性的、可持续性的,而且对目标人群是有实际意义的。

四、发展趋势和展望

麻风病的复杂性决定了麻风防治任务的长期性和艰巨性。在策略上首先要明确麻风病防治是公共卫生体系的组成部分,是政府的职责,要出台相关政策、落实各项防治经费。要将麻风防治提高到关爱弱势群体,体现社会文明、社会公平和卫生服务均等化的高度。

在制定麻风防治规划和计划时,要综合考虑麻风防治的工作任务和内容,使之与社会和经济发展的水平保持一致,要与社会保障体制的不断完善相一致。要充分利用社会、经济和卫生发展相关政策和成果为麻风防治服务。要将麻风防治与大公共卫生和综合医疗服务相结合,充分利用大公共卫生和综合医疗服务的平台,如信息平台、宣传平台、健康教育和健康促进平台等,逐步推进我国麻风防治一体化进程。这不仅可提高麻风防治的效益、节约成本,也可减少歧视。

麻风防治要纳入法制轨道,尽快修订我国“麻风病防治管理条例”或“麻风病防治管理办法”,做到依法防治。要加强麻风学科建设和人才队伍的培养,多学科交叉培养麻风防治人才,不断提高麻风防治人员的专业技能,以适应和满足麻风防治工作的需要。培训要重实效,特别是骨干人员的培训要加强。

在科研方面要加强以下领域的研究：①利用麻风菌基因分型分子生物学工具监测耐药和阐明麻风病的流行规律；②建立和改进麻风血清学诊断试验，提高诊断的敏感性和特异性，为现场麻风早诊断提供可靠工具；③继续提高麻风联合化疗疗效和缩短疗程，开发新的抗麻风药物和研究新方案，寻找新的免疫调节剂以有效治疗麻风反应；④通过研究神经损害的分子学、细胞学和免疫病理学，为畸残预防和神经损害的治疗提供新方法；⑤研究麻风化学和免疫预防方法；⑥通过对防控和流行病学等方面的应用性研究，改进麻风防治服务的可持续性和提高服务质量；⑦在消除麻风歧视、强化全民健康教育和健康促进作用，以及增强麻风患者回归社会的能力等方面的研究，对麻风的防治也是至关重要的。

麻风防治不仅要与公共卫生服务和综合医疗卫生服务相结合，也要充分利用公共卫生服务的政策和资源。改革开放以来，我国社会和经济发展迅速，党和政府高度关注民生和重视公共事业的发展，这是我国麻风防治难得的机遇。在新时期里，我们要明确发展定位、理顺思路，加强麻风防治学科建设，寻找症结、提出对策，总结几十年来我国麻风防治的成功经验，加强国内外多学科的广泛合作，开创我国麻风防治的新局面。

总之，通过几十年的艰苦努力，我国麻风防治事业取得了巨大成绩，但我们也要清醒地认识到，麻风病的问题还远远没有解决。如何在低流行状态下使麻风防治具有可持续性，如何通过提高和改善麻风防治的服务质量，以不断满足麻风病患者的需求，仍然具有很大的挑战性，麻风防治的任务还任重而道远。

第二十二节　毒 理 学

一、引　言

毒理学是研究外源化学、物理及生物因素对生物体和环境生态系统的损害效应及其作用机制，以及预防、救治或改善措施的综合性学科。它具有多元与集成、学术研究与管理服务、基础与应用并重的学科特点。进入 21 世纪以来，毒理学已成为维护环境友好与生态平衡、保障人们生命安全与健康生活、促进经济可持续发展、推动社会文明进步的重要科技力量。

二、本学科的发展概况

毒理学与中医药学一样，在中国有着久远的发展历史。早在炎帝时代，就有“神农尝百草，一日而遇七十毒”的记载。我国现代毒理学是从 20 世纪 50 年代起步，90 年代中期至今是我国毒理学的快速发展期。随着我国公共卫生体系的构建和完善、环境保护与生态平衡的维护，对毒理学科学技术的需求不断增加，也使毒理学学科发展面临更大的机遇。近年毒理学学科的发展，涌现出毒理基因组学、毒物代谢组学、毒代动力学、纳米毒理学等一批新的技术理论和分支学科，目前我国毒理学学科体系已基本形成。

毒理学作为一门独立的学科，其内涵有三大领域，即描述毒理学、机制毒理学和管理毒理学。目前我国毒理学学科的分支体系日趋完善，并已发展和形成了许多分支学科，这

些分支学科大体可从两个方面来进行划分：①从学科分支分类，包括生化与分子毒理、免疫毒理、生殖毒理、遗传毒理、环境与生态毒理、分析毒理、临床毒理、管理毒理等；②从研究或应用对象分类，如工业毒理、放射毒理、军事毒理、法医毒理、药物毒理、食品毒理、兽医药毒理、药物依赖毒理、纳米与新型材料毒理、生物毒素毒理、中毒与救治等。

近几年来，我国毒理学科技实力快速增长，毒理学科研、教学和管理队伍规模不断扩大，高层次科技人才不断涌现。随着国家对毒理学领域科研投入的增加，我国毒理学科技创新能力得到大幅提升，一方面毒理学的基础研究水平和国际影响力稳步上升，另一方面包括环境污染物、各类生活日用产品中残留物的分析检测和安全性评价等毒理学应用性技术平台建设也得到快速发展。毒理学科技成果在外源环境污染物、工业与农业化学品、药品、食品、化妆品、健康相关产品、新型材料如纳米材料等的安全性评价和危险度管理诸多方面发挥了不可替代的作用。特别是近年来，毒理学知识和科学技术在核、化、生突发事件的应急处置和医学救治，在北京奥运会和上海世博会等重大社会公共活动的安全保障，在履行国际公约、禁毒，在处理日本遗留化学武器、集体中毒、环境污染等重大事件中，发挥了关键性作用。在未来涉及国家安全、经济发展战略、人类健康事业和社会和谐稳定等很多重大问题上，毒理学科技力量将会发挥更大的作用。

三、近年来本学科的主要进展和成就

(一)毒理学基础研究进展

随着国家对毒理学领域科研投入的增长，我国毒理学基础研究水平不断提升，在国际学术刊物发表论文数量逐年攀升，年发表 SCI 论文已接近 400 篇，并且学术论文质量也在不断提高，国际影响力逐渐扩大。

1. 靶器官毒性机理

近年来，在对一些重要工业毒物、环境污染物、食品污染物以及生物制剂、中西药物、新材料等的靶器官毒性研究中，既采用了传统的体内和体外实验模型与方法，也适时引进或建立了一系列先进的靶器官毒理学研究模型与技术方法，比较准确地描述了外源化学物对整体动物或体外原代培养组织细胞的靶器官毒作用的性质、强度、可逆性及机制，为各类受试品危险度评价积累了大量的基础数据和科学依据。

2. 环境内分泌干扰物

日益增多的研究资料表明，人类多种生殖系统疾病与外源化学物(或药物)有关。国内学者采用体外与整体动物实验相结合、实验室研究与人群队列研究相结合，系统阐述了包括多种农药、杀虫剂在内的多个内分泌干扰物的生殖毒性特点和相关机理；证明环境内分泌干扰物(EDCs)，尤其是一些持久性有机污染物，可导致性分化异常、生殖道畸形、生精障碍、性功能异常、死(畸)胎和自然流产、恶性肿瘤、多囊卵巢综合征和出生缺陷等，为生殖毒性危险度评价和人群干预措施研究提供了重要理论依据。

3. 生物标志物

多年来生物标志物一直是毒理学研究的重点领域之一。近年来，我国学者发现了多

个化学物作用于机体的接触标志物和效应标志物。基因分析技术在易感性标志研究中得到广泛应用，在比较不同基因型携带者在相同暴露条件下的反应差异、确定危害效应机制和敏感人群识别中显示出了重要性。中美学者合作关于苯的职业暴露、代谢产物、血液学早期改变的复杂关系的研究成果，在促使美国安全生产管理局将苯的职业暴露限值降至1ppm 水平中起到了重要作用。

4. 氧化应激损伤

在现代毒理学研究中，氧化应激损伤成为研究热点之一，它主要涉及自由基、活性氧、氧化应激在有害因素的毒性作用中的反应机制。近年来，我国学者在该领域的研究也取得了较好的进展，多个实验室构建了抗氧化研究技术平台，提出了抗氧化剂复合链理论，研究揭示了多个化合物或污染物的氧化应激损伤作用与机制，开展了中药和天然药物的抗氧化力的测定和评价。

5. DNA 损伤修复

近年来国内关于 DNA 损伤修复研究，取得了重要的研究进展。阐述了 DNA 修复基因在不同类型化学物或电离辐射致细胞损伤响应过程中的作用机制；揭示了 DNA－PK 复合物在 DNA 损伤修复和细胞有丝分裂调节通路间的“cross－talk”作用；阐明了 p53 蛋白选择性调控分子 Apak 在细胞 DNA 损伤反应中的调控 p53 蛋白活性及分子机制；发现基于 Axin 的多蛋白复合体通过其组分的动态变化控制 p53 的活性，从而决定细胞抉择或凋亡或周期阻滞的命运；在新鉴定的 DNA 修复反应基因的功能研究取得突破，如揭示 JWA 在 DNA 氧化损伤修复反应中的功能机制。研究结果分别在一些国际著名学术刊物如 *Nature Cell Biology*、*Cancer Research*、*JBC*、*Nucleic Acids Research* 上发表。

6. 表观遗传效应

表观遗传变化是指 DNA 序列没有发生变化，可通过有丝分裂和减数分裂在细胞和世代间传递的基因表达改变。近几年我国学者在此方面的研究已取得明显进展，如在结晶型 NiS、BaP 以及电离辐射等因素诱发细胞恶性转化模型中，揭示了表观遗传效应及其对细胞基因组稳定性和细胞恶性转化的影响。纳米材料的表观遗传学效应也受到重视。放射毒理对表观遗传效应有另外一种表述，即辐射旁效应和基因组不稳定性。研究揭示细胞间缝隙连接对表达旁效应的重要性，发现细胞胁迫机制和活性氧分子如 NO 在辐射旁效应中的分子调节作用等。

（二）应用毒理学研究进展

近几年来，我国毒理学工作者针对国内环境、食品、药品、职业等安全性的社会需求和存在问题，积极开展有针对性的相关研究，在毒理学研究技术平台的建设与应用方面，均取得了显著成效。

1. 维护环境安全

研究成果体现在环境污染物检测及其在生物体内的吸收、分布、转化和排泄规律，一般毒性作用与机制；环境化学污染物对人和哺乳动物的“致突变、致癌、致畸变”等特殊毒性作用与机制；环境化学污染物对人体健康产生危害的规律及预防策略；环境污染物的毒

性评定方法、对人体损害作用的早发现和早防治措施。研究领域涉及大气环境毒理学、土壤环境毒理学、水环境毒理学等。

2. 促进职业安全

以工业毒理为主，紧紧围绕职业病预防控制、工业化学物对健康危害等领域开展研究工作，为职业病预防治疗提供了强有力的技术支撑。对铅、有机溶剂以及高分子化合物等的神经毒性作用机制、相应暴露生物标志物以及排铅药物等均进行了深入细致的研究。在职业接触人群生物标志物研究方面，发现了多个毒性效应标志物和易感性标志物。

3. 保障食品安全

我国出台了多个关于食品安全方面的行政立法，颁布了《食品容器和包装材料安全性评价毒理试验要求》、《新资源食品安全性评价规程》、《转基因植物及其产品食用安全检测大鼠 90 天喂养试验》等食品安全性毒理学评价的标准和技术规范，新建了一系列食品安全监测、预警与评价方法和技术，使我国食品毒理研究和安全性评价技术整体水平显著提高，并逐渐与国际接轨。

4. 保障药品安全

近年来我国药品安全事故频发，形势较为严峻。从 2006 年的“鱼腥草”事件、“欣弗”事件，到 2008 年的“刺五加”事件、“茵栀黄”事件，再到 2009 年的“糖脂宁”事件、“双黄连”事件和“甲氨蝶呤注射液”污染事件。为此我国加强了药物安全监管及药物毒理学研究力度，开始关注中草药的毒性问题。在实验动物管理、药物毒理学专业研究机构建设、毒性病理学诊断技术、新技术新方法的应用等方面均取得了长足的进步。发布了一批药物安全性评价技术指导原则，截至 2010 年已有 39 家毒理学研究与安全性评价中心（GLP）通过国家食品药品监督管理局（SFDA）认证，药物毒理和安全性评价研究逐步与国际规范化管理接轨。

5. 新材料安全

进入 21 世纪以来，新材料如纳米材料不断涌现，其生物安全性引起人们关注，由此形成了毒理学的一门新的分支学科——纳米毒理学。尽管纳米材料生物安全性的研究在我国起步不久，但在国家科技部“973”项目等的资助下，已经形成了具有一定规模和国际竞争力的纳米毒理和生物安全性研究的科研队伍，纳米毒理学科研工作在多个方面处于国际先进水平行列，为纳米材料安全性评价奠定了良好的基础。

（三）管理毒理学研究进展

管理学与毒理学以特殊的方式联系在一起，逐步形成和发展成为现代管理毒理学。近年来在国内制定和颁布的许多公共卫生与环境生态保护的政策和法令中，毒理学科研成果和基础数据、理论成为制定相关政策和法律的重要科学依据。自 20 世纪 80 年代后期以来，我国陆续制定和公布了一系列试验指导原则，用于毒理学实验方法和程序的标准化管理。针对食品、药品的安全性、化学品管理等，近几年又加紧起草、公布和实施了一系列毒理学试验指导原则和标准程序。

实验动物工作的规范化是保证国内 GLP 实验室与国际接轨的必要条件。我国的实

验动物工作正在逐步走向规范化、法制化管理。各种相关法规和文件中对实验动物的分级、饲养管理以及动物试验的环境条件和设施设备等，均制定了规范化的规定和要求，有意识地加强了替代、减少和优化原则(3Rs)的贯彻，重视了动物福利，有效地防止了因实验动物质量而对药品安全性评价所造成的影响。另一方面，国内的 GLP 实验室也按照国际惯例，陆续建立本机构的“动物管理与使用委员会(IACUC)”，实行动物试验的伦理审查制度。至 2010 年，我国共有 27 家机构通过了国际实验动物评估和认可管理委员会(AAALAC)的认证。

为确保实验研究的质量和可靠性，我国自 20 世纪 90 年代中期开始，逐步推行国际通用的良好实验室规范(GLP)。SFDA 明确规定，一类新药及注射剂的非临床安全性评价研究，必须由通过《药物非临床研究质量管理规范(GLP)》认证检查的实验室完成。国内部分 GLP 中心通过了 OECD 成员国的 GLP 检查。在国家科技部“十一五”科技支撑计划项目的支持下，我国农药毒理学的 GLP 体系开始建立。2008 年 10 月，农业部开展了第一批 GLP 实验室考核。2009 年环保部公布了第一批新化学物质登记测试机构名单。这些工作为提高我国化学品测试的技术水平，将来实现国际上化学品测试数据互认奠定了坚实的基础。

四、对本学科发展的建议

近几年来，毒理学学科发展非常迅速，而且，社会对毒理学学科发展和专业人才需求量还在不断增长，毒理学学科对人们健康事业、国民经济发展和社会稳定的重要性将会得到进一步的体现。

(一)扩展毒理学领域、满足日益增长的社会需求

在我国现行的国家学科体系中，毒理学还不是一门独立的一级学科，它归属于预防医学下设的“卫生毒理学”学科，所有的招生、教学、人才培养和人才评价体系都是在此架构之下实施。我国目前实际招收从事毒理学研究的硕士、博士生的高等院校和科研院所不仅涉及医科、药科、中医药和军医大学，而且还涉及工业、农业、林业、海洋(事)、水产、理工、国家 CDC 以及相关科研院所等。很多院校和研究机构是挂靠其他专业招收从事毒理学科研的研究生，这很不利于毒理学专门人才的成长和专业人才队伍建设。“卫生毒理学”学科明显存在局限性，其不能包含环境毒理学、生态毒理学、药物毒理学、兽医毒理学等很多毒理学分支学科，导致这些分支学科的地位和作用未得到应有的体现。因此，有必要树立起“大毒理学”的概念，将目前的卫生毒理学专业扩展为毒理学专业，以一级学科的规模设置各分支学科专业，赋予毒理学学科更大的发展空间和领域。同时，由中国毒理学会等权威学术团体组织建立国家毒理学继续教育培训体系，培养更高层次毒理学科技人才。要建立起与人才培养配套的毒理学人才评价机制，开拓社会急需毒理学人才的成长空间。很多西方发达国家和地区，已经建立了国家“毒理学家资格认证”体系，而且受到政府、企业和毒理学工作者的积极响应。国际毒理学联合会(IUTOX)也正在积极推动该项工作的国际间互认。在此大环境下，我国很有必要加大力度推行此项工作，使之成为国家毒理学人才培养和学科队伍建设的重要举措。

（二）建立中国国家毒理学计划、营造毒理学创新环境

鉴于毒理学的多学科交叉和多部门管理的特点，建议借鉴美国国家毒理学规划（NTP）和欧洲化学品管理局（ECHA）经验，结合我国实际，尽快建立有中国特色的毒理学研究和安全性评价机制和协调机构，即中国国家毒理学计划（CNTP），由政府有关部门联合推行，发挥全国性专业学术团体如中国毒理学会、中国预防医学会卫生毒理学会等在政府决策咨询和制定、指导与协调毒理学规划方面的作用。要确定主攻目标，加强毒理学科学基础研究，协调和指导全国毒理学测试技术方案和安全评价体系，开发和验证改进测试方法，及时为卫生、管理及研究机构、科学和医学界及公众提供有关潜在有毒化学品的信息；集中国家重点实验室、科研机构或高校资源、互通信息，组织全国各地区有基础的单位进行有计划、多方位、多层次的联合攻关，充分利用各自的优势，改变毒理学研究工作中的小而全、重复分散、交叉重叠的被动局面；加强各机构之间的沟通与合作，建立公用信息库，尽可能做到资源共享，包括技术与信息的共享。

（三）基础研究与应用并重，提升毒理学科技创新能力

毒理学具有多学科交叉融合的特色，既有基础研究，又有针对性强、符合社会需求的应用研究。毫无疑问，毒理学机制、人群易感危险因素和易感机理、理论模型等深入的基础性研究，是各类应用技术创新的思想源泉和推动力。在国家层面上要有切实的措施，稳定一批潜心毒理学基础研究的科研队伍，这对于毒理学学科发展是至关重要的。反过来，创新平台与实用技术，不但能解决国家的一些重大需求问题，而且又能大大促进基础研究的系统深入。

毒理学研究需要瞄准实际问题与国家重大需求问题，注重实验室研究与现场人群研究相结合。应统筹好全国的科研力量，整合优势科技资源，组成学科交叉互补的国家级科研团队，组织实施毒理学领域重大科研计划的协同攻关研究。

未来毒理学研究要重点关注环境重点污染物、新物质、新材料的毒理学和危险度评定，从基因毒性、表观遗传毒性、生物膜和重要亚细胞结构毒性，以及毒性作用信号通路和网络机制、毒性生物标志物等方面深入开展基础研究；巩固系统毒理学研究，加强毒理学替代法和新技术、新方法的创建和应用；进一步加强管理毒理学与健康危险度评定研究工作。

建议建立有国家政府部门、大学、科研院所和企业等多方参与的国家毒理学产学研联盟，扩大转化毒理学研究，使更多的技术成果转化为实际产品，直接服务于社会经济建设和人类健康事业。

第三章

学科发展研究报告(2010—2011)简介(英文)

1 Chemistry

The report compiled by the Chinese Chemical Society (CCS) consists of three parts, i. e. the comprehensive report, reports on special topics, and appendix. The comprehensive report is divided into four chapters in order to summarize the main progress made in chemistry at home and abroad. In the part of special topics reports, there are nine reports on coordination polymers, organic chemistry, small molecule probe-based signal transduction, utilization of green materials, chemical thermodynamics and thermal analysis, colloids and interface chemistry, micro/nano-fluidics, photovoltaic materials for organic/polymer solar cells, and persistent organic pollutants, respectively. The appendix is a white book with the title of *Powering the World with Sunlight*, which is published by the first meeting of series symposium of the Chemical Sciences and Society Symposium (CS3). The meeting was organized by Chinese Chemical Society, American Chemical Society, German Chemical Society, Royal Society of Chemistry, and Chemical Society of Japan and held in the summer of 2009.

The introduction of the comprehensive report emphatically pointed out that chemistry is a central science and the development of chemistry is together with the progress of human society. With the 30 years of reform and opening-up, the chemistry in China has entered into a flourishing age with high developing speed and China becomes an important force with the tremendous influence on in the international chemical community.

For helping readers to keep pace with the development trend of the chemistry, the references are provided. The partially important progresses of chemistry around the world, such as iron-based superconductors, graphene, organic reactions catalyzed by complexes, new energy sources, etc, are introduced in the second chapter of the comprehensive report. These progresses were chosen from the statistics of the top 10 chemistry papers published by "Science Watch" database and the chemistry issues on the great 10 breakthroughs in 2009 published by *Science*. At last part of this chapter, the report pointed out that the overseas Chinese chemists have made great contributions to the development of these hot fields as well as the chemists at home. However, chemists, especially experimental chemists did little

contributions to these original innovative works; it is truly worthy to introspect by all of chemists.

The third chapter named "the progresses of Chinese chemistry in recent years" is the main subject of the report. By using rich and accurate data and information, it is fully proved that the chemistry has gotten a great development on both basic and applied researches in the recent years. It can be summarized into the following points, the basic research is more solid and deeper, the developments of emerging fields are very fast, the new growing points in the classical fields continually appear, the quantities and qualities of achievements meet the great demand coming from the country and society, and practical applications are obviously increased and improved, the distributions of the academic fields further conform to the development request, agrees with international trend, and tightly combines with country's situation. In the selection of the topics, the more attention has been given to the sustainable development, the innovative achievements are fast increased, the academic exchange at international and domestic levels become wider and the quantities and qualities of the published papers are obviously increased. In last two years, this general development trend had become rather strong, the international impact had been extended and the position had been further promoted. At present, Chinese chemistry is attracting a great deal of attention from international chemical community.

In past two years, there were total 113 items of achievements to be awarded with three types of national prizes in the fields of chemistry and chemical engineering; the fields were the most awarded area in all of natural science fields in China. This fact indicated that the progresses of basic and applied researches of chemistry and chemical engineering have made the tremendous and very important contributions to the development of science, national economy, and society. However, it must be clearly recognized that more attention should be given to the promotion of integrated innovation from science and technology to industrial applications.

According to the national ranking, the amount of papers related with chemistry published by China has exceeded that by Japan and taken the second place in the world, the total cited numbers and average cited numbers for each paper have obviously increased, and the 68 reviewed articles had

been published in the seven top level journals publishing review articles (the impact factors of these journals are over 10) from January to July of 2010 alone. All of these phenomena are never appeared before. However, it must be noticed that the amount of papers with original creation and in the front and hot of international chemistry fields are still not enough, majority published papers should further improve their academic quality.

Based on the statistical data of chemical journals, the report pointed out that the journals published in China have steadily developed and made some breakthroughs on the cultivation of high-level journals.

According to the traditional classification of the chemistry, the progresses of various fields were summarized in detail in the second section of chapter two in the report.

Coordination polymer is one of important and very active front field in the inorganic chemistry. The report listed a series of achievements including the methods of molecular assembly for the coordination polymers, micro-porous coordination polymers used for storing future fuel gas, magnetic and photo-electronic coordination polymers, the coordination polymers used for the catalysis and the separation of chirality, etc. These achievements indicate that the researches on coordination polymer in China hewe formed own distinguishing feature and occupied a place in the world, some scientists have become very influential persons in the international arena of the field. For example, the as-synthesized cuprous triazolate framework (MAF - 2), a micro-porous metal-organic framework (MOFs) with three-dimensional multifunctional porous structures exhibits the largest efficient storage capacity for acetylene in the literature, it permits a usable acetylene storage capacity that is 20 times higher than its volume or 40 times higher than that of a gas cylinder working between practical limits of 1.0—1.5 atm. A series of functionalized coordination polymers had been successfully synthesized, such as magnetic heterometallic clusters containing both transition and lanthanide elements with diverse magnetic properties including antiferromagnetism, ferrimagnetism, and ferromagnetism; new ferroelectrics based on divalent metal ion alum which undergoes a phase transition from a paraelectric phase at room temperature to a ferroelectric phase at ca. −140℃; and rare earth hybrid materials with unique light-emitting properties; a direct white-light-

emitting MOFs with tunable yellow-to-white photoluminescence by variation of excitation light, etc. In addition, the progresses in the aspects of functionalized ceramic materials, other inorganic materials and bio-inorganic chemistry are introduced in the report as well.

The contribution made by Chinese chemists in organic and relative emerging cross-disciplinary is introduced in detail in the report from eight aspects, i. e. synthesis, reaction, mechanism, catalysis, organometallics, synthesis and separation of natural products, source chemistry and green application of biomass, and chembiology. For example, the organic reactions that include the formation of carbon-carbon bond by catalyzing of common metals, such as cupper and iron, direct formation of carbon-carbon bond between aromatics and multifluor substituted aromatics simply and rapidly by high efficiency, asymmetric hydrogenation of aromatics under catalysis condition, the electrophilic reaction of allenes with defined region-and stereo-selectivity by utilizing water as reactant, etc. have been realized. The researches on the green reactions of the cyclooxidation of the ethylene hydrocarbons by using H_2O_2 as oxidant and the oxidation of alcohols using oxygen as oxidant and the transformation of carbon dioxide catalyzed by ionic liquid or dual metallic catalyst and green transformation of several renewable biomass sources including cellulose and lignin, etc. have made the great and important progresses; the concepts of organo-dimetallic synthesized reagent and its cooperation effect, self-supported chiral catalysts, combining transition metal catalysis and organocatalysis and symbiotic reaction in source chemistry were proposed and proved; the reaction mechanism of catalytic asymmetric oxygen hydrogen insertion reaction was theoretically explained; the new multi-component reaction based on trapping active ylidium intermediate, the coupling reactions through activate of the inert C－O band and selective fragmentation of C－O bond in substrate by catalysis of transition metal and a new synthesis method for aromatic boric acid ester under mild conditions without metal participation were discovered; several small molecule chiral catalysts, chiral carbenium catalysts and building-block for synthesis of complicating natural products and important medicines used by clinic treatment were developed; complete syntheses and separations of some dozens of natural products were successfully carried out.

In the section of chembiology, advances in signal transduction research utilizing small-molecule probes are introduced from the areas as follows: construction and mechanisms of chemical small-molecule probes, the new methods for assessing the interaction information in bio-systems, the signal transduction and the important makers based on the route of signal transduction and identification of novel signaling pathway, verification of biological functions of various targets, etc. Besides, the important progresses and breakthroughs made on the exploration of active mechanism for the traditional Chinese medicines and the research on stem cells were also described.

Physical chemistry deals with a wide range of disciplines in chemistry. In the field of nano materials and chemistry, some results had received the great interest from international arena, the results included the discover of new forms (graphone and graphdiyne) of carbon materials, the preparation of "the Russian matryoshka"-like metallic fullerene, the theoretical simulation of the fluid of water molecule in the carbon nanotube and the mechanism and the ability of performable of the nano-hydroelectric, single molecule operation, and so forth. In the research on molecular kinetics, the observation of individual partial wave resolved resonances in the F+HD→HF+D reaction by measuring the collision energy-dependent, angle-and state-resolved differential cross section with extremely high resolution, which provides a spectroscopic probe to the transition state of the reaction, is first time reported in the world; a global 12 - dimensional *ab initio* Potential Energy Surface (PES)(BCLWS surface) described both H+SiH_4 abstraction and exchange reactions was constructed, and two new mechanisms (torsion-tilt and side-inversion) involved in the contribution to this reaction were proposed and designated. In the thermodynamics, a series of results that were obtained through deep and systemically basic research on the molecular interaction between ionic liquids offered the theoretical guidance for the application of the ionic liquids in chemical reactions. For the research on catalysis and catalysts, the discovery of the interface confinement effect can be used to stabilize the Coordinative Unsaturated Ferrous (CUF) sites by taking advantage of strong adhesion between ferrous oxides and metal substrates, the interface-confined CUF sites together with the metal supports

were active for the dioxygen activation to produce reactive dissociated oxygen atoms and the structural ensemble with the high efficient for carbon monoxide oxidation at low temperature under typical operating conditions of a proton-exchange membrane fuel cell were realized at first time; the near 100% of the efficiency and selectivity of the selective phenol hydrogenation to cyclohexanone on a dual supported Pd－Lewis acid catalyst in supercritical carbon dioxide with mild conditions were arrived; a passivated codoping approach for enhancing photoelectrochemical activity of TiO_2 and other wide-band-gap semiconductors was presented, i. e. the band edges of them are modified by passivated codopants to shift the valence band edge significantly up, and leave the conduction band edge almost unchanged to satisfy the stringent requirements; oxygen atom exchange mechanism of photocatalysis and the microimage of the single molecule layer of water on the (101) surface of anatase TiO_2, etc. have laid the scientific foundation for preparing high efficient TiO_2－based photocatalysts and controlling the photocatalysis reactions. In the area of new energy sources, the storage hydrogen capacity of the 3D micro-porous materials had been increased to 6.1(wt)% by using the lithium ion doping technique under conditions of 77K and 1 bar, which was the highest capacity record for physical absorption method in the literatures; the power conversion efficiency of the dye-sensitive solar cells had reached to 9.8%, which was the world leading level, by using a new designed and synthesized organic dye C217 with high absorption coefficient; the highest values of the filling factor, open circuit voltage and energy conversion efficiency of the polymeric solar cells made by using as-synthesized new C60 derivative as acceptor were reported in the literature so far; and the breakthroughs were reached for transferring macroalgae *Enteromorpha prolifera* to bio-oil by hydrothermal liquefaction and producing bio-hydrogen from dairy manures with acidification pretreatment by anaerobic fermentation, these techniques not only protect the environment, but also change the waste matter into useful fuel. It will produce the great economic and social benefits if these techniques can be applied and widened in practice.

For the researches on colloids and interface, the concept of supermolecular surfactant was presented and a kind of assembly-able supermolecular surfactant nanofibers with super length was built in aqueous

solution; one-dimensional order helical structures were fabricated by the as-presented method of self-template; the method for the formation of organic and inorganic hybrid supermolecular reversed micelle through the static electrical interaction and assembly of the inorganic multi-metal-oxygen cluster anions with multi-charge was established; the honeycomb films with high order and various morphologies were obtained; a new pattern crystal state material was synthesized by the colloid crystalline template method; the two-dimensional Kagome net structure was built through assembly of surface molecules. In addition, the obvious progresses on small molecule gel with responsive properties for stimulation, biosensors and super-hydrophilic and hydrophobic and super-superoleophobic surfaces were made.

In the section of analysis chemistry, the research achievements on the micro/nanofluidics were emphatically introduced. For example, the new chips fabrication methods involving liquid-plastic for PDMS chips, jet-ink printing for paper chips, and PDMS surface modification by combine of physical absorption and chemical modification were established; the some drops operation techniques on chips were developed; the instruments used in micro-fluidics, such as the micro electrodes and micro electrochemical detectors, hand-hold absorption spectrometer, and IC micro-fluidics system with detecting by mass spectrometer, were developed; the applications of the micro-fluidics on the sample pretreatment, high effective enzymolysis of proteins, culture and detection of the cells, nucleic acid-and immunodiagnosis, screen of drugs and enzyme enrich of nanofluidics, etc. were successfully realized. Furthermore, the new method of instrumental analysis, bio-chips, electrochemical luminescence, sensoring, fluorescence probes, cyclic voltammetry, toxicities of organic toxicants, and the analyses of the natural products and traditional Chinese drugs, etc. were introduced in the report. It is worthy to especially note that the as-presented shell-isolated nanoparticle-enhanced Raman spectroscopy (SHINERS) has the great significant for developing the spectroscopy.

In the polymer science, the method for adjusting the components of polymers and the direction of helical nano-fibers was presented. The complete phase graph for the assembly of the typical ABC star three block polymers in the solution phase was set up. The self-assemblies of the block polymers in

selective solvents and the interface between water and air were realized. The column-type micelles, rod-coil-rod triblock copolymers, and hybrid hollow/bowl-type SiO_2/PMMA micro-spheres were prepared. The methods of sequential click coupling of asymmetrical monomers, catalyst-free "click polymerization" self-organization assisted in the solid state, and long-chain click reactions for preparing hyper-branched polymers with 100% branching coefficient were presented. The high effective, high selective, thermally stable single-site Co (Ⅲ) catalyst for the copolymerization of carbon dioxide with epoxides and highly *cis* - 1, 4 selective homogeneous catalysts for polymerization of isoprene were successfully designed and synthesized. The Liquid-Crystalline (LC) phase structures and transitions of a combined Main-Chain/Side-Chain LC Polymer (MCSCLCP) with hierarchical structure and the conjugated polyacetylenes with properties of liquid crystalline and photoluminescence were prepared. A series of functional and responsive polymers including the dual reversible responsive supramolecular gels for temperature and pH, electrochromatic carbon nano-tube/polydiacetylene nano-composite fibers, the multi-functional and stimuli (such as biocompatible, biodegradable and photoluminescent) - responsive disulfide-containing hyper-branched poly(amido amine), the reversible assembly and disassembly of a polyethylene glycol (PEG)/α - cyclodextrin (α - CD) pseudo-polyrotaxane (PPR) hydrogel ternary system, peripherally dimethyl isophthalate-functionalized poly(benzyl ether) dendrons organogelators which break the limitation that the gel can not be formed in the high generation of dendrons, morphology controllable polyanilines with multi super structures, etc. were successfully prepared. The conductivity mechanism of semi-conducting polymer/insulating polymer composites was well explained with semi-conducting charge transportation enhanced by surrounding insulating matrix. The high detectivity polymer photodetectors with the spectral response from 300 - 1450 nm was prepared, whose dark current and noise were far lower than that of narrow gap inorganic semiconductor photodetectors. And, a series of biopolymers and enzymes used for drugs of release and transportation were synthesized and deeply investigated. The regenerated silk fibers with highly lustrous and uniform diameters and circular cross-sections which are stronger, more extensible, and tougher than

that of natural silkworm silk were obtained; a series achievement on the thermal processing of starch-based polymers in theoretical and practical areas obtained by Chinese scientists were reviewed.

The research on the organic optoelectronic materials and devices in China has an important effect on international academic arena. In the study on White light Organic/Polymeric Light-Emitting Devices (WOLED/WPLED) of host-guest doped system consisted of polymer, small organic molecules, and single polymers, Chinese chemists had successfully developed several kinds of white light system with the performances placed the leading position of the world, synthesized a series of high effective blue-and red-emitting materials, and constructed high effective solid state white Light-Emitting Cells (LECs). The important and obvious progresses in the research on the interface engineering of the Organic Field Effect Transistor (OFET), and theories and preparations of organic semiconductor films with structural order and micro devices, and so forth had been achieved.

In the last two years, several achievements with a world leading level had been obtained in the field of the applied chemistry. A series of sets were successfully run, for example, the industrialization exemplary set (10,000 t/a) producing the first set of technologies of "Ethylene Glycol from Coal" in the world with the Chinese independent intellectual property rights, the first and the largest industrial set in the world for fabricating ethylene hydrocarbons from methanol on its first test run, the huge capacitive sodium sulfur battery and its energy storage application and vanadium redox battery energy storage system (VRB - ESS), and the pilot production line of innovated green fabrication technique of print board by using nano materials. The technique for waste water treatment in oil fields and the high additional valuable application of pro-treatment waste matters were developed. These original creative achievements will generate huge economic and social benefits; they are the outstanding and typical cases that science services national economy and meets national urgent needs, and practical actions by scientists implement the policy for building innovation-oriented country. The important progresses of the ionic liquid lubricants, development of combustion diagnostics, and finding involving the clue to the mystery of the sticky rice-lime mortar used in historical masonry construction were also

introduced.

In the research on the environmental chemistry, there were breakthroughs in the formation and degradation mechanism of the Persistent Organic Pollutions (POPs), recognization of the pollution sources and pollution control, the characteristic and environmental behavior of the pollution, toxicity and health effect, etc., especially in the research on the chiral POPs. The obtained achievements not only occupy on the front place in the field, but also lead the development of this issue to a certain degree. For example, in the studies on the degradation and transition of POPs by utilizing the chiral characteristics, it was found that the Enantiomer Ratios (ERs) of POPs can be used as a bioindicator to distinguish the "new" source from "old" sources and trace the environmental fate, and based on it, the biomagnification of the enantiomers of POPs was established. A series of creation results in enantioselectivity in embryo toxicity, endocrine disrupting effects, immunotoxicity and of algae and plants had been obtained and it is discovered that the enrichment of (+)－α－HCH in brain is mainly caused by selecting through blood brain barrier of enantiomers. And the analysis method for the identification and quantification of Short Chain Chlorinated Paraffins (SCCPs) was developed. In addition, the research progresses made on the characters and controls of the pollution of the polycyclic aromatic hydrocarbons, pesticides residues, and heavy metal in China were also briefly introduced in the report.

The chapter four of comprehensive report, "Prospect and Suggestion", points emphatically out that chemistry should meet three developing tendencies. First, chemistry will extend along the direction of wider and deeper, second, green chemistry will lead the change of the production style of the chemistry and chemical industry, and third, chemistry must meet the new demands continuously generated from the social development. Chemistry will play an increasingly important role, make great contributions to solve the major issues, and address the strategic and overall perspective.

In the last part of comprehensive report, the developments of the different branch of the chemistry in the near future were briefly prospected.

2 Psychology

It is widely accepted by the psychological community around the world

that psychology had a long past and short history. After more than 100 years slow development, nowadays, psychology is entering into a fast growth line. Since the beginning of the 21st century, in the developed countries, the investments in psychology by governments have traumatically increased, comparing with the investments put into the psychology in the 20th century, and comparing with their investments put into some traditional branches of sciences. The similar situation is also true in China. From the year of 2005 to 2010, two key laboratories in the area of psychology were supported by the central government, five large scale psychology projects were supported by the Ministry of Science and Technology and the Chinese Nature Science Foundation. Many provincial level key laboratories and projects were supported by provincial governments and the Ministry of Education. The number of psychology departments in the universities has been increased, there are more than 200 departments now, and in the year of 1978, there was only one department of psychology in Beijing University that formed in same year. Psychology is currently focusing on the mechanism and biological bases of consciousness, brain function of behavior, biological bases of social behavior, psychological health, and relationship between gene and behavior. In order to better explain the world, the integrated researches conducted by both natural sciences and social sciences are emphasized in these days, psychology is paying a role as a nature bridge for the integrated researches conduced by both members of ICSU and ISSC.

The features of psychology and psychological researches were pointed as follows: Currently, many scientists from areas other than psychology are studying traditional psychological topics and problems formed by multidiscipline researchers; Multidiscipline approached and technology have been naturally applied to the study on psychological topics from various levels of the body, such as behavior level, brain level, neuron level, gene level, computing level, and mathematic level, et al; the relationship of body and mind are focused on, people attempt to find body bases of every piece of mind and psychological factors on physical health; Cross culture research provided exciting evidences that people's psychological functions are impacted by culture difference, this explains that environmental factors actually effect on development and provides new view for people to understand each other; As

it was indicated before, psychology wins its better position in sciences and societies, governments invested more money into psychology, medium talks more about psychology, almost every aspect of the human activities considers clear or potential role/impact of psychology. These give both more opportunities and challenges to the psychology.

In last three years, in terms of publication of psychology in the world, four areas of psychology, that is, cognitive and experimental psychology, educational psychology, social psychology, and physiological psychology and neuroscience contributed the most, while every sub-discipline of psychology was developed. Among these contributions, Chinese psychologists also have made great progresses in Chinese institutions. In cognitive neuroscience, researches on visual crowding, visual adaptation, perpetual learning, perceptual grouping, attention, emotion, language cognition, etc. have been published by Journal of *Neuroscience*, *Current Biology*, *PNAS*, *PLoS Biology* and other key journals. Leading by Professor Zhu and Han, Chinese psychologists have contributed more on social cognitive neuroscience. Some brain function of self-recognition and decision making, and self (ego) difference of eastern people vs. western people by brain differences have been identified. In the area of psychological health, the Institute of Psychology, Chinese Academy of Sciences, developed a new mental health scale specifically towards ordinary Chinese people rather than psych patients, and samples are collected across all provinces and areas in China in both daily situation and after disasters. It provided a whole picture of psychological health situation in China. The early symptom of schizophrenia research was also appreciated by the China Nature Science Foundation. Researches on influences and impacts of internet usage on the psychological health and social behavior found factors of addiction and brain changes. Some theories of pathological compensation were suggested. Pilot researches on natural user interface, brain-computer interactions, and social computing were also carried out. After Wenchuan earthquake occurred in the year of 2008, disaster psychology, specifically research on the psychological intervention after drama was launched in China and various approaches of psychology, such as field study, personal interview, questioners, lab-experiments, ERP, and fMRI technique were also applied to researches on the disaster psychology,

models of psychological services after disasters have been developed and tested. Recently, two national scale data banks of psychological characteristics of Chinese people, one focused on youth with the age under 18 years old, the other focused on people old than age of 18, were supported by the Ministry of Science and Technology. The first one is approaching to its completion and the second one is undergoing, both of them will provide data for psychological basic researches and implications in China. These data banks are the first ones in the world, indicating that psychology research in China is part of the national policy bases, despite the fact that it is still a pure and applied science. With the governments' generous investments, Chinese psychology possesses the most advanced equipments for the psychological researches. For example, six departments of psychology have their own fMRI machines for research and more machines located in the hospitals are collaborated with researchers.

Six items was expected and suggested for the future development of psychology and for psychological services in China, they are as follows:

(1) More investments to psychology are pressing needed. By comparing with the budget to psychology in advanced countries and the needs of psychology generated from Chinese society, it is an urgent need in the science part of next five-year national development plan.

(2) A new run of education system reform for psychology is needed. Needs for undergraduates training should be given attention in time and the formal education structure needs to follow the successful models of psychology training in the advanced countries.

(3) International exchanges and cooperation need to pay more attention to. It is suggested to employ more international faculty members for all the departments of psychology in China.

(4) A national law of psychology development and national regulations for psychological service needs to be proclaimed. The top priority is to distinguish psychological service from psychiatry treatments and work of mental hospitals practice.

(5) More journals and magazines in psychology are needed for both development of research and for public understanding of psychology and themselves.

(6) More efforts for public understanding of psychology are urgently needed, a preliminary psychological course should be provided to the primary school students.

3 Mechanical Engineering

Forming manufacturing techniques include casting, plastic forming, welding, modification and control, surface engineering, and remanufacture. Their developments can arrive at a high-performance and high-precision forming technology of light-weight components with advantages of rare material waste, green forming, and cost saving. It becomes one of the main technologies to support the sustainable development of domestic economy and national defense construction, and contribute significantly to the industries, such as aerospace, military equipment, energy, and automobile. It satisfies the urgent and great demand proposed by national key special subjects and major projects, such as the in-operation medium-term and long-term plans on science and technology in domestic economy and defense. Also, it plays an irreplaceable role in aspects of energy-saving and emission-reduction, low-carbon-economy and innovation-oriented country.

3.1 Recent developments in Mechanical Engineering

3.1.1 Casting forming

In recent years, casting forming techniques with energy conservation, environmental protection, high efficiency, and low cost in China have been rapidly developed, and play a very important role in the improvement of casting techniques and enhancement of core competitiveness of China. The adjusted pressure casting technology based on the integrated innovation of solidification theories, techniques, and equipments have cracked the hard nut of large and complex thin-wall castings of aluminum-magnesium alloy with high quality. The rapid digital-driven pattern-less casting techniques realize the rapid production of complex castings, such as automobile engine cylinder and tailpipe. The laser rapid prototyping and repairing systems have also been widely applied to the advanced airplanes and aero-engines. Based on the phase field method and the cellular automata method, multi-scale simulations of solidification process and micro-structural evolution have also provided the

theoretical foundation for the quality control of single crystal turbine blade in China.

3.1.2 Plastic forming

Breakthrough developments have been achieved in the fabrication techniques of large-scale forgeable components in China. It makes almost all of the forgeable components home-made for the equipments of nuclear islands, 700 MW hydro-power generating units, and 1,000 MW thermal-power generating units. Furthermore, most advanced equipments of 150 – 800 MN hydraulic forging presses, large-tonnage hydraulic press for free forging, 360 MN tube extruding press, and 45 MN high-speed forging hydraulic press are either completed or under construction. In addition, on novel forming technologies, isothermal forming combining with local loading is proposed for reducing the loads in order to break through the limitation of forming equipments, which is developed as a force-saving advanced forming technology; in the meantime, precision shape-forming and performance-controlling technology is also presented, which helps the largest complex components of titanium formed for the aerospace use. Also, the important progresses have been made in technologies of precision cross wedge rolling of non-cylindrical axis, precision rolling coupling with spinning of lightweight wheels of automobile, multi-point forming of irregular spatial curve-surface parts, internal high pressure forming, precision NC tube bending of large-diameter lightweight tube with small bending radius, and thermal ring rolling of complex cross-section.

3.1.3 Welding engineering

Recently, significant progress has been made in the areas of integrated welding process, distortion control, regulation of joint properties, and assessment of joint integrity of large-scale structures. The achievements have been applied to welding Three Gorges ship-locks, hydraulic turbine rotors, Spiral Case and Bird's Nest. The technological achievement on the welding of the Bird's Nest has received the award of UGO GUERRERA Prize. The findings in purification, uniformization, grain refinement and low-carbon of welding materials have been used in the second project of west-to-east natural gas transmission. The new developed laser-arc welding and solid-state laser-metal arc welding techniques have been used in the automobile manufacture

with advanced aluminum alloys and military assembly of high strength steels, respectively. Chinese engineers have mastered the Electron Beam Welding (EBW) of common aero materials, and high-voltage EB welder has been developed which can weld any part within 4 m×2 m. The welding technique for large-scale titanium alloys (e.g., maximum thickness 105 mm) has been developed; it solves the critical problems associated with the defect and distortion controls of joints. The great achievement has also been made in numerical simulation, automation, and intelligentization of the welding process.

3.1.4 Material modification and control engineering

Based on the theories of atomic and electric structures, according to the designs of chemical composition and microstructure, a series of high strength steels, especially Aermet 100, were developed. The theory on the precise heat-treatment method for alloying and strengthening-toughening was also presented, and the optimal heat-treatment process was obtained, which has been widely used in the modification of high strength steels. Moreover, a new theory on chemical heat-treatment by using rare earth metals with high-efficiency and high-quality processes is presented. An advanced and practical achievement on property design while ensuring the uniform deformation of the heat-treated parts was obtained by means of numerical modeling method. Furthermore, the significant progress on materials property modification by nano-phase has been made, which is the key technology to improve products properties, service life, and reliability.

3.1.5 Surface Engineering

Several special high-performance lubricating materials used for space and nuclear environments were developed. Lubricating films used for space technology, such as MoS_2-Au-RE tri-compound, Ni-Cu-Ag gradient multilayer, inorganic and nano-metallic multilayer, and TiAgN nano film, were developed which have been successfully applied to the various carrier rockets and spaceships, such as "Shenzhou" and "Jianbing". The polyimide solid lubricant membrane resisting strong radiation was developed and patented, which has been applied to many parts of the domestic HTGR and other reactors, such as bearing, gear, slide, cam, chain, and linkage. It solves the special lubrication problem in the nuclear reactor equipments under

strong radiation and high temperature. As the only extravehicular mission of Shenzhou－7, various orbital flight experiments of space lubricating materials were carried out. First-hand data involving the effect of space environment on the variations of solid lubricating materials has been collected. Based on the M3 additive, the anti-friction additive M6 was developed by adding nano-sized Cu particulates, the M6 is mainly used to reduce the friction between the engine cylinder and piston, i. e., almost "non-wear". Furthermore, the significant progress has been made in the equipment and technology of solar energy power generating membrane, super-lubricating composite carbon films, and nano ceramic coatings prepared by the micro-arc oxidation technique.

3.1.6 Remanufacture engineering

Remanufacture has become an effective approach for the energy saving and recycling economy. Recently, China has explored a remanufacturing mode with Chinese characteristics that depend on the innovative technology, based on repair and property improvement by surface engineering, "industry-university-research institute" combination, integration of economy and recirculation. The techniques using nano-particle composite electro-brush plating to efficiently repair worn or damaged components have been developed, which have been applied to the airplanes, naval vessels, and other engineering equipments. Moreover, automatic high-speed arc spraying, plasma spraying, and laser cladding for remanufacturing are also developed, and the remanufacturing technique by laser forming was developed for aero components, in which processing parameters, directional solidification of microstructure, mechanical properties, and heat treatment of laser formed parts have been investigated.

3.2 The comparison of the discipline developments at home and abroad

Currently, there is still a big gap in the area of casting techniques and equipments between China and developed countries. To solve the problems existing in castings in China, such as poor dimensional accuracy, poor surface quality, bad mass stability, and large energy consumption, the systematic and in-depth fundamental researches and technique innovation are urgently required.

Technologies of cold/thermal precision punching on high-strength sheet,

age forming of integral panels, internal high pressure forming, and precision NC tube bending of lightweight alloy have been developed and are suitable for the manufacture in developed countries, however, it will take long time to exceed developed countries. Although Chinese precision cross wedge rolling technology is on the top of world level, the key machines still depend on import due to the weak innovation capacity of manufacture. The same situation happens in precision forming of large-scale complex integral components.

The flourish of domestic economy and increment of defense needs have pushed the rapid progress of welding. However, there still exist many problems that need to be resolved, comparing with the developed countries, especially in the areas of high-quality and efficient welding of low-density and high-strength materials, welding under extreme conditions, welding automation, diffusion bonding, and modeling of processes.

The developed countries have achieved the precise control of heat treatment. Although the numerical simulation of heat treatment in China is in the internationally leading position, the overall heat treatment technique is under many restraints and unable to satisfy the requirements for high performance and reliability of equipments.

China takes the lead in the research and applications of nano thermal spraying, nano-brush plating, nano surfacing, nano antifriction additive, and nano micro-arc oxidation techniques. However, the technologies for producing nano-materials and nano-functional coatings, and nano manufacturing of coatings should be greatly improved.

We have moved ahead of other countries in the field of remanufacturing by the fundamental theory systems and characterized technologies based on advanced surface engineering, such as laser forming and nano-composite layer forming, which rebuilds the shape and improves performance of the components, while the other countries intend to replace and machine components for remanufacturing. However, the integration of processing facilities should be greatly improved.

3.3 Development trends and perspectives of the discipline

3.3.1 Casting forming

In order to further improve the core competitiveness in casting forming field for China, we should aim at the development of high performance

solidification forming techniques, including precise solidification forming techniques for large and complex castings with high performance, high purification and homogeneity under the conditions of multiple energy fields, digital-driven pattern-less investment casting techniques, precise laser forming and repairing techniques for complex parts, methods of accurate controlling technology-microstructure-performance during directional solidification of superalloys, and multi-scale numerical simulation methods with high efficiency for solidification process and micro-structural evolution.

3.3.2 Plastic forming

Aiming at precision and saving, shape-forming and performance-controlling, integrated technology of large-scale complex components, the technologies should be further developed in the following fields: cold/thermal precise punching on high-strength sheet, flexible incremental forming, inner/ thermal internal high pressure forming, precision forming and performance controlling of lightweight tubes with multi-constraints, cooperative control of shape-forming and performance-controlling of global, local or combined loading forming, micro-forming, forming precision prediction by multi-fields coupling, multi-scale, through-process modeling and optimization.

3.3.3 Welding engineering

With the goal of developing high quality and efficient welding techniques and welding techniques under extreme conditions, composite welding for low-density and high-strength materials should be further developed, for example, laser-arc welding, ultrasonic-friction stir welding, ultrasonic-brazing, ultrasonic-diffusion bonding, and fusion welding-brazing. The advanced welding technologies, modeling of welding processes, process monitoring and quality control for large-scale complex structures or under special environment should be paid more attention to.

3.3.4 Material modification and control engineering

Exerting efforts on the development of various whole and surface processing technologies and equipments to achieve the precise control on the composition, microstructure and property, and deformation of the materials or parts, the methods should be developed to fabricate the high-performance and high-reliability components with the multi-field, composite, and precise control, which includes the microstructure design, microstructure evolution

and control under multi-field, visualization of microstructure evolution, optimization of precise heat-treatment, and intelligent control of heat-treatment parameters under the multi-filed.

3.3.5 Surface engineering

For the purpose of high performance, low energy consumption, and green surface engineering technologies, the coating techniques for corrosion and oxidation resistance under the conditions of extremely high temperatures and pressures should be developed to improve the service life of turbines used in the wind power and hydropower. The thermal barrier coatings, clean control coatings, oxidation and corrosion resistant coatings, and anti-wear coatings should be developed. Furthermore, the functional surfaces should be studied in order to meet the requirements of environmental protection and energy-saving.

3.3.6 Remanufacture engineering

For the improvement of remanufacturing industrial level and the batch remanufacturing with intelligentization, combination, specialization, and flexibilization, the subject should focus on various auto-remanufacturing techniques, evolve from macro-scale to micro-scale, and shift from the pure mechanical uses to the combined functions, such as mechanical-electronic and mechanical-functional combinations. Furthermore, the breakthroughs in fundamentals, life prediction, key techniques and industry standards, and specialized talents of remanufacturing are expected.

4 Agricultural Engineering

Agricultural engineering is a key material base and guarantee for agricultural modernization, and is also one of the most important fields of science and technology in the construction of modern agriculture and new socialist countryside. The development of agricultural engineering plays an indispensable role in promotion of fundamental reforms of agricultural production, growth pattern, and farmers' lifestyle, protection of eco-environment, efficient use of natural resource and production materials, and sustainable development of economy and society.

Currently, the traditional agricultural pattern is shifting towards the

modern agricultural pattern in China. With the advance of industrialization and urbanization, great changes have taken place in the structure of rural labour force and farmers' attitude towards labour. Therefore, the desire for the mechanization operation and the demand for high-quality agricultural equipments become increasingly important and strong from farmers; the dependence of agricultural production on agricultural engineering science and technology applications is obviously growing. Moreover, with the further development of informatization, internationalization, and marketization, the external relations among supply and demand for agri-products, agricultural production and the agricultural development have experienced great changes in the different periods. It will result in a rather new and high requirement on agricultural engineering discipline and bring unprecedented opportunities and challenges to the innovation, reform, and development of agricultural engineering.

In the period of 2009—2010, based on the original foundation, China's agricultural engineering integrated multiple disciplines and new technologies. The focuses are on the seven research fields with relative stability, distinctive features, outstanding advantage, and wide application prospects, namely, agricultural mechanization engineering, agricultural soil and water engineering, agriculture environmental engineering, rural energy engineering, agricultural electrification and automation engineering, agriculture-products processing engineering, and land-use engineering. The quantity, quality and funding of research projects and research results in the above seven subjects have been continuously improved with new progresses in innovation and application.

During the period of 2009—2010, agricultural engineering has achieved great results in the areas of scientific research and education reform, it received 1 second prize of the State Technological Invention Award, 10 second prizes of the State Scientific and Technological Progress Award, 1 first prize of the State Teaching Award, 4 second prizes of the State Teaching Award as well as a batch of provincial and ministerial level awards; there are 2030 new research projects including 9 international cooperation projects and 306 national-level projects; and total scientific research funds reach at 1,181,000,000RMB *yuan*, 58% of them is found by projects of international cooperation and national level. The considerable progresses have made in the

undertaking research projects, research papers and invention patents have realized a great jump both in quality and quantity: in the period of 2009—2010, 4,117 papers published in SCI and EI as well as first-grade academic journals, among them, 603 papers are SCI indexed and 1,569 are EI indexed; the number of authorized invention patents reached at 416.

Disciplinary team-building of agricultural engineering has achieved remarkable results, with a marked enhancement of overall academic strength. A batch of high-level talents and discipline leaders is emerging: Professor Luo Xiwen is elected as an academician at Chinese Academy of Engineering, two Professors are selected as Professors of "Cheung Kong Scholars Program", three teachers are rated as national prestigious teachers, and a number of young and middle-aged teachers have won the titles as New Century Excellent Talents awarded by the Ministry of Education. Bring high-level talents from foreign countries is strengthened, and a total of 19 foreign talents are introduced, two of them enter into the "National 1,000 - Talent Program". The number of teachers and researchers in agricultural engineering who receive doctor degree is significantly increasing year after year.

In the area of talent training, 283 doctoral candidates including 3 overseas students graduated and received their doctor degrees; 469 doctoral candidates with 24 overseas students; 37 out-station post-doctors, 88 in-station post-doctors including 4 foreign post-doctors are recruited; one National Excellent Doctoral Dissertation Award and three nomination awards have been scored. The discipline of agricultural engineering has achieved fruitful results in the construction of scientific research and teaching bases: there are 1 state-level key lab, 2 state-level engineering labs, a batch of national engineering research centers, jointly-built key labs by Ministry of Education, Ministry of Agriculture with the provincial governments, and all kinds of provincial education bases. The discipline of agricultural engineering in 4 universities including China Agricultural University is listed in national "985" key construction projects; the discipline of agricultural engineering in 8 universities including Northeast Agricultural University is listed in national "211" key construction projects.

In terms of international and domestic exchange, 18 international academic meetings attended by 2,662 participators including 557 foreign

representatives are hosted; 53 domestic academic meetings are hosted with more than 7, 000 attendants. Total 395 researchers and teachers in agricultural engineering went abroad for academic exchange, giving lectures, and attending international academic meetings (187 person-time). The experts and scholars in the research areas of agricultural engineering are actively invited to China to give lectures and 14 person-time of foreign experts are employed to engage in research and teaching with the long term; 176 person-time of foreign experts are invited for short term, 12 agreements on international cooperation are signed with foreign universities and research institutes and 4 international cooperation agencies are established. The international influence of experts and scholars on the agricultural engineering is increasingly growing. The Secretariat of Asian Association for Agricultural Engineering has moved to China; 29people work with relevant international academic organizations, 49 people assume chief editors or editorial board members of international academic journals, and two becomes the guest professor of Kansas State University in US. We also written numerous academic monographs internationally and domestically with 85 books and 117 textbooks published. The quality of academic journals in agricultural engineering has been significantly improved. *CIGR Journal* and *Asian Agricultural Engineering Journal* have settled down in China; *International Journal of Agricultural and Biological Engineering* develops rapidly.

The report reviews the development and achievement of agricultural engineering during the period of 2009—2010. By comparing with the current international situation in similar subjects, the characteristics, issues, and trend of agricultural engineering are analyzed. According to the requirements on new stage, trend, and task for Chinese agriculture, the measures and suggestions for China's agricultural engineering development in terms of academic team building, talent training, scientific research, and international cooperation, etc. are presented by the report.

5 Refrigeration Science and Technology

Refrigeration Science and technology, conducting scientific research, engineering applications, and relevant system and equipment manufacture,

faces the task to create a temperature micro-environment and state of materials lower than that of natural environment temperature. It is a very important platform for implementing modern science research and engineering. And it is also one of the most rapidly-developed and most abroad-applied technologies that support three important service systems, that is, food engineering, building environment, and medical and health care system.

The cryogenic technology in refrigeration science is to produce a low-temperature environment with the temperature varying from absolute zero to 120°K, which is the key technique for superconductor, far infrared observation and imaging, etc. It is also of great helpful to solve the key issues for controlled nuclear fusion, electron-positron collider, and many other modern scientific research instruments. The refrigeration technology that produces low temperature environment (from 120°K to nature environment temperature) is widely applied to the heavy industry and energy industry, agriculture area, cryo-biomedicine, and building environment. It is also wildly used to build the life support system for the manned space vehicle, aviation, navigation, diving, and ground transportation. In a large civil engineering project, the refrigeration technology also plays a very important role. The refrigeration science and technology is an indispensable support technique in the modern science research, modern industry, and modern daily life.

In China, around 20% of the total energy consumption is due to the operation of the refrigeration and its auxiliary system. According to the investigation, the 20%—30% energy saving potential remains with the current operation level. And most of the HCFC refrigerants applied to the vapor compressing refrigeration, as one of the major refrigeration methods, cause ozone depletion and greenhouse gases emission and are going to be banned in the near future. Therefore, the refrigeration industry and refrigeration science take their overall responsibility and challenges to solve the problems for energy saving, greenhouse gas reducing, and environment protection.

China is the biggest equipment manufacturing country for refrigeration in air conditioning, food storage, and fresh keeping, etc. in the world. It produces half of the products in the world for the absorption chiller, room air-conditioner, refrigerator and cold storage reveal cupboard, etc., which

has great influence on the domestic economic development and export. It is also the biggest market for the above refrigeration equipments.

In the recent years, the refrigeration science and technology has made the significant progress and magnitude innovation in China. However, comparing with the number one position worldwide for the refrigeration product manufacturing, Chinese researches in this areas have lagged behind, such as fundamental research, high quality product, overall manufacture level, and energy efficient system operation. On the whole, we are lack of original, core, and advanced techniques except few outstanding achievements. The main reason is due to the fact that the fundamental research of refrigeration science and technology in China falls behind in the latest development of the application requirement; the overall level of the science research does not conform to the current status of refrigeration manufacturing and application. The role of China refrigeration academic community in the international academic world could not keep pace with the improvement of international status of China manufacturer and application engineer. The introduction of the present status and comparison for the major research areas of refrigeration science and technologies in China are as follows:

5.1 Novel refrigeration technology

In aspect of thermoacoustic refrigeration, many important progresses have been made in recent years. In the fundamental research field, a new mesoscopic scale thermodynamic theory has been developed for alternating flow heat engine and refrigeration machine. A new non-linear theory for thermoacoustic effect has been developed in order to establish the weak non-linear analytic theory for thermoacoustic. So far, an energy-focused traveling-wave thermoacoustic engine with the highest efficiency of 32%, which can be used as a thermal wave compressor, was successfully developed. Also, a thermally driven thermoacoustic cryocooler achieved the lowest temperature of 18°K which is below liquid hydrogen.

However, in the research field of magnetic refrigeration, laser refrigeration, and semiconductor refrigeration, there is still a long way to go in order to reach at the world advanced level. Although in the field of magnetic refrigeration, Chinese scientists have made a good progress in iron-based NaZn13 - type

magnetic material for room-temperature cooling with advantages of low-cost material and easy fabrication, there is still a gap for developing magnetic refrigeration prototype between USA and China. American scientist developed the best rotated-type magnetic refrigerator with several hundred watts of cooling power. The research of laser cooling is also being led by American scientists. And there's almost no practical development for this kind of research in China, the reason is lack of the research on laser refrigeration material and laser system. In the area of semiconductor refrigeration, there was a major breakthrough for the material development in the recent years in the US; however, the research in this field is at a standstill in China.

5.2 Refrigerant replacement

Chinese government actively participates in and promotes international cooperation in the refrigerant replacement. In order to sustain the China's refrigeration development, and maintain the current superiority of the refrigeration field, a new self-directed innovation refrigerant replacement route with Chinese characteristics must be developed. With the effort and the close cooperation between all involved parties, the refrigerant replacement route with Chinese characteristics is initially formed. The development in the refrigerant mixture also achieves gratifying successes. Great progress has also been made for measuring and calculating refrigerant thermal properties.

Nature refrigerant is another solution for the refrigerant replacement. Research on the application of CO_2 and hydrocarbon in refrigeration has made some progresses in China. China also involve in the ISO standard development for testing and evaluating compressor performance. The refrigerators using hydrocarbon as refrigerant have already export aboard. However, there is still a long way to go to reach at the world advanced lever for the CO_2 application in compressor and refrigeration system.

5.3 Cryo-biomedicine

Cryo-biomedicine including cryobiology and cryo-medicine is an interdisciplinary science that grows with the development of biology, medicine, and cryogenics in the last few decades. Huge progress was made in the research of biological bodies, tissues, and cells preservation with the cooperation of the nano technology and cryo-biomedicine. In China, there are already seven umbilical

cord blood stem cell banks. A major innovation and optimization for low temperature refrigerator under −40℃ has been made in order to fulfill the biomedical material preservation. A low temperature refrigeration cabinet with all temperature zone series has been developed.

Great progress has also been made in the area of the cryo-surgical operation technology and instruments development. By combining the nano technology with cryo-engineering, an advanced minimally invasive treatment method for the therapeutics of malignant tumors has been development, and further development has been made on mechanism study, experimental study, and medical instrument study. The original technical solution for cryoprobe technique and its instruments are in the stage of full inspection and testing.

However, comparing with the other countries, there are still a few of independent innovations in the field of cryo-biomedicine development in China.

5.4 Refrigeration equipment development

China is the biggest manufacturer around the world for the refrigeration equipment production. For the development of small scale cooling and refrigeration equipments, we already possess the capability of scroll and rotate compressor research, design, and manufacture. A great breakthrough has been made in the area of linear compressor development, but there is still a long way to go for the further improvement. For the large and medium scale refrigeration equipments development, China has already become one of the major research and development bases for the screw compressor. However, there's still a gap for the three-screw compressor research and development due to lack of core technique. The large scale centrifugal compressor with mixture refrigerant is under the development for the on-megaton/y LNG plant. But, it still lags behind with the advanced level for the system design and processing technology, especially for the magnetic centrifugal compressor development, which can represent the future development of the centrifugal chiller.

The development on the absorption refrigeration system has been greatly improved in the past two years. China has become the leader in the world in the field of the technological level and production scale of absorption

refrigeration system. Except refrigeration system, the absorption heat pump system has also been widely applied to the industrial waste heat collection, combined electricity and heating plant.

China also plays a very important role in the adsorption refrigerant system. With the development of the refrigerant, processing, instrument structure, the adsorption refrigeration system has been successfully utilized for building solar energy air conditioning, bus air conditioning, and fishing vessel in deep sea cold storage, etc.

5.5 Frozen and refrigerated storage-transport technology

Currently, the patterns for pastoralism, agriculture, and fishery production and supply in China enter into a very important transitional period. The traditional handicraft industry with a local supply-marketing-production chain has changed into industrialization with reasonable scale, long distance transportation and different places marketing, it leads to stupendous demand for the research and operation management on frozen and refrigerated storage-transport technology. In order to meet the requirement, great progress has been achieved in the relevant field of fundamental research. The basic storage data acquisition for curtain kinds of food has been conducted. More clear ideas have been derived for the storage condition requirement of the products. Chilling and freezing of aquatic food products also have been greatly developed. However, comparing with the rich and complete storage data in the developed countries, there's still a long way to go. A series of pre-cooler, fast cooling, fast freezing and thawing equipments have been developed in the recent years. The energy performance of cold storage has been improved by introducing new design standard and new type of terminal units. For the long distance storage-transport, the insufficient transportation capability becomes a stumbling-block for the development of the cold chain. With the development of the rail system, the research on the transport refrigeration container technology has opened a new path for the cold chain development.

China is the biggest manufacturer for the supermarket cooling cabinet. However, the main manufacturing technique used by the cabinet imports from abroad with very letter innovation.

5.6 Refrigeration for air conditioning in buildings

China is the world biggest market for the building air conditioning systems. With the thorough work on building energy efficiency, different kinds of heat pump system have been widely applied to the buildings for heating in the winter and producing domestic water. In the industrial sector, research institute, and medical department, refrigeration for air conditioning also plays a very important role for producing special micro climate conditions.

China has made a great progress in the development of the heat pump systems for ground source, underground water source, surface water source, and sewage source. The analytic solution and integral solution for heat transfer and storage process have been deduced for different type of ground heat exchangers. The application of the unique single vertical well collecting and recharging technique in the suitable geology condition can decrease the number of the wells and insure recharging ground water. The techniques of scroll compressor injection and rejection are also widely applied to solve the problems of insufficient capacity and compressing ratio of the air source heat pump system in the low temperature climate conditions.

The central air conditioning system with temperature and humidity independent control has been widely applied to the civil and industrial buildings. The new type of liquid desiccant air handling unit has been developed. A big progress has also been made for the wheel dehumidification process in high performance desiccant preparation and honeycombed ceramic rotate core model. The indirect evaporative chiller has been widely applied to the dry area in northwest part of China with the overall 50% of energy improvement comparing with the vapor compressing chiller. The new kind of temperature and humidity independent control system has expanded industrial scale and applied to many cases.

5.7 Gas separation and gas liquefaction

China is a leader in the area of small scale natural gas source, CBM, and associated gas in oilfields source liquefaction technology. A new type of movable device has been developed with an efficient process. However, we just begin with the research on the large scale nature gas liquefaction. Currently, most of the large scale gas separation equipments used in China

still import from overseas. Only small capacity instruments are domestically manufactured.

5.8 Refrigeration in the large scale civil engineering

A new process based on refrigeration technology has been established to solve the problem of concrete heat emission during the dam pouring process. The heat pipe technology resolves the problems of the permafrost melting in the Qinghai-Tibet railway construction project. Freezing construction technology is developed and applied to many large scale civil engineering projects by solving the key problems existing in the underground, mine, and large bridges construction process.

In conclusion, the refrigeration science and technology in China, accompanied with the urban and rural development, economic development, and improvement of people's living standard, has been great improved and developed. However, the modernization development continuously drives new requirements for the refrigeration science and technology. In order to accomplish the three major tasks, namely, improving the living standard, raising energy efficiency, and reducing greenhouse gas emission, we must accelerate the researches on the refrigeration science, such as frozen and refrigerated storage-transport technology, cryo-biomedicine technology, refrigeration technology in air conditioning. On the other hand, refrigeration science and technology will take on its overall responsibility and copy with the challenge for replacing refrigerant that damages atmosphere environment and improving operation energy performance of the refrigeration systems applied to the all fields. The refrigeration science will face a long task with the great significance. And it will continue to strengthen its efforts in the following research areas:

(1) Fundamental theoretical research should put forward the new findings and analysis method for the current refrigeration system based on the new theory of heat science, create new refrigeration method, establish new refrigeration cycle and thermodynamic design method, develop a material properties testing platform, build material properties database, build a research platform for refrigeration and low-temperature flow and heat transfer in order to obtain the data of low temperature flow and heat transfer process.

(2) Refrigerant replacement. An overall balanced evaluation method is necessary for the refrigerant replacement. Meanwhile, the exploitation of refrigerants, the analysis of refrigerant's thermal properties, and the application research are very important for developing environment-friendly alternative technology. It is important to push forward the HC290 and HFC32 applications as an attractive choice by considering with the balances of carbon dioxide emissions, safety, energy saving and availability, and an ideal and long term refrigerant alternative to replace HCFC22; the development of the key techniques on the application of nature refrigerants should be accelerated; and high efficient and safety system equipments with ammonia, CO_2, and HCs should be developed as the refrigerant.

(3) In the research and development of refrigeration key equipments, compressor is the "heart" of the refrigeration system; it also plays a key role for the energy efficiency improvement of refrigeration products. Great progress could be made for the centrifugal compressor research by making breakthroughs on the key technologies, such as high efficient impeller design, magnitude bearing, small sized clearance and dry-gas seal, etc., in order to achieve localization of the centrifugal compressor. It is important to push further the development of the small scale frozen and refrigeration storage equipment and room air-conditioner by developing larger scale linear compressor. In addition, the great attention needs to be given to the study of expansion valve performance and new expansion valve control algorism. The refrigeration system performance could also be improved by means of accurate and precision design on the high efficient heat transfer and processing matching.

(4) All the standardization works should be perfected. In order to meet the above requests and push further the development on refrigeration science in China, the following questions emphasizing on the interaction between policy and system need to be addressed: Firstly, the refrigeration science should be upgraded as the discipline in the subject management catalog, which will be of great helpful for the refrigerant science development and strengthen the infrastructure. Secondly, national key scientific research projects for refrigeration science and technology should be set up in order to push forward the research on the subjects related to refrigeration science

comprehensively and systematically. Thirdly, the new mechanism of development of talents with high skills in refrigeration science should be set up in order to avoid talents shortage. Fourthly, the organizational research institute and research platform construction should be strengthened.

6 Control Science and Engineering

The development of the automation science and technology liberates people from heavy and dull work. In the scope of industrialization, automation is a step beyond mechanization, and plays an important role in the country development and people's daily life.

In China, the "control science and engineering" discipline is divided into five branches; that is, control theory and control engineering, pattern recognition and intelligent systems, systems engineering, navigation, guidance and control, and detection technology and automatic equipment. Over the past decades, the fundamental theory of control has gradually matured. "Control" has been widely applied to the military, transportation, medical area, and service industries, etc. In the past several years, there was significant development in the control science and engineering. From 2008 to 2010, there were 21 "National Awards in Science and Technology" granted in the field of automation science and technology. Among them, there are five second class National Awards in Natural Sciences, 12 second class National Awards in Science and Technology Progress, and four second class National Awards in Technology Invention.

6.1 Development of control science and engineering in China

6.1.1 Control theory and control engineering

There has been important progress in the researches on robust control, non-linear control of power systems, discrete event dynamic systems (DEDS), quantum control. The parameterized design method of the robust control system proposed by Prof. Duan Guangren was a great contribution to the robust control theory, which was recognized as the 2008 second class National Award of Natural Sciences. The team led by Prof. Lu Qiang of Tsinghua University made an important contribution to the non-linear control of the large scale power systems. The team was granted the 2008 second

class award of National Award of Natural Sciences. They developed a nonlinear robust stabilizator "NR－PSS" and applied it to Baishan and Fengman hydropower stations in Jilin Province in 2007 and 2008, respectively. Prof. Cao Xiren proposed a unified framework for learning and optimization, which is fundamental theoretical contribution to the control theory. Prof. Zhao Qianchuan and Prof. Jia Qingshan in collaboration with Prof. Ho Yuchi extended ordinal optimization theory to multi-objective and constraints existent cases. Prof. Cao Xiren, Prof. Zhao Qianchuan, Prof. Chen Xi, and Prof. Jia Qingshan were granted the 2009 second class award of National Award of Natural Sciences. Prof. Wu Rebin gave the optimal control policy on continuous variable quantum system, and the general control method based quantum landscape. The team led by Prof. Wang Yiqun was granted the 2009 second class award of National Award of Science and Technology Progress for the contribution to AGC systems.

6.1.2 Pattern recognition and intelligent systems

In the past several years, there has been important process in the fields of the pattern recognition theory, the computational genomics, brain-computer interface (BCI), and the mechanism of acupuncture. In the dimension-reduction research, Chinese scholars are at the world leading position. A group working on this research direction in the Nanjing University of Science and Technology was awarded the 2009 second class National Prize of Natural Sciences. Tsinghua University in collaboration with the Cold Spring Harbor Laboratory, US obtained the most accurate identification method for the core promoter. In the BCI research, the researchers from Tsinghua University proposed a new paradigm of BCI, and the research was published as a cover article on *IEEE Transactions on Neutral Systems and Rehabilitation Engineering* in 2010. The research group led by Prof. Tian Jie of Institute of Automation, Chinese Academy of Sciences, has done a lot of significant research on the mechanism of acupuncture.

6.1.3 Systems engineering

In the area of emergency decision for the public security, information service, and intelligent systems, there has been important research progress as well. The study on the national emergence platform was started in 2004 by

Tsinghua University and some other institutions and now is a hot research topic. Prof. Wang Feiyue of Institute of Automation, Chinese Academy of Sciences, applied the ACP method to the transportation, and proposed the theory of parallel control and management. The research results have been used in the transportation management practice and have played an important role in the Asian Games held in Guangzhou in 2010.

6.1.4 Navigation, guidance, and control

China has made great progress in the satellite navigation, inertial navigation, flight control, big airplane R&D, and the companion flying technology of the accompany satellite. China launched the first five satellites successfully for the BD－2 system in 2007, 2009, and 2010, respectively. Around 2012, BD－2 will provide service for the Asian-Pacific area. Mechanical support inertial flywheel was applied to the meteorological satellite. There has been a breakthrough process in the product R&D and application of magnetic suspension support flywheel and control moment gyro (CMG). The research group led by Prof. Wu Hongxin of Beijing Institute of Control Engineering proposed the feature-based intelligent adaptive control theory. China launched the big airplane plan in Nov., 2008, and exhibited the shape sample in Sep., 2009 in Hong Kong. In Oct., 2008, the companion satellite of Shenzhou－7 was launched and it ran well. On Mar. 1, 2009, a satellite of Chang'e－1 successfully impacted the surface of the moon and returned clear images. China has made much porgress in navigation and guidance, but there is still a long way to go in comparison with the world advanced level.

6.1.5 Detection technology and automatic equipment

In the field of the fundamental technology of the sensors, China has obtained a breakthrough in the research of high performance ceramic material. The research on chip capacitor level and their components are at the world advanced level. The "electrochemical gas sensor" developed by Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, was listed in the "Top 10 News of the 2006 Scientific Instrument Analysis and Test Industry" indicating that China has achieved the world advanced level in this area.

6.2 New directions and interdiscriplinary studies

Besides the progress made in the above traditional directions, there has been progress on some new directions and interdisciplinary studies. Some important ones are given as follows:

6.2.1 Management and control of the information in the Internet era

As the Internet develops, the life of people has been changed a lot. Due the wide connectivity of the Internet, the information spreads very fast, which enhances the destructive power of the false news. The "human flesh search" has received a lot of attention. With the situation, the public relations capability via the Internet plays a very important role. This is why the research on "social computing" was developed. There have been many international research institutions and companies working on the social computing; they are University of Arizona, Carnegie - Melon University, University of South California, IBM, and Microsoft. The Institute of Automation, Chinese Academy of Sciences, is at a leading position of the social computing research. It hosted the first and second national conferences on social computing.

6.2.2 Control of the human-in-loop systems

In the early period, the control objects are machines, pressure, and temperature, etc. But now, human's participation plays a more and more important role. In the fields of public security, chemical process, and nuclear energy, the consideration of human factors should be placed at the first importance. In the transportation system, the relationship among people, vehicles, and roads should be fully considered. Due to the uncertainty of human, the control for the human-in-loop systems is a rather challenging problem.

6.2.3 Unmanned system and swarm system

On one hand, the research goes into the men participated system and the society; on the other hand, the research goes into the unmanned system and unmanned swarm system. The "unmanned system" refers to the unmanned platforms and ancillary equipments, including unmanned aerial vehicle (UAV), unmanned ground vehicle (UGV), unmanned undersea vehicle (UUV), and unmanned surface vehicle (USV). There are demands for autonomous control as well as "unmanned/unmanned" cooperation. Research in this direction produces the challenges in fault tolerant control, autonomous

navigation, environment sensing, and autonomous decision-making and planning.

6.2.4 Interdisciplinary studies with biology and medical science

The research on biology system has become an important direction for automation. Besides bioinformatics, system biology and BCI have attracted the wide attention. The direction will become more and more important in the future.

6.2.5 Studies on emerging industries

With the development of sensors and Internet, the research on the Internet of Things (IOT) becomes a hot topic. The big airplane, the high speed railway, and the magnetic levitation are important things in the development of the industries in China. At the same time, they bring many challenges to us. For the purpose of energy conservation and sustainable development, China launched a big program for developing the nuclear power. The self-healing instrument control, digital and intelligent protection technologies combined with man-machine intelligent robot technology and 3D simulation modeling technology are highly demanded. These new developments in the industry will drive the further advance of control theory and applications.

Since the sustained efforts made by several generations, China's economy has maintained a rapid growth. The development level of a country is often highly affected by the development of the science and technology. The development of the science and technology promotes the development of the social and economic development, and the development of the country supports the development of the science and technology, which is a complement to each other. China has made great progress in the research on the automation science and engineering. However it is still too early to celebrate since the gap between China and the international advanced level is still large. In the 21st century, the role of technology will become more important. The automation level, a symbol of nation development, is of extremely importance. With the development of the country, the more research on the automation will move to the fundamental theory and newly emerging interdisciplinary studies. We need to continue the efforts, and to make contributions to the fundamental theory and significant applications.

Only in this way, we can repay the country and the people.

7 Aeronautical Science and Technology

With the construction of innovative nation goes into deep, the strategic status of aeronautical science and technology becomes more and more prominent. In the year of 2008, the aviation industry was restructured. Greater support is given to the innovation in aernautical science and technology. As a result, aernautical science and technology enters into a rapid development period. Remarkable progress is witnessed in the following fields:

7.1 Aircraft design and analysis

The C919 full-scale mockup was officially displayed in Zhuhai Airshow and C919 received 100 initial orders.

7.2 Helicopters

On December 17, 2009, EC-175/Z-15 co-developed by China and France successfully finished its first flight in Marseille, France. On March 18, 2010, the large civil helicopter AC313 succeeded its maiden flight in Jingdezhen, Jiangxi Province, China. Some new results were achieved in multi-discipline optimization, stealth design, manufacturing technology of helicopters, and tilt rotor studies.

7.3 Unmanned aerial vehicle system

Thanks to the progress in the information technology, UAV is the most rapidly developed one among all kinds of aircrafts. Currently, the long-endurance home-made Pterosaurs I UAV is being tested and is likely to enter the international market. A great number of unmanned helicopters developed by China including WD100 and U8 have finished their first flights successfully. Besides, the flapping-wing Micro UAV ASN211 was developed.

7.4 Aero engine

After many years' construction and development, the infrastructure and standards for experimenting, testing, and processing of aeroengine industry in China undergo dramatic improvement. There are a large number of advanced facilities to carry out experiments or manufacture aeroengines and their parts, which provide solid basis for developing high bypass ratio

turbofan engines.

7.5 Flight mechanics

In recent years, new breakthroughs in the studies on non-linear flight dynamics, elastic flight dynamics, unsteady aerodynamic modeling, and civil aircraft flight quality and airworthiness are achieved via China's independent innovation based on digesting and absorbing foreign high-level research results.

7.6 Flight test

For newly-developed civil aircrafts, we can basically finish the certification and flight test according to the airworthiness standards specified by *China Civil Aviation Regulations*. Besides, some of Chinese flight test institutes are capable of testing one particular aspect, such as aerodynamics, flight dynamics, structural integrity, power plant and airborne systems and solving technical difficulties through flight test.

7.7 Flight technique

As aeronautical transportation develops rapidly and new technologies are applied constantly, flight technique advances fast and obtains a number of achievements. A320 family flight training device, Kitty Hawk 500 training device, and B737 cabin and warning training device succeeded in development; flight training technique improves steadily.

7.8 Aviation safety management

Perspectives closely related to aviation safety management like human factors, safety information management, safety culture, risk management, accident investigation are improved to a large extent. The theoretical level, model, technique, and applications of aviation safe management all progress with the different degrees.

7.9 Air traffic management

To adapt the fast growth of our air transportation, China's civil aircraft ATM system carries out technique tracking, studies, experiments, and applications. Performance-based Navigation (PBN) is promoted step by step; the study and application of Automatic Dependant Surveillance (ADS－B/C) shows remarkable progress.

7.10 Ground support system

At present, China possesses a certain capability for developing and

manufacturing special vehicles for the purpose of ground support. A comparatively complete set of solutions to emergency rescue equipments and operation management was formed. Domestic airfield lights technology is relatively mature. Ground support operation under special circumstances was studied. Ground command and dispatch management system was developed and applied to the practice.

7.11 Aviation reliability systems engineering

After 30 years, China's reliability systems engineering has been developed into a multidiscipline subject and is seeking the discipline optimization. It targets a complete set of aviation products instead of a single one like before. It is applied to the entire life of an aviation product not just on the development stage. It was used to remedy and prevent problems, but now it can predict them. The working measures experience the transformation from manual operation to automation, intelligentization, and simulization.

7.12 Aeronautical composites

In China, composite materials for the vertical stabilizer, the forebody, the horizontal stabilizer, and the wings of aircrafts were studied one after another since 1980's. In the middle of 1990's, the composites applied to the vertical stabilizer of Y-7 were studied and finally pasted the ground validation test and the airworthiness certification. Composite materials are used in the secondary load carrying structure of ARJ21 which is going to deliver to the customers in the year of 2011. In October, 2010, the successful development of the rear pressure bulkhead for C919 provides the valuable experience for the application of composite materials in the whole project.

7.13 Testing technique

With the development of equipments and growth of national defense scientific research capability, the testing technique is widely addressed by both militaries and the national defense industry. The revision of the Testing Outline is basically completed. Comprehensive test is evolving towards vertical test integration in the whole life cycle of aeronautical products. Prognostics and Health Management (PHM) is improved. New sensor technology has been applied.

Nowadays, more and more countries are involved in the competition of aeronautical science and technology. In order to gain the competitive edge,

America issued *Aircraft Investment Plan Fiscal Years* (*FY*) 2011－2040; EU started *Clean Sky Plan*, Russia restructured its aviation industry at a deep level and required Russian airliners to purchase domestic airplanes. Due to the increasing support from governments, aeronautical science and technology has entered a rapid development stage and has made a series of breakthroughs. .

In recent years, China has successfully developed J－10, ARJ21, MA600, Z15, and AC313 and made breakthroughs in the field of structural design and analysis, aerodynamics, structure, avionics, aviation electro-mechanics, and so on. The capability of aeronautical science and technology to support our economy and national defense is greatly enhanced. Despite all the above achievements, China still lags behind foreign advanced levels in aeronautical science and technology which can be reflected as follows:

Firstly, the development of military and civil aircraft is unbalanced. There are a few competitive civil aircrafts and so far no product family has been formed.

Secondly, a little research on new technologies is implemented. Foreign countries have given great importance to new concept vehicles. America formed the X family research aircrafts, Russia and EU develop research aircraft of S－47 and Neuron respectively. By exploring these new concept vehicles, professional knowledge on aircraft configuration and technology selection can be accumulated, which could lay a foundation for the development of new aircrafts. China's technical storage in this respect is insufficient.

Thirdly, there is a shortage of design tools, and the design means should be updated. Aviation technology incorporates many high-techs. Design is actually a process to balance, compromise, combine, and optimize different systems and techniques. The complexity of modern aircrafts is continuously increasing due to the development of science and technology. Traditional design measures are not competent for designing modern aircrafts. Under such conditions, design software and multidiscipline optimization software represented by CATIA and iSIGHT have been developed by other countries, which enhance the capability of digital design, simulation, optimization, and concurrent engineering. However, we have not developed any software of

this kind.

To accelerate the development of China's aviation industry and foster the construction of innovative country, strategic requirements proposed in this article are as follows:

Firstly, the model development of new products should be supported. China's new aviation products represented by C919, ARJ21, and JL 600 have entered into a very critical period. We must overcome all difficulties occurred in every developing stage to guarantee the quality, performance, and security of Chinese products, and therefore provide reliable equipments for air transportation, and aviation S&T development.

Secondly, we should push forward technologies by developing large aircrafts. Premier Wen Jiabao pointed out that the large aircraft is considered as a pearl of modern manufacturing industry, because it highly integrates many modern high-techs. Its development can stimulate swarms of the breakthroughs of core technologies in new materials, modern manufacturing, advanced dynamics, electronic information, automation, and computer science. China is continuously making breakthroughs in the field of materials, information, and energy with the deepening of innovation. Aviation science and technology should play a strong role in the advancement acceleration in newly-emergent technologies.

Thirdly, innovation capability should be further enhanced. China's aviation industry from maintenance and imitation stage enters into independent research stage. To increase Chinese innovation competence, we should strengthen the exploration of frontier technologies, which not only add new technical elements to independent innovation, but also push forward other technologies in relevant.

By taking the environmental and strategic requirements for domestic development of aeronautical science and technology into consideration, we suggested that future emphases might be put on green aviation, new generation of helicopters, Future Air Navigation System(FANS), advanced aerodynamics configuration, active structure technology, autonomous control and decision making technique, engine with high thrust to weight ratio/high power to weight ratio, high-performance composites, nano materials and application technology, aircraft prognostics and health management.

8 Ordnance Science and Technology

During the National Day Military Parade for celebrating the 60th anniversary of the People's Republic of China, some new types of ordnance, such as the new main battle tanks, 155mm self-propelled howitzer, the long-range multi-tubular rocket cannons, etc., made their first performances on special force formation in the parade on the Tian'anmen Square to accept the inspection of the party and country's leaders, which exhibited Chinese national and military strength and prestige, and also showed the achievements and advanced level of the ordnance science and technology of China.

Some important progresses have been made in the field of both weapons producing technologies, such as armoring, barrel weapon, guided weapon, ammunition, underwater weapons, etc, and basic technologies, such as high-energy materials, defence, combustion and detonation, ballistics, information, material and manufacture, etc, which produce and develop a passel of new ordnance.

The topics of the academic developing report on ordnance science and technology have been chosen from the correlated subjects of enginery and firepower systems. Four special topics, namely, ordnance launch theory and technology, propulsion and extended range of theory and technology of projectiles and rockets, precision theory and technology of projectile and rocket, and high efficient damage theory and technology, have been discussed in order to present the current developing status of correlated subjects of enginery and firepower systems in China, the disparities with foreign advanced levels, and also the developing tendency of weapon systems in the last two years.

8.1 Main developments of firepower system for ordnance science and technology in recent years

8.1.1 Theory and technology of ordnance launch

In recent years, some important achievements have been made in the field of new launching technologies, such as electrothermal chemical launch, electromagnetic rail launch in China. At present, it is hopeful for the electrothermal chemical launch system to be applied to the engineering field,

and the mechanism principle samples have been manufactured for electromagnetic launch. Multi-tubular launch systems for middle or small calibers have been produced; investigations on the weapon safety and launch dynamics have also been conducted.

8.1.2 Propulsion and extended range of theory and technology of projectiles and rockets

The ranges of compositing range extension of cannonball and tactical rocket weapons have been obviously increased. Some investigations have been made in the fields of high energy propellant, shell material of high intensity and light weight engines, aerodynamic drag reduction, and electromagnetic drag reduction.

8.1.3 Projectiles and rockets precision theory and technology

In recent years, many kinds of guided and accurate precision technologies have appeared, such as, the terminal sensitive, trajectory correction, guided and terminal guided, simplified-control, etc., which enhanced the probability for hitting target greatly.

8.1.4 High efficient damage theory and technology

The penetration performance of nano-grained composite material of penetrator has been greatly increased. The passive mass of the penetrator has been decreased with the use of magnesium matrix composites as the ball base. The damage power of ammunition has been enhanced with the application of high energy mixtures to composite explosives. Some breakthroughs have been achieved in the fields of formation and transition mechanism of multi-damage models, explosion control technologies. The penetrating law of multi-layer building target and stability of explosive charge has been studied, the mechanism of high-velocity penetration has also been researched; the evaluation theory of target damage has been improved.

8.2 Comparison of both the domestic and international developing status on firepower system of ordnance theory and technology

8.2.1 The theory and technology of ordnance launch

There are some disparities with foreign advanced level in the areas of system integration, electromagnetic compatibility, weapon structure, and continuous feeding technology; and the same is true for the weaponization process as well as the high frequency launching of the artillery.

8.2.2 Propulsion and extended range of theory and technology for projectile and rocket

The range of extended range cannonball of foreign advanced levels has been over 100km, and over 300km for the simple guided rockets, and we have an obvious gap in above fields. As for the new concept propulsion technologies, some of them have been successfully applied to the design of new projectile and rocket in some foreign advanced countries, and there are still some gaps in China, and the capabilities of high energy and composites still need to be improved.

8.2.3 Precision theory and technology of projectile and rocket

The investigations on the field of incorporate design, simulation, virtual prototype, etc. need to be deepened. There are some disparities for the multimodal guiding and kinds of compound guiding technologies, and the advanced control theory has been explored.

8.2.4 High efficient damage theory and technology

Comparing to foreign advanced level, there is a gap for Chinese evaluation theory of target damage. As to the investigation on the penetration mechanism of hard targets under the high velocity impact, such as reinforced concrete, rocks, etc, the new technology of damage is not consummate; also it is later for the starting of study on high energy/super high energy materials.

8.3 Developing tendency and prospect of firepower system of the ordnance science and technology

(1) To explore the new concept of launch principles, increase the initial velocity and launch frequency, and implement the enhancement of launch performance of ordnance.

(2) To improve the range of rocket, cannonball greatly, and achieve the long-distance flight of ordnance.

(3) To develop the precision of projectile and rocket, and improve the probability of hitting target.

(4) To develop the ammunition of smart damage, high energy low damage, and new type of damage, and realize the high efficient of hitting all kinds of targets.

9 Textile Science and Technology

As the traditional pillar industry, the important industry to people's

livelihood, and industry with international competition advantage, textile industry plays an important role in flourishing market, expanding export, absorbing employees, enhancing rural income, and promoting urbanization. China's textiles rank the number one in the world in term of production scale and export trade.

9.1 Advances in textile science and technology in recent two years

9.1.1 Scientific and technological achievements of textile industry

9.1.1.1 Significant achievements in fiber materials

Industrialized production has been realized for high performance fibers and some biomass fibers, such as bamboo pulp and flax pulp fibers. The industrialized high performance fibers include carbon fibers, Nomex1313, ultrahigh molecular PE, PES, and Basalt fibers. Series varieties are further developed to expand their applications. Majority technologies and products reach at the international advanced level. Kevlar1414 and solvent-spun cellulose fibers have been in the medium-scale. The synthesis of new type PTT resin has made a breakthrough in respect of medium-scale.

9.1.1.2 Obvious advances in textile preparation and product development

The new technologies including automation, continuity, and high speed for cotton spinning have been nationalized and popularized in a large scale. All of these technologies contribute to the improvement of productivity and product quality.

New technologies promote the developments of high rank yarns. The application of compact spinning, air-jet spinning, air-vortex spinning, and insert spinning enrich yarn varieties and decrease yarn fineness of natural fibers as well as enhance yarn quality.

The blended/interlaced yarns with multiple fibers and innovation in the fabric structure greatly enrich fabric varieties. In dyeing and finishing industry, cold pad-batch pretreatment with reactive dyes and other new technologies, such as dyeing, digital printing, and pigment printing, are the self-oriented development. Advanced electronic information technologies including electronic color separation and plate making, automatic size mixing, and online inspection are adopted. The applications involving above-mentioned new technologies greatly improve the quality, stability, and additional value of fabrics.

9.1.1.3 Fast development and application of environment-friendly technology

Lots of breakthroughs have been made in new technologies with the low energy and water conservation, and these technologies are popularized in the industry.

9.1.1.4 Rapid development of industrial textiles

The properties of industrial textiles have been greatly enhanced due to the application of high performance fibers. New cellulose and PLA fibers are successfully prepared by solvent spinning. These biomass fibers are antibacterial and degradable, and promote the development and application of medical and healthy materials.

9.1.1.5 Big enhancement in self-oriented innovation capability and manufacture level of textile machine

The batch productions have been realized for large-volume spun polyester complete equipments, high efficiency and modern cotton production line with new type blowing-carding unit, automatic winder, and mechanical-electronic integration rapier and air jet loom. Part of products reaches at the international level and replaces import products. The number of self-oriented equipments for producing chemical fibers and cotton significantly increase in China. Some nonwoven and knitting equipments are successfully developed and are rapidly pushed into the market. These equipments include both spunbond and meltbond water-needle punched nonwoven equipments and smart circular weft knitting machine, multi-function computer-controlled flat bed machine, and modern warp knitting machine. The application of these advanced equipments reduces product costs. For the dyeing and finishing equipments, many new products with low energy consumption and water conservation are developed.

9.1.1.6 Popular application of information technology

The level of digital product design and automatic manufacture has made the great enhancement. Digital product design technologies, such as CAD and CAM, are extensively used, which results in the effective improvement of product innovative capability and response time to the market.

9.1.2 Achievements of sci-tech in recent two years

In recent two years, the scientific and technological achievements are plentiful and the subject develops rapidly. Among excellent project

achievements, some projects have been bestowed awards of State Invention Prize and the first-class and second-class awards of the State Scientific and Technological Progress Prize. The projects have a wide coverage, contain high content of science and technology, possess excellent economic effectiveness, and indicate great advances of textile industry in the implementation of scientific outlook for developing and building innovative country.

9.2 The discrepancy between overseas and domestic textile industry and development goal

Textile industry is a resource intensified industry. The industry greatly depends on natural fibers of cotton, flax, silk, and wool and synthetic fibers produced from petrochemical materials. The consumption of energy and water is enormous. The conflict with reusable resources will become increasingly significant with the industry development, and further increases the pressure putting on the balance supply and demand and raise utilization ratio. The environment pollution and unhealthy effect on human race more or less exist during the fiber and textile production, dyeing and finishing, cloth manufacture, and product disposal. With increasing attention given to the living environment and quality, textile industry is facing a great revolution on production technology and products. Modern science and technology provide technological supports for the harmonious and sustainable modern textile. The global information tide is greatly influencing the develop process of various industries. The consensus of opinion that traditional textile industry should be transformed with the graft of information technology has reached for insiders. Occurrences of new materials with special performances enrich textile products variety, upgrade product properties, and also provide new resources. The revolutionary changes of production method and development trial have taken place due to the combination of biological technology and traditional textile industry.

9.3 Suggestions on textile science and technology

In recent years, China's textile industry realized enormous transformation and upgrade. Content of science and technology and innovative capability are greatly enhanced. Achievements based on the original innovation, integrated innovation, and the second innovation after introducing and digesting are

plentiful. Lots of technological developments are industrialized, and become the most important support for promoting industry production and enhancing the productivity in the new period. In the new phase of China's market economy, textile industry has further realized the urgency for changing development mode and speeding up industry upgrade. The main tasks are as follows:

(1) To conscientiously implement key and industrialization projects proposed by the Twelfth-Five Outline of Scientific and Technological Progress of textile industry;

(2) To increase sci-tech investment and support technology innovation and advance;

(3) To perfect talent policy and optimize talent structure;

(4) To increase support for the majority of SMEs.

10 Pulp and Paper Science and Technology

10.1 Introduction

In China, the first machine made paper appeared in the year of 1884. However, modern papermaking industry in China has only been developed for about 30 years. Now, China has already become the number one paper production and consumption country in the world. The great changes in the papermaking industry of China are attributed to the development of pulp and paper science and technology. However, with the continuous high-speed growth, China's papermaking industry faces increasingly grim pressure and obstacles, such as fibers and water resource shortage, high pollution emission, and major technical equipment relies on imports, etc. These problems are not only the problems that must be solved for the further development of the industry, but also the key issues of the pulp and paper science and technology develop in the future in China.

10.2 Development situation of pulp and paper science and technology

The research and development resources for pulp and paper science and technology in China have a reasonable allocation and different levels. The principal parts are the research and education institutions and enterprise R&D centers. They are independent research institutions, research institutions

associated with the universities, and enterprise R&D centers. They include the state key laboratory for pulp and paper engineering, the pulp and papermaking national engineering laboratories, the pollution control national engineering research center, six enterprise technology centers certificated by government, and 20 universities with pulp and paper discipline.

Pulp and paper engineering, which belongs to first level discipline of engineering or second level discipline of light industry technology in China, is composed of a relatively independent discipline with their own systems of theory and knowledge. Pulp and paper discipline has formed a modern applied science and technology system with the pulping process, the papermaking process, mechanical equipment, chemicals, and environmental protection technology as its core.

As one of the upgrading traditional industries supported by government during the period of Eleventh Five-Year Plan, pulp and paper discipline carried out a number of key researches around national science and technology plan projects. All these projects have enormously promoted the development of discipline and the technical level of the papermaking industries.

10.3 Primary technology progress of pulp and paper discipline in China

The technical progresses of discipline at home are mainly embodied in the five aspects as follows:

10.3.1 Pulping science and technology

High yield pulp, in which chemical mechanical pulping technology is the mainstream technology in China, is heading for the direction of technical development with high strength, high brightness, low energy consumption, and low pollution. Domestic engineers and scientists have made an in-depth research on the utilization of waste paper, which greatly boosts the theory and technology progress of recycled fibers application. In the aspect of chemical pulp technologies, traditional batch cooking technologies are substituted by the new energy-saving and efficient cooking techniques step by step. At present, cleaner pulping technologies of wheat and bamboo can be applied integratively to the mills.

10.3.2 Papermaking technology

To meet the development of the wide width and high speed modern paper machine, China has researched, developed, and applied a series of techniques

to save water and energy and improve product quality. The applications of DCS and QCS realize the automatic control in the whole process. Domestic engineers and scientists have completed a lot of researches to enlarge non-wood fiber and HY pulp application proportion and achieved outstanding achievements. High ratio of GCC coating technology and coating technology of high-grade culture paper containing chemical mechanical pulp were studied. Formula of high coverage coatings and coating technology are used in coated kraft test liner and obtained practical technical achievements.

10.3.3 Pulping and papermaking equipments

Rapid development of paper industry greatly promotes the development of domestic equipment manufacture technology. In spite of the gap of the design and manufacture level between the domestic and international equipments is gradually narrowing, there still has the obvious disparity in the large complete sets of equipments and the core technologies of key equipments. At present, part of non-wood fiber pulping complete sets of equipments has reached at the international advanced level. Horizontal tube continuous digester and alkali recovery equipment using in the chemical and semi-chemical pulp of non-wood fiber raw materials have already exceeded the international level.

10.3.4 Chemicals of pulping and papermaking

In the process of pulping and papermaking, a large amount of various special chemicals are used and many achievements are obtained in this field. Pulping and bleaching agents, high-performance filler retention aids, synthetic surface sizing agent, and antiseptic agent have been deeply studied. Many new technology achievements have been obtained. Chemicals of waste water treatment are still a hot point of current research.

10.3.5 Pollution control technology

According to the new paper industry waste water pollutant emission standard (GB3544 — 2008), lots of researches in advanced waste water treatment were carried out. Some technologies, such as advanced oxidation process, activated biofilter, and super efficient dissolved air floatation technology, present a good effect on the in-depth degradation and decolorization of the effluent. Concentration techniques of solid wastes of pulping and wastewater sludge have had a further development. Water

recycling techniques were researched and developed in order to achieve the goals of ultra-low discharge or zero discharge. Some of enterprises have basically achieved wastewater zero discharge.

10.4 Comparison of domestic and international research progresses in pulp and paper science and technology

Due to the advantage of R&D conditions in the equipment, Europe and America are still ahead of China in HY pulp technologies and chemical pulp new technologies. With concerning the new energy development, overseas research hotspot is transferred from the single pulping and papermaking process to the compound biorefinery process which can produce chemicals, polymers, and biomass energy and pulp at the same time. Papermaking technology research abroad is mainly driven by papermaking equipment companies through the new equipments mainly focus on upgrading product quality and lowering down energy consumption. Reduce of the emission of COD and BOD of wastewater and the comprehensive resources utilization of solid waste are the research emphases at the home and abroad in the area of wastewater control technology. Due to the new water pollutant emission regulation (GB3544 — 2008) has come in to effect, wastewater advanced treatment and reuse techniques are becoming the hotspot. In the area of chemicals of pulp and papermaking, researches at the home and abroad generally pay attention to the development of new functional products. Domestic researches have many achievements; however industrialization and in-depth application technology are still relatively weak. In terms of pulp and papermaking equipment, China has obviously fallen behind the international advanced level despite the gaps between the domestic and international equipments are gradually narrowing. The market for the large complete sets of pulp and papermaking equipment is still monopolized by the multinational corporations abroad.

In spite of the rapid development, there still exists certain disparity between the domestic and abroad, except in the field of pulp and papermaking technologies using non-wood fiber. The reason comes from the following aspects. Firstly, independent innovation ability of pulp and papermaking technologies is relatively weak. Secondly, engineering technology development ability and industrialization ability are deficient. Thirdly, new technologies

are too difficult to realize industrialization.

10.5 Suggestions on the discipline development trend and research direction

10.5.1 Goal and prospect of discipline development

In recent years, China's paper industry is facing increasingly grim pressure and challenges during the high-speed development period. Due to the constraint of resource and environment, the development of pulp and papermaking discipline should take "low resources consumption, low discharge, renewable product, and waste recovery" as the target, take "developing circular economy, innovating development pattern, and building resource-conserving papermaking industry" as the core to seek the development. Discipline will also pay attention to the research on resource efficient and recycle utilization, pollution control, energy-saving, and emission-reduction technologies, and equipment researches in order to realize the perfect unification of industrial development, environment, and social benefits.

10.5.2 The future development trend of the discipline

Research achievements and its application will enlarge the scale of the pulp lines with more simplified process system, decrease the consumption of fiber resource and energy, reduce pollution load, and make the closing water system perfected. Future pulp mill will hopefully be a biological refinery complex plant in which pulp, energy and chemicals can be produced. The development of pulp and papermaking discipline will provide a powerful technical support for the development of the industry.

10.5.3 Advice on the research direction of discipline

In order to speed up the pace of technological progress, the following researches and technologies are suggested in future based on the consideration of papermaking industry status, development needs, and industry policy. They are high efficient and recycling utilization technologies of plant fiber resources, environment-friendly key technology in pulp and papermaking process, technologies of high performance paper-based functional materials, large, advance and special technical equipment with high integration and obviously promoted performance, and the key technologies of circular economy and low carbon economy in pulp and papermaking industry.

11 Food Science and Technology

With entering into the 21st century, food industry in China keeps on growth at a robust rate of over 20% for every year. Food science education and research programs across the country provide a solid support for the food industry and other relevant industries by their innovation development involving talents, knowledge, and technology. The development of food science programs thus has a fundamental impact on modifying industrial structure, enhancing industrial competitiveness, and achieving sustainable and inclusive growth for the food industry. This report gives a detailed introduction on the newest progresses that food science programs have made in the areas of discipline building, talents training, scientific research, and academic exchange. Countermeasures and advice for improving food science programs in China are proposed based on the analyses on the gap between domestic and overseas food disciplines and the study on the relation between innovation in food disciplines and food industry using mathematical model.

11.1 Current situation and tendency for food science and technology

Food science education and research program has gained a growth reputation and its impact increased in recent years. It becomes more influential on both domestic and overseas academia for its importance to the discipline orientation, the composition of academic teams, the level of scientific research, the quality of talents training, and social service.

11.1.1 Growth and upgrade of academic teams

A large number of high level academic backbone recruited recently have improved the composition of academic teams, a team composed mainly by highly educated young and middle-aged faculties who are full of pioneering spirit and innovation in study from many different but coordinative professions is built up. Up to September, 2010, three distinguished faculty members had been included in the national recruitment program of global experts and there are five experts from the field of food science and technology who are elected as the academicians of Chinese Academy of Engineering, it is regarded as the highest honor in Chinese academia.

11.1.2 Progress in teaching quality and its reformation

Many colleges and universities in China are trying to build a knowledge hierarchy in the direction of training talents of food engineering and establish a three-level curricular system by reintegrating curricular system and reformation in the content of courses, and teaching skills. In the year of 2010 alone, there were 11 courses approved as the national elaborate courses. Five courses had been approved as the national bilingual teaching demonstration courses between the years of 2009 and 2010; they are the major breakthrough in this program.

11.1.3 The fast-growing scale and continuous quality improvement of talents training

The amount of talents who have the major in food science and technology and train in colleges and universities is rapid growing, and there are more and more food science program were set up as well in order to meet the increasing demands for growing food industry in China. Since the year of 2008, 30 more colleges and universities have set up food science programs, it made the total number of colleges and universities offering food disciplines up to 235 nationwide.

11.1.4 The level of research keeping on the rise

Financial support for colleges and universities concerning food disciplines has been increasing in recent years. Value of laboratory equipments per student increased from 23,000 RMB *yuan* in the year of 2003 to 53,000 RMB *yuan* in the year of 2010. As the main source of financial input, government has continuously offered more and more support. For example, National Science Foundation of China granted the financial aid to more than 200 projects closely connected with food science and technology in the year of 2009, the total amount reaches at 62.625 millions RMB Yuan with an increasing rate of 156.7%, the amount was 24.4 millions RMB *yuan* in the year of 2007.

Science research capacity of food disciplines in China is improving significantly due to better teaching staff and more financial input in this filed. A major breakthrough was made, it is indicated by the 2010 National Award for Food Science and Technology Progress, among the 214 awards of the year, nine awards are directly connected to the food science and technology

including one first prize.

Dissertations with the high quality are also showing a significant increasing. By taking the articles published in SCI source periodicals of the food disciplines as an example, Chinese articles accounted for 7.75% of all the papers published in the field of food science and technology around the world, the statistic data for the year of 2004 was 3.71%.

Food disciplines in China not only realized a lot in science research and innovation, but also encouraged the development of industry-university-research institution cooperation by taking advantages of academia in research and making research results industrial use. Some enterprises have set up the state key laboratories, and bring the function of an important platform for developing common and critical technologies into play.

11.2 The breakthroughs in theories and technologies of food science and technology

Food disciplines have obtained major achievements with remarkable economic and social benefits in the three main systems, that is, food processing, biotechnology in food production, and food safety and quality control by keeping in touch with current trend of the disciplines and active exploration and by tackling key scientific and technological projects and indigenous innovation. A series of high-value-added research findings with high technological content and efficient industrialization are the major achievements of food disciplines from the year of 2009 to 2010, the findings greatly improve the international competitiveness in scientific development and application for Chinese food disciplines, allow farmers to sold agricultural products with a higher price than before, and increase the incomes for them.

11.3 Comparison between domestic and oversea food science and technology

Significant progress has been made in Chinese food discipline over the past few years as described above. However, comparing with developed countries, there is still a gap in food science between China and developed countries, it mainly embodies in the aspects of discipline building, discipline innovation capacity, and social service capacity.

11.3.1 Gap in discipline construction

In regard of cultivating methods, most western countries adopt a mode of combining general education with quality oriented education at present,

which is an all-around development with creative education through the whole process of teaching. Special education used to be prevailing in China. In recent years, the teaching method is turning to a mode of combining general education with special education; however the training for students' creativity is not yet sufficient. With regard to education background of academic teams in universities, only 12.1% of the teachers holding a doctor degree in Chinese universities, the number is much lower than that in the universities in the United States where this figure was 60% on average.

11.3.2 Gap in innovation capacity for the discipline

In the development country, adequate funds for research and development are usually guaranteed for the innovation capacity of the discipline. In terms of amount, total financial input for universities' research was 73.3 billions RMB *yuan* in the year of 2008, while in the same year it was 51.9 billions USD in the United States. In the year of 2011, NIFA in the United State initiated the "Program for Core Competence", in which research projects for food and agriculture received investment of 429 millions USD, a 63% jump compared with 262 million in the year of 2010. As the result, although papers and academic impact of Chinese study on food science have been growing with the high speed, gap with the top 5 countries in science and technology is narrowing, a major distance is observed from the amount of the papers and citation index reflecting academic impact. In term of academic impact of papers, the United States is 9.9 times higher than that of China from year of 2001 to 2009 according to the Chemical Abstracts Service, CAS by using 30 academic journals in food area, such as *Journal of Agricultural and Food Chemistry* and *Food Chemistry*.

11.3.3 Gap in social service capacity

The cooperation among industries, universities, and research institutes in the United States is not only limited to laboratory or research center, but also actively engaged in the production and application. For example, Massachusetts Institute of Technology (MIT) has transferred over 100 patents of biological technology since the year of 1986 with annual income of 3 billions USD, which is a quarter of the industry in the United States, it makes Boston the second largest biological technology industrial base in the nation and greatly push forward the development of American biological technology industry.

11.3.4 Domestic disciplines are still not yet comparable with overseas disciplines in overall competitiveness

Comparing with the advanced disciplines in developed countries, there is still a gap for Chinese food disciplines in the research level, although China has been making continuous progresses in this field. The proportion of teachers holding a doctorate among the teaching staff is still low, and professors and associate professors tend to age, this is the problems existing in the research team. Undergrads and graduate students at the home are weaker in social service abilities. Imbalance development is noticed in the aspect of basic research and skill level and thus further improvement is expected in both quantity and level for Chinese food disciplines. Global impact of the Chinese academia is still lagging behind the famous universities and institutions in the United States and Japan.

11.4 Strategies for development of food science and technology

Food disciplines in China have to determine direction and objectives based on the needs of the country and food industry and international frontier of food research science and technology, so as to fulfill the development goals of the Twelfth Five-Year Plans and especially the inclusive sustainable development of food industry. Detailed strategies are as follows:

11.4.1 Talents cultivation

The purpose of talents cultivation is to enable the students to achieve sustainable development; they could not only adapt to the society, but also orient to the future. Food disciplines shall take on the task of cultivating high-quality talents with high sense of social responsibilities, global vision, and the spirit for innovation by applying various types of cultivating methods with different standards in respond to diversification in higher education and diverse needs for the talents from the society.

11.4.2 To optimize the composition of the teaching staff and environment for disciplines development

Improving the teaching team is the most effective way to improve the quality and level of teaching and science research. Open attitude, excellent treatment, and preferential policies together with effective system and mechanism are helpful for attracting masters and leaders in food disciplines who are famous due to their achievement in food science and technology in

international academia. Internal training of talents remains vital, and a better teaching team can be built by cultivating masters and leaders in the disciplines based on the idea that everyone can play his full role.

11.4.3 Cooperation of industry-university-research institution promoting the industrialization of achievement in food science research

Promoting industrialization of research achievement in universities requires the government-engineered efforts as well as asset allocation by market, which can not be separated from further cooperation between enterprises and government-universities-research institutes. A service system which guides the work for encouraging application of scientific achievement in the industry may be improved with more funding.

11.4.4 To increase funding input

Funding in research is not sufficient as it is abroad, which is a limitation to further development of research and innovation in food disciplines. Government, as the main source for putting funds into education system, shall increase the investment in higher education, and provide a sufficient guarantee to the construction of a strong China. Expanding the ways for funding, such as social service, is also an effective solution to the problem of inadequate funding for university. Some practice in developed countries, such as encouraging public donation to the academies, can be followed.

11.4.5 To keep on platform build-up and to strengthen resource integration

A platform for innovation research is vital for the development of the food disciplines. More efforts shall be made to build platforms supporting development of the food disciplines and application of the research achievements, such as bases for scientific research, technology transfer center, public service platforms, technology sharing platforms, and the platform for commercialization of research findings and technology transfer.

11.4.6 To develop the disciplines with open exchanges

Development and innovation of food disciplines in China have to meet with the needs of the world, modernization, and future. Colleges and universities involving food disciplines may upgrade teaching quality, expand influence and keep in touch with the world in the process of exchange, and communicate with foreign universities; therefore, the vision of students may be broadened by high level of international cooperation and exchanges.

12 Cereal and Oil Science and Technology

12.1 Introduction

Cereal and Oil Science and Technology (COST) studies the physical, physiological, biochemical features and control technology of grain, oil and fat and oilseeds in the course of purchase, sale, storage, transportation, and process. It is an inter-discipline and relatively independent comprehensive subject, involving science, engineering, agriculture, and medicine (nutrition and health), etc. The COST contains such subjects as purchase and sale in post harvest, storage and logistics, process and comprehensive utilization, equipment and automation, quality and safety guarantee, nutrition, information network, business management, and so on.

As the special commodities, cereal and oil are of vital importance to the need of military and people, national welfare, the people's livelihood, and social stability. COST supports the development of modern grain logistics, healthy life satisfaction of the people, safeguards national grain security, takes an important part in the national economy, and receives the great attention from the party and the state.

12.2 Progresses in COST in recent years

12.2.1 Unprecedented development obtained

(1)In the field of grain storage, the Chinese characterized ecosystem of green grain storage has been established. The grain storage technology, in general, has leaped ahead of the world, and technological levels in some fields are higher than that of developed countries like America and Europe.

(2) In the field of grain processing, the research and processing technologies for the rice machine have reached at the advanced level in the world, the process of wheat flour milling is in the leading position in the world, and the cost performance for the main machine of wheat flour milling equipment has exceeded that of the overseas corporations.

(3)In the field of oil processing, technical performance indexes for some oil equipments have approached or reached at the international level, a series of phospholipid products with independent intellectual property rights have also been developed, and the quality has reached at the index of the same

kinds of products overseas.

(4)In the field of the inspection of grain and oil, the quick methods for detecting grain freshness and staleness degree and relevant instruments with proprietary intellectual property rights have been developed, and standards of inspection methods have completely achieved both ISO international standards and the standards of the developed countries.

(5)In the field of grain logistics, the system theory for the grain logistics supply chain has been preliminarily established, and the grain logistics has developed greatly on networking, "four deconcentration" process, mechanization operation, and informatization management.

(6)In the field of the nutrition of grain and oil, nutrition enriched flour, enriched edible oil, enriched rice, and enriched rice and flour products have been produced in an industrialized way.

(7) In the field of feeds processing, some transformation rate of feeds have reached at the leading level in the world, and the technologies of feeds processing and equipment manufacture have approached the international advanced level.

(8) In the field of fermented flour products, the study on active dry yeast, which has made a breakthrough progress, has been in a leading position in the world, furthermore, the equipment set of steamed bread series can be manufactured.

12.2.2 Significant Achievements Accomplished

Innovative achievements are fruitful. During the period of "Eleventh Five Year Plan", the scientific and technological innovation of cereal and oil has endlessly produced new technologies, new equipments, and new results. Seven National Awards for Science and Technology Progress have received including 1 for first prize and 6 for second prizes; 3 scientific awards rewarded by National Development and Reform Commission and over 60 provincial awards have won. Total 147 scientific and technological prizes of Chinese Cereals and Oils Association and near one hundred other prizes have been received. And 336 national and industrial standards in the field of grain and oil have been drafted and revised, including 248 national standards and 88 industrial standards, and they are officially promulgated and implemented. Four kinds of new materials, 104 kinds of new products, 1,416 set new

equipments, 190 new technologies, 160 new production bases and 321 sample bases have developed.

(1) Special important scientific and technological projects have been implemented. State Administration of Grain has taken in charge of 14 sub-items in 4 projects, like the sample items of research and development of the key technology and example of China's green grain storage, and has made a great progress.

(2) Scientific research platforms have been fully constructed. Three laboratories of grain storage and transportation, deep processing, and equipment engineering have been approved. In addition, 14 engineering technology research centers for grain storage, transportation, and process under the State Administration of Grain have been established.

(3) Science education has fast developed, With 4 grain universities, namely Henan University of Technology, Jiangnan University, Wuhan Polytechnic University, and Nanjing University of Finance and Economics as its artery, this subject has established a cereal and oil talent training system which covers 31 provinces and cities in China and the trained talents have bachelor or master degrees.

12.2.3 Substantial Industry Development Driven by the Achievements

The integrated innovative project and the research and development of "four-in-one" new technology on grain storage receive first prize of National Awards of Science and Technological Progress in the year of 2010, the achievements of which have been spread to the central and local grain warehouses in 31 provinces and municipalities with a total capacity of 60 million ton, and has brought an economic benefit over 29 billion RMB *yuan*.

In the year of 2010, the key technology and industrialization development project on soybean lecithin production, that received the second prize of National Awards for Science and Technological Progress, has expanded its achievements in 20 enterprises with 46 production lines, which has brought an economic benefit of 2 billion RMB *yuan*.

The spread and application of 13 projects, which have won the first prize of scientific and technological progress of Chinese Cereals and Oils Association from the year of 2008 to 2010, respectively, have brought outstanding economic and social benefits.

The transformation from scientific and technological achievements to production has played a very important role. In recent years, the cereal and oil industry of China has greatly changed. China has established a modern grain storage system with complete layout, reasonable structure, and advantageous equipment. Until the year of 2009, the total warehouse capacity of all Chinese grain warehouses was 364.243 million tons; the capacity is 20 times greater than that in the period of founding of the People's Republic of China. The amount of national and local reserve grain is well above the demand forward by FAO, which should be more than 17% (60 days) annual consumption. Thus it laid a good foundation for ensuring the national grain security and quality. The industry has been developed to the largest one in grain and oil in the world. In the year of 2009, the value of gross industrial output was 1,118.42 billion RMB *yuan*, and the gross profit was 31.2 billion RMB *yuan*. Besides, the categories and quality of the cereal and oil products are in the leading position of the world, and the cereal and oil machines have been sold overseas. The grain logistics system has been preliminarily established according to the market, which makes China control and manage the grain market better in order to deal with the emergency. There are over 200 national inspection centers for grain and oil, and the quality and safety inspection system for grain and oil has been preliminarily established.

12.3 Comparisons on the research advances in COST between China and foreign countries

The COST has rapidly developed worldwide, In China, it has obtained outstanding achievements; however, it is not in a balanced development. Although in the leading position of the world, only a few of technology have been expanded in the whole country. Therefore, there is still a wide gap between China and developed countries.

12.4 Directions and strategies for future development of COST

(1) The directions for COST development safeguard the national grain security and ensure the safety and nutrition of cereal and oil food. The key research is reforming the traditional cereal and oil industry with advanced and new technology.

(2) In the field of grain storage, the non-chemical prevention and

treatment technology of Integrated Pest Management (IPM) is the focus of the research and development, as well as the temperature control, energy saving, and the biological control of pests and mould in stored grain.

(3) In the field of grain processing, the attention is paid to the new products of grain processing and the manufacture of new key machines. Advanced and new technologies are introduced to improve the traditional processing and promote the efficiency in the processing, and make products better and casting yield higher.

(4) In the field of oil and fat processing, the technology of oil expression technology with low temperature and appropriate temperature has been spread. Large and intellectualized oil processing machines were developed and researches on integrated utilization of oil protein and by-products are the focuses.

(5) In the field of the inspection of grain and oil, the attention is paid to the near infrared technology, image-processing technology, headspace analysis technology, as well as the quick instruments inspection of grain quality during the grain acquisition.

(6) In the field of grain logistics, the attention is paid to grain supply chain and integrated management technology, the integrated technology of reasonable warehouse buildings, the technology application of things internet, and so on.

(7) In the field of nutrition of grain and oil, the attention is paid to the research on the relationship study between material components and processing features, so as to reduce the nutrition loss caused by processing.

(8) In the field of feeds processing, the attention is paid to the production technological design of clean fodder, the efficient and energy-saving ingredient mixture, smash, extrusion, puffing, drying and intellectual control technology.

(9) In the field of the fermented flour foods, the attention is paid to the industrialized production and the nutrition titer.

13 Lighting Science and Technology

Lighting science and technology is an interdisciplinary subject covering physics, physiology, psychology, architecture, and arts. Not only lighting

provides humans with safe and comfortable light and visual environment, but also it plays a pivot role in the development of industries bearing national economy. However, lighting also consumes considerable amount of electric energy. Therefore, it is important to carry out "Green Lights" measures to save energy and preserve ecological environment.

Lighting science and technology includes vision and color, image technology, physical measurement for photometric and radiation quantities, indoor lighting, outdoor lighting, transportation lighting, photobiology and photochemistry, light sources, luminaires and control system, etc. This report briefly reviews the progress in the above facets, compares domestic R&D level with the international R&D levels and development trend, and suggests how China lighting should develop in the future.

Solid State Lighting (SSL, also called Semiconductor Lighting in China) is leading the revolution in lighting science and technology. Blue Lighting Emitting Diode (LED) based on GaN ushers in the new ground of blue SSL technology and subsequently lays a foundation for the progress in white lighting. The late 1990's witnessed the dramatic increase of luminous efficacy of GaN based blue LEDs. And the beginning of the 21st century readily witnesses the great increase of the efficacy of LEDs by 10 — 20 lm/W annually. At present, luminous efficacy of commercial power white LEDs has reached over 130 lm/W, and is far higher than that of thermal radiation light sources, such as incandescent lamps and halogen lamps, and will probably replace other light sources, i. e. Compact Fluorescent Lamps (CFLs) step by step in the near future.

The governments of many developed countries have viewed SSL as an emerging industry possessing the strategic significance and have offered financial supports and preferential policies to it. Chinese government also attaches great importance to the SSL. According to "*Resolution by the State Council on speeding up fostering emerging industries of strategic significance*", the strategic emerging industries including SSL will become the leader and pivotal in China's national economy. China has made a gradual progress in the LED cutting-edge technology exploration and equipment development. However, at present we mainly follow international mainstream in key technology, lack creativity on the whole, and have no

advantageous technology. China is among the international leaders in the technological development and market application of SSL system integration. But we lack scientific standards and measurement methods at the current stage of LED R&D, fail to keep the uniform, high quality of LEDs on the market and to maintain an orderly market. All those facts severely affect the customers' confidence with the market. Therefore, with LED's entering into a general lighting market, great attention should be paid to setting up standards, measurement methods and equipment should be improved, and supervision should be intensified on the quality of LEDs.

Photoreceptor cell of the third type (ipRGCs) found on the retina of mammals is among the world top 10 discoveries in the year of 2002. Being different from the rod and cone photoreceptor cells discovered previously, ipRGCs has nothing to do with visual sense. The cells connect not to the optic nerves, but to the biological clock in human mind, receive light signal which restrain pineal gland from secreting melatonin (also known as "hormone for sleeping"), and subsequently disturb human's biological rhythm. Since the biological rhythm of human body is important and it depends on lighting, the health effects should be taken into the consideration in the future applications of various light environments.

Traditionally, photometry and colorimetry are mainly based on the fact that continual spectra, such as light from incandescent lamps, are taken as visual objects or background. The emerging of new light sources, such as white LEDs in particular, poses great challenges on the traditional evaluation methods for light sources. The following revolutions are accordingly triggered. First, new photometric measurement methods and equipment are set up for light sources with narrow beam, such as LEDs, because the inverse square law (the illuminance of light radiating from a point source is inversely proportional to the square of distance from the source) is no longer valid for those light sources. Second, since light sources is rich in short wavelength radiation, such as ceramic metal halide lamps and white LEDs, and are increasingly applied to the outdoor lighting, especially road lighting at night, the Mesopic Vision System (MES 2) based on experiments of visual ergonomics, that is newly issued by CIE in the year of 2010, ignite a new round of research fever on the design and measurement of mesopic

environments, such as road lighting application. Third, mixed white light emitted by LEDs, fluorescent lamps, etc. have posed doubt on the accuracy of traditional Color Rendering Index (CRI) issued by CIE. New index for color rendering system, such as CQS is under research. Fourth, evaluation system for lighting quality based on visual evaluation will become the tendency.

Great progress has also been made in traceability of basic quantities. Promoting by application need and modern advanced technology, calibration principles and methods for photometric and radiation quantities have developed dramatically worldwide. Typically, the low temperature absolute radiometer has become the new primary standard for photometry and colorimetry, and the transfer links of standards based on detectors have been established and have been widely applied. In China, national standards for luminous flux and intensity, that are very close to international average value, make a boast of high accuracy, and pave the path to increase our measurement level.

Since the year of 1985, professional sports lighting began to be applied to the television broadcast, China has passed the examinations through its National Sports Games, the Asian Sports Games in the year of 1990 and 2010, and the Olympic Games in the year of 2008 in term of its light sources, luminaires and standards for sports lighting, and in term of its design level and lighting effects both at the spot and on TV, as well as in term of its lighting support for the games. China is among the world leaders in sports lighting, and many of its lighting equipment and effects represent the latest international advanced level.

Challenges from environment protection caused by lighting products in their production and application have called on the wide attention, especially the issue involving the environment pollution and harm by mercury. Recently, mercury pollution has been sharply decreased by replacing liquid mercury with amalgam and by reducing filling mercury dose in the discharge lamps. Recycling deserted fluorescent lamps and high intensity discharge lamps dosed with mercury has gradually progressed; this work has already been put on the agenda of Department of Environment Protection.

Applying daylight not only saves energy and protects environment, but

also creates healthy and efficient room for our work and residence. According to the "Design Standard for Building Daylighting" (GB/T 50033—2001) that is a Chinese national standard, the requirements for daylight quantity and quality in the industrial and civil buildings have not been seriously implemented in construction design and lighting design. Though daylighting was put into play and performs well in the underground parking lot of the Olympic Village in Beijing and in the Sunshine Valley of Shanghai World Expo area, daylighting application is far from satisfactory in China. The reasons lie in the fact that architectural designers do not fully realize the benefits of daylight to human's health and energy conservation, systematic products for controlling and guiding light have not been developed, and the intelligent control technology for integrating natural and artificial light fails to adjust and control daylight effectively. Indoor lighting control technology and equipment in China still have a lot of work that needs to be done. Currently, only some public spaces are equipped with lighting switches control by sound, light, or infrared radiation, while most places are only with manual switches.

Under the support of Global Environment Fund (GEF), China has undergone several green lights programs. As a result, performance of lighting products has been greatly improved, energy efficient products are widely applied, and the concept of energy efficiency and environment protection has received the popular support.

14 Power Machine Engineering

The power machine engineering is a basic discipline for the development of modern science and technology. Power machine together with its related systems forms a foundation of technology and material base for developing national economy, improving people's living standards, and modernizing defense industry. It is a major indicator for illustrating the productivity and competitiveness of a nation.

In the boiler design, China has already mastered the technology of the waterwall structure design and manufacture, the waterwall hydrodynamic calculation and analysis, developed the performance design programs, and formed a structure design foundation with complete independent intellectual

property rights for supercritical (SC) and ultra-supercritical (USC) boilers.

By means of the digestion and absorption of the introduced foreign technologies, Chinese boiler manufactures have successively researched and developed the quadrangle contact circle and whirl opposite flushing combustion technology for the pulverized coal, especially for soft coal, lean coal, and lignite, the "W-flame" combustion technology for pulverized anthracitic coal, the combustion technology for mixed pulverized coal and biomass, the technology for inferior coal burning re-circulating fluidized bed, the technology for pulverized coal gasification, and the technology for water-coal-slurry gasification, etc. At the same time, the academic and industrial communities have conducted fundamental, theoretical, experimental, and pilot-plant test researches on the pure oxygen combustion, chemical chain combustion, and catalytic combustion.

In the area of research and development of boiler materials, through the cooperation among manufacturers, academies, and research units in the metallurgical industry, the power equipments manufacturing industry, and the power industry in China, the supply of boiler steel tube and pipe materials for 600～1,000MW, 600℃/600℃ USC has been localized, and thus laid a foundation for the development of high-parametric boiler technology.

The boiler manufacturing enterprises in China have mastered the technologies of design and manufacture 300MW and 600MW subcritical and 600MW supercritical boilers. Except some large forging blank, the batch supply of 1,000MW ultra supercritical boilers has been localized on the basis of a successive introduction of the technologies for designing and manufacturing 660～1,000MW ultra-supercritical steam turbine. By the end of year 2010, about 250 of 600MW～1,000MW supercritical, ultra supercritical units had been domestically manufactured, installed and put into the operation.

Currently, the 300MW Circulating Fluidized Bed (CFB) boilers in both the introduced type and the optimized, innovated, perfected, and updated independent type are available in batch supplies. The research and development on the key technologies for 600MW supercritical (SC) Circulating Fluidized Bed (CFB) boiler are in progress. The first 600MW SC CFB boiler is in course of construction, and is expected to put into the

operation in the year of 2011. The state plans to complete Huaneng Tianjin 250MW-class Integrated Gasification Combined Cycle (IGCC) demonstration plant by the year of 2015. It is estimated that by the year of 2020, the 400MW-class IGCC demonstration project will be completed, the 2,000t/d class of dry and wet gasifiers will be manufactured, and the 3,000t/d class of gasifiers will be designed and produced domestically in order to gain and apply the experience with design, operation, and maintenance step by step.

The manufacturing enterprises of China have mastered the packaged design and manufacture technologies for Electric Static Precipitation (ESP), baghouse filter, and electric-bag compound precipitation, various design and manufacture technologies for wet, half-dry, active coke, etc., desulfurization, and the packaged design and manufacturing technologies for low - NO_x staged combustion, denitrification catalyst for Selective Catalytic Reduction (SCR) and SCR denitrification devices, carried out the research on the multiple pollutants removal technology, conducted a great amount of engineering applications, and demonstrated the technology of CO_2 capturing in flue gas, synthetic copolymers, and regenerating technologies. In order to realize the low-carbon emission in the future coal-burned power generation in China and reduce the impact of greenhouse gases on the climate, it is necessary to actively promote the engineering application of the technologies for pure oxygen combustion, chemical chain combustion, and catalytic combustion, and to actively research, develop the CO_2 Capture and Storage (CCS) technologies for coal-burned power plants from now on.

The steam turbine manufacturing enterprises in China have extensively applied the computational fluid dynamics-based numerical simulation and finite element analysis to the studies on the bending twisting, stream flow shock excitation of the stationary blade labyrinth gland packing, rotors, impellers, cylinders, valve housing, and other important parts. They have conducted the blowing test of plane cascades, the test of circular cascades of blades, valve tests, etc. They also have successfully developed and applied various new steam seal structures, conducted the universal technology research on the strength design for high-temperature components and large-sized components, carried out the research on the status evaluation, life assessment, and life estimation for the key components of steam turbines.

At present, the steam turbine manufacture enterprises of China have mastered the design and manufacture technologies for 300MW, 600MW subcritical and 600MW supercritical steam turbines. After the design and manufacturing technologies of 660～1,000MW USC steam turbines have been successively introduced, except some large forging blank, the batch supply of 1,000MW USC steam have localized. By the end of year 2010, about 250 units of 600MW and 1,000MW SC and USC steam turbine units will be produced and put into the operation by the steam turbine manufacturing enterprises of China.

During the period of the "Twelfth Five-Year Plan", along with the development of coal-burning power generating units in the direction of higher parameters, the domestic manufacturing enterprises will further independently design and demonstrate the 1,200MW level of 610℃/625℃ ultra-supercritical boiler technology. At the same time, in terms of future energy strategy development plan of China, the National Energy Administration formally established and launched a national innovation alliance in July, 2010 for the 700℃ ultra-supercritical coal-fired power generation technology in order to achieve the goal for independently designing and producing 700℃ ultra-supercritical boilers and steam turbines by integrating research and developing resources with the above measures.

In China, the research on gas turbine key technologies is in good shape, the studies on the fundamental theories of heat transfer and combustion are quite strong, and the research and application of aviation craft and ship gas turbines have almost reached at the current advanced level. Since March, 2003, the National Development and Reform Committee has organized three bundled biddings for F-class and E-class gas turbines, and brought the manufacturing technologies without design technology of advanced gas turbines from abroad. At present, the effort on the development of design and test platform for gas turbines on one's own has embodied. The research of the directional heat corrosion-resistant materials and single-crystal alloy materials has been started, and strived to make some breakthroughs on the areas of the materials research and manufacturing technologies in order to lay a foundation in the fields of the preparation of alloys, complex mode cores, large-sized directional molding, and composite thermal barrier coatings, etc.

During the periods of the "Tenth Five-Year Plan" and the "Eleventh Five-Year Plan", the prime item in the 863 Program for gas turbines is to carry out research, development, design, and prototype development of E-class (110MW) gas turbines, which lays a foundation for the R&D of F-class (200～250MW)heavy-duty gas turbines.

The level of gas turbine technology development reflects on the comprehensive level of the science and technology development in multiple disciplinary and engineering fields of engineering thermophysics, information electronics, material metallurgy, machine building, automatic control, etc. in a relatively intensive way; and it turns to be one of the important marks of national scientific and technological level, military strength, and even the comprehensive national strength. It is imperative to increase the investment in the research and development on the science and technology of heavy-duty manufacturing technologies as soon as possible in order to form the capability of independent development of the advanced heavy-duty gas turbines.

At present, China is able to carry out hydraulic design, CFD analysis, modeling, and model test of the existing products, and possesses the engineering application capability for implementing prototype design, technologic design, product manufacture, equipment on-site installation, control, regulating, testing, and operation, etc. The CFD technology has been applied to the hydraulic optimized design and performance estimation of hydraulic turbines, and used in the design of the large-sized hydroelectric power station like that at the Three Gorges, Shuibuya, Xiaowan, and Xiluodu, etc.

China is already able to research, develop, design, manufacture, and install various kinds of hydroelectric generating units on its own to meet the demands for the large-scale hydroelectric development. The dam-building technology of China is also reached at the world advanced level. The rotating wheel of the hydroelectric generating units at the right bank of the Three Gorges, that has a core technology with intellectual property rights and is concerned with the development of large-size hydroelectric generating equipment of China, is an example for the digestion, absorption, and re-innovation of import technology. Not only its efficiency is higher than that on the left bank, but also its stability has made a great breakthrough. In the

entire operation range, the high-load pressure fluctuation is eliminated, thus a worldwide thorny problem perplexing hydropower industry is resolved.

Through the introduction, digestion, absorption, and re-innovation of technology in Three Gorges project, China has reached at the international advanced level in the research, manufacture, and installation of the radial-axial flow turbine, and is able to compete with the most advanced foreign hydraulic turbine manufacturers at the same stage. In some areas, especially in the area of stability of the units, China has reached at the international leading level.

Large capacity and high efficiency are the major directions for the development of future hydraulic turbines. Research on the mechanisms of cavitation erosion, stability, and silt abrasion of hydraulic turbines and research on the flow-solid coupling CFD computational analysis and the model test techniques should be carry out. It is imperative to actively research and develop large capacity radial-axial flow turbines, axial flow turbines, through-flow turbines, impulse turbines, pump-turbine technology (pumping water energy storage technology), and carry out technical transformation of the old in-service hydroelectric stations in light of the concept of refabrication.

The third-generation nuclear power technology with intellectual property rights that is formed by introducing, digesting, absorbing, and re-innovating third-generation AP1000 nuclear power technology will further enhance the nuclear power design, manufacture and installation level of China. Meanwhile, it is necessary to carry out domestic R&D on the fourth-generation nuclear power technology at home, and build the demonstration fast reactor power plant as soon as possible after completing the experimental fast reactor in order to commercialize the fast reactor technology as early as possible, and achieve the great-leap-forward development of nuclear power design, manufacture, construction, and operation technologies of China and to join the ranks of advanced nuclear power countries.

China should foster the brand name for wind generating unit of 3MW and above class and its components and parts with independent intellectual property rights to boost the wind power technology and equipment in order to reach the international advanced level. It is important to further perfect

various techno-economic indicators for the wind power construction and operation, and raise the competitiveness in the market of wind power.

The technologies of solar photovoltaic and solar thermal power generation, as well as the mass biomass and pulverized coal mixing firing power generation technology and the distributive power generation technology of post-gasification and pyrolyzation of biomass and biotransformation need to be actively promoted.

Moreover, the smart grid (intelli-Grid) technology should be actively built up and the technology should focus on the development of intelligent dispatching, intelligent substation, intelligent residential district, large-capacity energy storage, and intelligent electric vehicles, and the intelli-Grid should cover the entire process which includes power generation, transmission, distribution, and application in order to realize the intelligent control of all aspects from power generation to power consumption.

15 Basic Agronomy

Agriculture is the basis of national economy, while basic agronomy is the foundation of the advancement and development of agricultural science and technology. Currently, China is in the historical periods that urban areas elevate rural areas and industry promotes agriculture. Thus, changing mode of agricultural development has become the important strategic choice in China. With the rapid development of economy and society, basic agronomy plays an extremely important role in the development of modern agriculture and the construction of agricultural modernization with Chinese characteristics.

According to the overall plan of China Association for Science and Technology, the basic agronomy project development 2010—2011 has been researched by Chinese Association of Agricultural Science Societies in order to change the way of agricultural development, develop modern agriculture, and build agricultural modernization with Chinese characteristics. The research project consists of nine subjects; the subjects include agricultural biotechnology, plant nutrition, irrigation and drainage technology, farming and farming systems, agricultural environmental science, agricultural

information science, agricultural storage and processing technology, farm products safety technology, and agricultural resources and regional planning. The research project analyzes recent progresses, significant achievements, and applications in basic agronomy and its branches, grasps status and dynamics of the development of the subject, compares the research and application in China with that in other countries, estimates the strategic needs and trends of the subject, and puts forward the policy suggestions of quickening the development of basic agronomy.

As a branch of biology, basic agronomy is the subject for understanding natural phenomena related to agriculture, revealing objective laws and principles of agriculture, and researching natural phenomena and their nature in agricultural production systems. The research aims at fully develop and protect agricultural native resources, coordinate the relationship between crops and the environment, prevent the pests from damaging and environment to agriculture from being adverse in order to obtain the best combination of agricultural production, enhance the yield and quality of farm products, accelerate the development of high-yield, high quality, efficient, eco-friendly, and safe agriculture, effectively ensure national food security and ecological security, increase the income of farmers, and improve the international competitiveness of farm products. The subject of basic agronomy is characterized by the concept of integration, dynamics, and development. With the development of economy and technology, it has various connotations in different historical periods. Since the 1990's, new characteristics and trends have emerged in the research of basic agronomy as the rapid development of modern science and technology, especially as the mathematics, physics, chemistry, earth, health, and other basic sciences penetrating into agricultural sciences and the application of information technology, such as Internet of Things and cloud computing technology.

In recent years, the subject of the construction of basic agronomy has been paid much attention to in China, and great achievements have been made in the research and application of basic agronomy.

In the field of agricultural biotechnology, transgenic insect-resistant cotton has been independently bred in China, thus the monopoly of transnational corporations is broken and China takes hold of advanced

international biotechnology. In the past 10 years, transgenic cotton with single gene or double gene also has been successfully developed in China; thus it creates huge economic, social, and ecological benefits. Up to the year of 2009, Bt cotton planting area had reached at 400 million hectares, it accounts for 75% of the total area. Total extension area of domestic Bt cotton had reached at more than 127 million mu, which brought the revenue of about 33.8 billion yuan.

In the field of irrigation and drainage, in terms of basic theory of water-saving agriculture, identification and evaluation technology to drought resistant water-saving crops has been initially established. The proposal of water-saving high yield and nutritional compensation technology of water shortage response compensation mechanism provides a theoretical and technical support to the improvement of water-using efficiency in vast area and to the establishment of efficient irrigation systems. The shortage irrigation mode and key technologies of main crops in north and northwest regions of China have been identified. The techniques, such as shortage compensation irrigation and divided alternate irrigation for major crops have been established. All of those have played an important role in the guidance of field irrigation practice. The research and development of laser controlling ground scraping devices and the corresponding hydraulic lift control systems has improved irrigation uniformity by 20% to 30% and irrigation water-using efficiency by 30% to 40%. In terms of creating water saving products, a number of environmental protective, high-efficient, and low-cost new materials for rainwater accumulation have been developed. SWR－4 tube-type soil profile moisture sensor prototype for replacing imported TDR/FDR similar instrument has been developed. PY series, ZY series, and GJY series of nozzles, whose performance has reached at the international advanced level, have been developed.

In the field of agricultural resources and regional planning, the intension of soil quality has been enriched and developed and the function of agricultural soils has been expanded. The technologies to alleviate water stress, resist droughts caused by climate change, save water, and improve agricultural water resources production efficiency have been researched and developed. Planning and controlling theories concerning with agricultural climate

resources and disaster prevention technology have also been researched and developed. In the collection and preservation of agricultural microorganism resources, the number of progress has significantly increased, and is strengthened. A series of efficient fertilization technology and new fertilizers have been developed; high value-adding utilization technology to agricultural waste has formed; the development and application of monitoring technology to agricultural resources has been strengthened; industrial zone theory of farm products has been perfected; and the planning research of agricultural function has been strengthened.

In the field of agricultural environmental science, especially in the direction of agricultural engineering facilities, the interaction rule between agricultural environmental factors and the agricultural biological factors by research topics has been revealed, agricultural environmental control mechanism has been elucidated, simulation of agricultural system in controlled environment has been realized, key equipments of controlling modern facility environment of plants and animals has researched and developed, and engineering measures and environmental safety production technology ensuring the growth environment of plants and animals have been brought forward. During last 10 years, greenhouses have been rapidly developed in three north regions of China, the areas has extended to latitude 32°—48°, and thus the important contributions have been made to solve the problem supplying off-season vegetables for northern region and to increase farmers' income. According to the statistics from the Ministry of Agriculture, the national greenhouse area reached at 700,000 hm^2 in the year of 2007, and reached at 780,000 hm^2 in the year of 2010, respectively.

In the field of agricultural information science, major breakthroughs have been made in intelligent service technology of agricultural information which consists of precise accessing technology of agricultural information, automatic data processing technology, and information push application technology.

At present, the subjects of basic agronomy and their branches have developed and formed a complete range of discipline, important progress and breakthroughs have been achieved, new theories, methods, and technologies have been invented, new ideas and insights have emerged, and some subjects

are close to or have reached at the world advanced level. However, since the subjects of basic agronomy in China have started late, and their development has lagged behind, there is still a wide gap between them and those in developed countries. By means of following the requirements of "being independent in innovation, focusing on spanning, sustaining development, and taking the lead in the future", we must closely relate to the reality of Chinese agriculture, rural areas and peasants, fully understand the basis for the development of the strategic needs of agriculture, and accelerate the reform and development. We must also improve the institutional mechanisms, increase investment efforts, and strengthen international exchanges and cooperation. Furthermore, first of all we should train men' abilities, organize prudent and efficient research teams, choose international frontier of basic and advantageous subjects, the key areas affecting the national economy with overall focuses, badly needed services to the "three rural", and significant theoretical and technical issues should tackle with joint efforts in order to develop by leaps and bounds, and lay a solid technical foundation for the development of modern agriculture.

16 Soil Sciences

Soil is a biogeochemically dynamic natural resource that supports all critical components comprising terrestrial ecosystems. It has been called as Earth's living skin. Soil science is one of basic disciplines related to agriculture science and resources and environmental science. It was developed from plant nutriology, pedogenesis, and pedogeography in middle and later periods of 19th century. In the past 160 years, soil science has formed its own theories and research methods centered on forms, properties, and functions of terrestrial materials with the development of geoscience, biology, and related technology. It has grown into a propping basic discipline connected with resources, environment, and ecological sciences from the beginning of 20th century. Meanwhile, modern soil science will play an important role in enhancement of farmland productivity, conservation of ecological system, prevention of environmental pollution and maintaining and support of construction and engineering, enjoyment of landscape and natural

aesthetics. In general, modern soil science has made an incomparable contribution to the life and health of human being and the sustainable development of society.

Nowadays, China as well as the entire world is facing big challenges including shortage of resources and energy, environmental pollution, and global climate change, etc. Against this background, soil science should play a more and more important role in the improvement of soil fertility and crop productivity, planning and management of national territory, treatment and remediation of regional environment, prevention and control of ecological system degradation.

During the past decade, there are a lot of later developments and improvements in soil science worldwide, which include earth critical zone researches related to soil progress and temporal and spatial changes, application of new methods and long-term experiment, innovation of basic theory, technological improvement and industry development, integration and intersect of multiple disciplines, and service for the society and the public. Correspondingly, China has experienced a fast development stage during the past 50 years. Especially in the latest 30 years, the 12 sub-subjects related to soil sciences, such as pedogeography, soil physics, soil chemistry, soil mineralogy, and soil biology, etc. are undergoing a fast development with the emergence of environmental pollution, global climate change, and other problems. Progresses were also made on the following aspects during this period: they are soil resources and environmental protection, soil genesis and classification, green house gases emission, interface chemistry of soil colloid, soil fertility and water management by long-term experiment, development of long effective fertilizer and nutrient elements, soil-plant nutrition, rehabilitation of soil degradation, soil information system, and advanced analytical technology.

Chinese soil taxonomy gradually integrated with the U. S. classification system and became one of four important soil classification systems in the world. Besides, for the research on the electrochemical characteristics of variable charge soil, there are great progresses in in-situ observation and understanding of soil physicochemical and biochemical processes of nutrients and pollutants on the surface of soil colloid. There is an integrated research

system for soil pollution investigation, pollution process and control mechanism, risk assessment and risk based standards, monitoring technology and equipment, pollution control and remediation technology. In which, the pollution risk assessment based on the metal complex dissociation and diffusion theory model in soil solution-plant interface made a big progress. The soil ecological engineering became a prospective engineering in the control of non-point source pollution and restoration of environment for the polluted water bodies in China. The regional estimation of CH_4 and N_2O emission in the paddy field systems and the FACE study on rice-wheat system were internationally recognized. Plant-soil rhizosphere interaction theory become the core of soil-plant nutrition, which is well developed into a system to reach at a balance among crop yield, resource efficiency, and environmental protection by using the biological resource of plants and microbe via the combined approaches on biological manipulation (of plant-soil-microbe interaction) and nutrient managements. Soil hydrology and mechanics, the dynamics and molecular mechanisms of interface reactions of minerals have also been approached to the international forefront in the field of soil physics and soil mineralogy. Besides, the research on paleosol, soil digital mapping, and the mechanism of soil quality evolution and soil degradation is synchronized with the international development. A series of books has been published, such as *Soils of China*, *China Soil Series* (volume 1 - 6), *Soil Atlas of China*, *Paddy Soils of China*, *Red Soil of China*, *Red Soil Fertility and the Nutrient Cycle*, *Cycling*, *Balance and Management of Nutrients in Agro-ecosystems in China*, *Pedogenesis and Soil Taxonom* y, *Soil Quality of China*, etc. These books proposed the research contents of material cycling in pedosphere and established the soil theory with Chinese characteristics. All these progresses have made a considerable contribution to China's sustainable development of economy and society.

The development trends can be summarized with the words of integration and intersection, quantification and standardization, information and internationalization. According to the demand for the future development of China, the future strategic priorities for soil science researches are put forward. The priorities include the researches on soil environmental protection, energy-saving, and emission-reduction, farmland cultivation,

food security protection, ecological high value agriculture, and soil pollution control and remediation.

In the area of soil development and soil information, soil evolution rate, influencing factors, and process simulation in the context of global environmental change at the large space and fine time scale; the ancient soil (paleosol) and environmental changes based on geological dating; soil basal classification (soil series) and the international reference of Chinese soil taxonomy; soil remote sensing image processing and automatic categorization technology, advanced sensor and data processing technologies; and soil digital mapping and data standardization, soil information system based on "3S" integration technology should be given higher priorities.

In the area of soil resources and soil quality, systematically observe and study soil quality under high-intensity use, especially the environmental and health quality; soil degradation mechanism and prediction of landscape ecology; the formation processes, mechanisms and regulations of soil erosion under the influence of natural factors and human activities; trans-scale integration of soil erosion research methods and prediction models; interaction of runoff, sediment and non-point source pollution; evolution of soil quality of saline soil, assessment method, control mechanism and rehabilitate technology; and accelerate acidification mechanisms of red soils and its biological control technology should be given higher priorities.

In the area of soil properties and multi-interface processes, the quantitative description methods and monitoring technologies for soil properties and biophysical processes; the coupling mechanisms and simulation models of soil physical, chemical and biological processes; internal relationship between soil properties and characteristics of soil water, salt, solute (including nutrients and pollutants), heat and gas transfer; mechanisms and measures for coupling regulating soil water, salt and fertilizer; the structure, sub-structure and properties of soil colloids, and nano-phase interface reaction and interaction of nano-particles based on advanced technology of microscopic spectrum in molecular level; soil fixation and liquid flow of nutrients and pollutants in the domain of nano-particles, and the corresponding non-homogeneous system model; interface processes, the molecular mechanisms and molecular simulation between soil components and organic matter and

microorganisms; chemical processes of iron cycling and material transformation in the soil mineral surface; and biological origin-mineral formation mechanism and its role in the transport of pollutants should be given higher priorities.

In the area of soil molecular biology and proteomics, construct microbial environmental genomics and proteomics database for the genetic information of microbial communities by using advanced molecular biology methods, such as DNA micro-array and high-fluxed DNA sequencing technology; soil biological processes, influencing factors and metabolic products; biochemical processes and mechanisms of the formation of black carbon; soil organisms driven processes and their interactions and regulation mechanisms in the extreme environments, micro-domain space and rhizosphere interface; and interactions, evolutionary mechanisms, and their ecological functions of soil organisms at the scale of complex community and food web should be given higher priorities.

In the area of soil use and global change and ecosystems, study on the mechanisms of soil carbon sequestration and stabilization in different ecosystems through the multi-objective, multi-type (farmland, forest, grassland, wetlands, etc.) long-term field observation network; the response and feedback of soil ecological processes to global changes, in particular, the key processes and controlling factors of soil carbon and nitrogen cycling and greenhouse gas production and emission; modeling and accurate prediction of soil carbon dynamics in different ecosystems under the global change; interactions of soil, organism and plant in fragile and degraded agricultural ecosystems; coordination mechanism and feedback of soil biological diversity and plant diversity during restoration of ecosystem services; and soil, plant, and microbial enhanced rehabilitation mechanisms of polluted soil should be given higher priorities.

In the area of soil nutrients, soil fertility and productivity, the turnover processes and its key functional biological communities for the internal source organic matter in the farmland ecosystems; the impact of soil organic matter accumulation on the ecosystem stability under the high productivity conditions; biological processes and mechanisms of the transformation of multiple nutrients, such as the biological processes of nitrogen and

phosphorus coupled by organic carbon in the soil-water interface; rhizosphere processes and mechanisms for high-efficient use nutrients including root-induced mobilization processes and its molecular mechanism, function of the rhizosphere microbes for nutrients transformation coupling soil nutrient, water supplication and root growth; and assessment methods and indexes for soil fertility at the different scale, evolution and regulation of soil fertility in different ecological regions should be given higher priorities.

In the area of basic soil science research for ecological high value agriculture, oriented cultivation of land quality and intensive use of land resources; coupling management of water and fertilizer and its application to water resources protection at the basin scale; agricultural clean production system and control of non-point source pollution in agriculture; system for adding carbon sinks and reducing carbon emissions to mitigation global climate change; formation mechanisms of barrier soils and their regulation technologies; precision agriculture and information technology; soil quality standard system; and prevention and remediation technology systems for soil environment pollution should be given higher priorities.

However, there are some imperfections hindering the development of soil science in China, which are mainly reflected by the aspects of scientific research system, personnel training, financial supporting, apparatus and facilities, measurement and observation techniques, and management systems. All these imperfections shall be highly concerned with and corrected in the future researches on soil science.

In summary, we are firmly convinced that the development of soil science will definitely push forward agricultural productivity and eco-environmental improvement, and move a great new step forward along with emerging disciplines, such as biology and information science. A stride shall be achieved in China's soil science and greater contributions shall be made to the development of worldwide soil science.

17 Plant Protection

Plant protection is a comprehensive discipline, it involves in the study on biological characteristics of various pests including plant diseases, insect

pests, weeds and rodents, and their interactions with different environmental factors, and development of control and prevention technologies.

Under the guidance of Scientific Development Ideology and "Self-Innovation, Selective Breakthrough, Supporting Development, and Leading the Future", Chinese plant protectionists have been focusing on the strategic needs of modern agricultural development, the food safety, ecological safety, and income increase of farmers which restrict the sustainable agricultural development, and, having eyes on the frontiers of world science and technology, carrying on tradition, exploring and innovating, and tackling key problems collaboratively. Through crossover and mergence of different disciplines and ceaseless innovation of research technology and measures, the plant protection discipline has achieved the rapid development in research, discipline construction, personnel training, and establishment of scientific research platforms. A series of important research achievements and breakthroughs, that are supported by the national basic and applied basic research program, high-tech R&D, and applied technology research, have been made during the past two years or so, they significantly promote the capability of the overall research level in plant protection science and prevention of biohazards in China.

17.1 Plant pathology

Through a study on pathogenic mechanism of plant pathogen, a novel DNA virus, that can parasitize plant pathogenic fungi, was discovered from a hypovirulent strain of *Sclerotinia sclerotiorum*, it unravels the long-time mystery of whether or not a DNA virus exists in fungi, and also is the first report about fungal DNA viruses in the world. An eco-management technology system with utilization of biodiversity at its core has been innovatively established in a pathogen base of the wheat stripe rust, the system aims at ecological disaster relief, biological pest control, and chemical disaster alleviation. In addition, 3S (RS, GIS, and GPS) technologies have also been successfully applied to over-summering and over-wintering division, monitoring and pre-warning of the wheat powdery mildew disease.

17.2 Agricultural entomology

Through insect physiological, biochemical, and molecular biological studies, the mechanisms of tri-trophic interactions between pest insects, crop

plants, and natural enemies, insect reproductive physiology and anti-stress physiology have been clarified. Through insect chemical ecological studies, the genetic regulation mechanism of plant semiochemicals and regulation mechanisms of insect behaviors by odorants were revealed. Insect radar technology has also been used to illustrate the migratory behaviors, migratory paths and original sources of key pest insects, such as the cotton bollworm, the beet webworm, the brown planthopper, and the white-backed planthopper among others. Furthermore, the mechanisms of resistance development, genetics and evolution of the cotton bollworm to Bt-transgenic cotton, and the resistance mechanisms of different agricultural insects to chemical pesticides have also been verified.

17.3 Weed science

The genetic diversity of several weeds and potential habitat suitability of *Flaveria bidentis* in China have been determined. The insecticide resistance level of *Descurainia sophia* and molecular mechanisms of cross-resistance and insecticide resistance of important resistant weeds were clarified. Meanwhile, the allochemicals produced by allochemical rice in China and its weed-inhibiting mechanisms have also been defined. An integrated management technology system combining ecological weed-control with chemical control measures has been established in rape-seed fields. A safe and high-efficiency herbicide-application technology system with herbicide-reduction technology as its core has been constructed in wheat/corn fields. Furthermore, a distributed sampling system for field weeds and precision spray control system have been developed.

17.4 Biological control

It has been demonstrated that parasitic natural enemies can exploit the same or similar volatiles to locate different herbivorous hosts, and the volatiles induced by herbivores can regulate the interactions between parasitic natural enemies and predatory natural enemies. The first marine microbial pesticide, 10^9 CFU/g wettable powder WP of *Bucillus marinus* (designated as marine WP), was invented and a scale-up production line has been built. The soil-restoration technology for combined absorption of excessive heavy metals (Cd^{2+}, Cu^{2+} and Zn^{2+}) by *Trichoderma* and *Brassica napus*has has been developed for the first time in the world.

17.5 Pesticide science

Profited from major advances in basic research on pesticide invention, more than 30 new pesticide varieties with independent intellectual property rights have been developed. Twenty-one testing methods for pesticide environmental behaviors and environmental toxicology have been set up in China. A handbook for environmental risk assessment of pesticides was compiled. Six standard scenarios for environmental risk assessment of pesticides were preliminarily established in China. A basic framework for environmental risk assessment of pesticides has been delineated. The environmental behaviors that include residues, degradation, and metabolism, of more than 10 kinds of chiral pesticides in soils, water, plant samples, and animal bodies (*e. g.*, rabbits and rats) were defined. Furthermore, a multi-residual analytical method for several pesticides was set up, and a sophisticated pesticide residual standard system has been formulated.

17.6 Invasion biology

Population formation, expansion, and ecological adaptation mechanisms of important invasive speciess, such as *Eupatorium adenophorum*, *Bemisia tabaci*, and *Bursaphelenchus xylophilus*, were elucidated. Risk assessment and early warning technology for some of the important invasive species have also been developed.

17.7 Biosafety research on GMO

Significant advances have been made in the fields of systematic evaluation of potential biosafety risks of insect-resistant transgenic Bt rice and phytase maize, systematic monitoring the regulation of transgenic Bt cotton on cotton bollworm, outbreak mechanisms and control strategies of mirid bug after growing of transgenic Bt cotton, and resistance risk assessment of the cotton bollworm to Bt cotton and preventive management technologies. Research papers of "*Suppression of cotton bollworm in multiple crops in China in areas with Bt toxin-containing cotton*" and "*Mirid bug outbreaks in multiple crops correlated with wide-scale adoption of Bt cotton in China*" published in the world-known academic journal, *Science*, have received much attention from domestic and international media.

17.8 Rodent control science

The effects of foods and vegetation on rodent population outbreak were

elucidated. It is suggested that El Niño-Southern Oscillation (ENSO) may be an important factor initiating rodent population outbreak. A computer-based numerical simulation of regional rodent outbreak and the monitoring and forecasting system has been set up. Rodent immunity function at reproductive stage and the relationships between heat-producing by the Brown Adipose Tissue (BAT) and immunity of rodent were clarified. Meanwhile, the influences of cold acclimation and IBAT incision of rodent on immunologic index were also verified. It was found that the genetic diversity of rodent populations was positively correlated with rodent population outbreak, and which is one of the important factors for genetic expression of *Microtus brandti*. In addition, it was shown that the tannic acid in food can inhibit the protein metabolism of mouse; the addition of tannin can suppress its breeding ability, and also reduce its immune function.

Overall, the research level of plant protection science in China is far behind the international advanced level, and is incarnated by lack of originality and relatively weak in basic research and high-tech research and development.

In the next five to ten years, using the international advanced level and major national demands as the goal, a systematic and comprehensive study should be carried out on catastrophism, mechanisms of disaster formation, monitoring, forecasting, and integrated control theory and technology of important agricultural pests, so as to elevate the overall level of plant protection discipline in China, offer the sustainable control of crop biohazards, and provide science and technology support for the safe agricultural production.

18 Pharmacy

After entering the new historical period, the party and the state emphasize the improvement of people's life as the starting point and the foothold of science and technology, and have made clear that the development of the biological medicine industry is a high-tech pillar industry. In April, 2009, the opinion on deepening the reform of medical care system issued by the state council reflected that the party and the government attach the great

importance to people's physical health. Healthcare reformation scheme proposes to put medical and health technology innovation as the highlight of national science and technology development through increasing medical research investment, integrating advantageous resources of scientific research, encouraging independent innovation, and strengthening the study on major diseases prevention and cure and key technology of new drugs development. China's medical health industry is facing an unprecedented opportunity to develop.

At present, the pharmaceutical industry in China has maintained an overall rapid growth, and the scale has been unceasingly expanded. Multidisciplinary integration in pharmaceutical innovation has been rapidly progressed. A series of lead compounds and candidate drugs have been found against major disease, some of which have already entered preclinical and clinical research, and have showed encouraging development prospects. Biopharmaceutical industry with a core of genetic engineering drugs is booming, and it becomes an important direction in new drug improvement. Now, in China there have had many biotech drugs and vaccines being awarded new drug certificates with independent intellectual property rights. Chinese scientists have obtained a series of new active compounds with novel skeleton structures from different strains of marine microorganisms and a number of marine candidate drugs are undergoing preclinical and clinical research. China has significantly improved the study of high efficient anti-tumor antibiotic lidamycin and jaliqimycin, especially in that of lidamycin antibody target treatments of tumor. In the basic research of drug function mechanism, we have achieved the international advanced level. And many new progresses have also been made in the domains of major diseases relating to function transformation of gene and protein.

In May, 2009, the major science and technology projects "creation of major new drugs" officially launched, the project played an important role in promoting the innovative level of Chinese pharmaceutical industry. Three new drugs, such as h. pylori (Hp) vaccine which was specially supported by the project, have already obtained new drug certificates, and all the research projects of 10 new drugs against drug-resistant bacteria, such as levorotatory ornidazole, have been completed. Forty-three anti-tumor drugs, such as

Hemopofin, are on the Ⅲ period clinical trials. Anti-bacterial drugs antofloxacin hydrochloride which was studied by Shanghai Institute of Materia Medica, Chinese Academy of Science was awarded the first category new drug certificate on April 15, 2009 after 16 years hard work. Six GLP have passed the international AAALAC authentication, and National Chengdu Traditional Chinese Medicine Safety Evaluation Center has passed the American NIHOLAW authentication. Shanghai Institute of Drug Safety Evaluation Center, AstraZeneca, the Biotechnology Center for Safety Assessment has been constructed and a series of molecular toxicological models have been set up. Twenty-six new drugs clinical research platforms supported by the project have also made a rapid progress; among them, some institutions have obtained international recognition and started to undertake international multi-center studies. The discipline framework and technological platform system of modernization innovative drug research in China have been basically built up, which significantly improve the basic and application research level of our innovative drugs and provide foundation for the preliminary basic research of our innovative drugs in order to reach international frontiers quickly.

Under the background of giving high attention to people's livelihood, deepening the comprehensive medical and health system reform, and gradually increasing the research funds in medical and health field by the state, the medical industry has been rapidly developed, the concentration ratio of pharmaceutical industry has been further improved, and the sale scale of pharmaceutical enterprises has also been increased year by year with the enhanced competitive ability in China. However, the international medicine situation indicates that there is a wide gap between China and the developed countries in the overall level of pharmaceutical industry. Drugs with independent intellectual property rights are extremely deficient because pharmaceutical innovation ability and potentiality are not strong enough, which deeply restrained our domestic pharmaceutical industry from entering the high-tech and high value-added downstream processing area. The medical and health field urgently craves for the drug innovation. In addition, continuous improvement and enhancement are also needed in strategy design, research means and methods, interdisciplinary talent cultivation, and

achievements transformation.

Modern biology has made great progress, and has deeply affected strategy and research mode of drug developments. In June, 2009, the state council promulgated "Several policies to promote the rapid development of biology industry", and proposed to cultivate the biology industry as China's pillar industry in high-tech fields. At present, China focuses on developing biotechnological drugs, such as humanized antibody, and strives for multi-point breakthroughs in biotechnology field in order to close to or arrive at international advanced level. With the continuous progresses of global cell and molecular biology, chemical genomics, and proteomics research, the understanding and research of disease pathogenesis have reached a high level. Domestic drugs researchers have paid attention to search for key target molecules related to drug discovery from genomics information resources, and now have made a new progress. With small molecules as probe, the influences of small molecules on regulating biotechnology system and signal transduction of biotechnological system at the molecular and cellular level were investigated to reveal the regulation rule of signal transduction. Based on results, finding new drug targets, designing and researching new pilot molecular structures have become a new research trend on new drug development. In 21st century, synthetic drug still belongs to the key development field of new drugs. Our innovative research on traditional Chinese medicine occupies a leading position by inheriting the superiority and features of traditional Chinese medicine and accelerating the modernization of traditional Chinese medicine. The breeding, normalization, standardization, and scale planting of famous-region Chinese crude drugs are strengthened. To elucidate the substantial basis and mechanism of traditional Chinese medicine drugs on the basis of inheritance and development of Chinese medicine theory. Efficacy and safety evaluation system with special characteristics of traditional Chinese medicine should be established. And the quality control system of traditional Chinese medicine is to be set up according to the characteristics of traditional Chinese medicine compound ingredients. In 21st century, it is still an important way to discover new drugs by isolating new lead compounds from natural products, and then modify the structure or fully synthesize it.

19 Physiology

19.1 Introduction

Physiology, as a classic discipline, has played an indelible role in the development of modern medicine and biology. Physiological sciences began to establish in China over 80 years ago and has attained remarkable development in the recent five years, mainly due to the increase in research funding, the home-coming of prominent physiological scientists from abroad, and the strategic direction of the country.

19.2 Progress of Physiology in Research, Teaching and others

19.2.1 Brief Introduction on the Progress of Scientific Research

19.2.1.1 Neurophysiology

The study of sensory systems in China reached international level in some fields, particularly in vision, hearing and pain. In vision research, advances were made in retinal signal transduction and visual cortex plasticity. In auditory research, significant progress has been made in the perception of supersonic signals. Pain research in recent years mainly focused on pathological pain, such as inflammatory and neuropathic pain. Many of these findings have been published in *Nature*. In the studies of olfactory sensation, progresses have been made in molecular mechanism underlying the detection of CO_2.

In advancing our understanding of the pathophysiology and treatment of nervous system diseases, remarkable progresses have been made in several areas. Notably, in neuodegenerative diseases such as Parkinson's disease and Alzheimer's disease, systematic and comprehensive studies have been performed on the etiology, pathogenesis, early diagnosis, and treatment. In the case of stroke, important genetic and environmental risk factors of stroke have also been revealed. In addition, new strategies for the prevention and treatment of stroke have been proposed. Furthermore, achievements have been made in understanding the mechanism, prevention and treatment of epilepsy. Finally, the treatment of glioma has focused on the inhibition of angiogenesis and the pathway of glioma tumor growth.

19.2.1.2 Circulatory Physiology

A lot of studies have been done in the mechanism of promoting

atherosclerosis through the vascular inflammation induced by HHcy. It has been found that lipid metabolism in endothelial cells can be improved by adjusted arachidonic acid, activated PPARγ and increased stearoyl desaturase induced by laminar flow. The work on nuclear receptor LXR, FXR and the regulation of lipid metabolism have also been published in leading journals. Studies have also been conducted to investigate mutations leading to high triglyceride level, mechanisms of oxidative damage of lipid, and the development of new drugs regulating lipid level. It has been confirmed that the expression of KChIP2 and minK were decreased during atrial fibrillation. Our works on the PGE2 system is leading the world and have been published in a series of excellent research papers. We first reported that H_2S is a new signal molecule regulating cardiovascular function and is ubiquitous in maintaining cardiovascular homeostasis. It has also been demonstrated that activated κ-opioid receptors have definitive regulatory role on the cardiovascular system.

19.2.1.3 Reproductive Physiology

Studies of the male reproductive system covered the vaccine of birth control, molecular basis of cryptorchidism infertility, new targets for male contraception, and microbial genomics in reproductive tract. Studies on the female reproductive system mainly focused on the abnomalities of meiosis or chromosome segregation in the process of oocyte production. This dysfunction substantially increased the differentiation and meiotic capacity of PGC *in vitro*. A number of up-regulated and down-regulated microRNAs responsible for embryonic implantation have been screened. The molecular basis of angiogenesis and its role in the ovary have been revealed, providing a novel explanation on ovarian aging during perimenopausal period. The mechanism of synthesis and secretion of placental CRH has been clarified, revealing the role of placental endocrine network in the maintenance of pregnancy and initiation of labour. A new target molecule was identified for early prediction of preeclampsia and the theory of "placental dysfunction leading to preeclampsia" was proposed.

19.2.1.4 Endocrine Physiology

By proposing the non-genomic glucocorticoid effect and membrane receptor hypothesis, physiologists found that glucocorticoids could inhibit

activation of ERK1/2 mediated by NR2A through the non-genomic effect, enhancing the NMDA-induced. Neuronal damage. It was also found that steroid-receptor complex, PKC signaling pathway, and estrogen, via the action of CRE, could regulate target genes. We have also investigated the regulatory effect of neuropeptide CRF and CRF receptor on hypoxic injury and adaptation, and proposed CRFR1 as early warning signals for the injury and a target of intervention.

19.2.1.5 Respiratory Physiology

It was found that extract from cigarette can activate calcium in smooth muscle, and reduce the expression of Kv1.5 potassium channel and voltage-dependent potassium channel. Histamine H_3 receptor, substance P, VEGF, NGF, GDNF, and AQP5 can regulate inflammation caused by asthma. It has been found that NO, 5－HT_{2A} receptors, dopamine D1 receptor and ASICs may regulate both the suspension of inspiration and the volume of respiration. BKCa channel could mediate the regulation of central respiratory circuit by CO. It has been discovered that chronic intermittent hypoxia could increase the expression of synthase (CBS) in medullary cystathionine and elevate the H_2S content in the medulla oblongata to protect the respiratory center. Further, the expression and up-regulation of TRPC1/SOCC were the common pathway underlying pulmonary hypertension caused by chronic hypoxia. We confirmed that glutamate, VIP, substance P, CGRP, and ET－1 could regulate the function of epithelial cell during stress, inflammation and damage of lung.

19.2.1.6 Digestive Physiology

It has been found that HCO_3^- secretion and Cl^- absorption of colonic epithelial cells played significant role in adjusting the pH in the micro-environment. It was proposed for the first time that 5－HT_3 receptors in submucosal plexus were involved in inhibiting ion transport in colon. The actions of 6－OHDA on TH－and DAT－positive cells were different between the substantia nigra and the digestive tract. The protective effect of electrical stimulation of the paraventricular nucleus and lateral hypothalamus during gastric ischemia-reperfusion injury was discovered. It has been proposed that stretch stimulus could be involved in the contraction of smooth muscle mediated by the muscarinic receptor and the depolarization of Cajal interstitial

cell membrane. It has also been confirmed that atrial natriuretic peptide, NO and oxytocin receptor could regulate the movement of gastrointestinal smooth muscle. Three types of afferent nerve innervating the small intestine were categorized according to their electrophysiological characteristics. TRPV1, SST2, ASICs, TRPM8, and TRPA1 are the important proteins mediating signal transduction in the afferent nerve of intestine.

19.2.1.7 Exercise Physiology

It has been discovered that newly synthetized mitochondrion induced by NO can generate ATP through oxidative phosphorylation pathway. It has also been confirmed that injury of skeletal muscle exhibited changes in sarcoplasmic reticulum, contractile proteins and structural proteins. Micro-injury of skeletal muscle is always associated with the loss of strength. Myogenic regulatory factors played an important role in muscle damage and repair caused by exercise and hypoxia. Exercise of different intensities could change the function of heart, cholinergic nerves M2 receptors and MAPK to different degrees.

In the preparation of the 2008 Beijing Olympic Games, physiological sciences were further applied to the monitoring and evaluation of training methods and achieved significant results. New findings were reported on core strength, serum CK and BU during training. There was low correlation between the fitness level and the adaptive ability of human beings. Moderate degree of physical training can reduce the degree of psychological stress.

19.2.1.8 The Physiology for Traditional Chinese Medicine

Computerized diagnosis and visualized model for health condition was set up in the practice of Traditional Chinese Medicine, allowing the categorization of sub-types of constitutive body character. Diagnostic equipment of traditional medicine was developed and certificated by sFDA. For example, a model of pulse patterns that could mimic over 10 types of pulse manifestation was developed for teaching. Drug delivery system via micro-emulsion and transdermal administration at SHEN QUE and YONG QUAN acupoints was also investigated. New models were developed to study the discipline of prescription and compatibility of medicines. These models may illuminate complicated relationships and compatibility of different herbs in Traditional Chinese medicine.

19.2.1.9 Applied and Comparative Physiology

The hypothesis of storm of inflammatory cytokines induced by heat stroke was proposed and proven. Targeted and protective drugs were also developed. The novel idea of "vascular endothelial cells as the target for inducing low temperature injury", was proposed. This promoted the development of novel drugs. Neuroendocrine changes were observed in the Antarctic expedition team members. In the field of underwater physiology, various topics have been investigated. In particular, dive training below 470 - meters was achieved. In the field of aviation physiology, research contributed significantly to the development of domestic aircraft and the training of pilots on carrier-based aircraft. In the field of space physiology, medical support to the manned spaceflight, extra-vehicular activities, and MARS500 were explored. In the area of high altitude physiology, a series of discoveries has been made with regard to the induction with multi-pathway and turnover with multi-direction related to hypoxic adaptation. The study related to hypoxia adaptation of Tibetan has been published in *Science*. Furthermore, a series of intervention strategies were adopted to fulfil the great demands of the Qinghai-Tibet Railway, YU SHU earthquake and other plateau areas.

19.2.2 Teaching work

In 2002, Chinese Association of Physiological Sciences established the Education Committee which is responsible for promoting the development of teaching in physiology. This Committee held national academic conferences once every two years. These conferences focus on the content and pedagogy of physiology teaching, the introduction and comparison of overseas physiology teaching content and materials, the study on the bilingual physiology teaching, the problem-based learning (PBL), the design of featured courses, the design of multi-media courses, and the development of teaching equipment for physiology. Future directions will focus on featured courses, bilingual education, and the improvement of web-based courses in physiology to meet with the requirements of digital and web-based teaching.

19.2.3 Society work

Under the guidance of the Chinese Science and Technology Association, our Association has completed a large number of work concerning academic exchanges, continuing education and popularization of science. We have held

40 national meetings and several international conferences. For instance, 700 physiological scientists from 35 countries participated in the Beijing Joint Conference of Physiological Sciences 2008 which achieved great successes. Meantime, we also encourage local scholars to attend overseas conference. As a result, more than 170 Chinese scholars attended the 36th Congress of the International Union of Physiological Sciences (IUPS) and one senior member of our Assocaition was elected as the Vice-P resident of IUPS. Our Association was the first in China in founding the Youth Committee and this initiative was followed by other national societies. Furthermore, we actively participated in social scientific activities organized by the Chinese Science Association. We set up a website and published *Progress in Physiological Communication* as the bridge between the society and our members. Our official journal, *Acta Physiologica Sinica*, was awarded the honor of "The Outstanding Journal of New China in 60 years".

19.3 Application of Physiology in China's economic construction and national defense

At present, there are more than 200 medical schools that offer physiology classes. Physiology education can be recognized as the basic building block of Bio-medicine. Moreover, physiology has made significant contribution to national needs, such as the 2008 Beijing Olympic Games, national plan for health guarantee, Qinghai-Tibet Railway, Antarctic DOME A, and manned space flight, etc.

19.4 Comparison of the international and domestic progress of physiology

In general, the development of Physiology in our country is parallel with that in the world. Some research areas, such as circulation, reproduction and neuroscience, have already reached international level. In other areas such as comparative physiology, exercise physiology and environmental physiology, the development of research is escalating rapidly in recent years because of national demand. Targeted areas with special resources are able to reach leading level of the world.

19.5 Development trends and prospect of physiology

The following opportunities and challenges emerge through the analysis of future demands and directions:

19.5.1 Opportunities brought by the various "-omic researches"

A lot of information has been produced with the development of various

"-omic researches", such as genomics, proteomics, etc. These molecular information will not bear any impact unless their functional significance can be elucidated. With a breakthrough in both technology and data throughput, Physiology is destined to yield useful information.

19.5.2 Challenges of integrative biology to Physiology

The reductionist approach in research that dominated for centuries has to be changed. More and more scientists incline to use a holistic approach in understanding life as a whole. Physiology will face greater challenges to unveil the linkage amongst massive data generated from different levels.

19.5.3 Importance of Physiology in translational medicine

Physiology serves as the bridge between the normal state and the disease state of the body. It is also a cardinal link between upstream research and application to health protection. Physiology indeed constitutes the most important basis of translational medicine.

In the development, prospects and future trends of Physiology in China, our aim is to play a leading role in a spectrum of fields in the world and to publish our research findings in high impact journals. Meanwhile, we must pay close attention to the requirements of our nation in order to promote the national economic construction as well as national defense. Physiology in China is advancing and will continue to serve as a spearhead forever.

20 Pharmacology

Pharmacology is bridge linked the basic and clinical medicines, pharmacy and medicine, life science, chemistry, and other sciences. Therefore, pharmacology is an important science in the areas of life science, medical science, and pharmacal science, especially in clinical therapeutics, drug discovery/development, and basic life science research.

In China, pharmacology research and education started from 1910's, when the western scholars propagated western medicines in China and performed education in medical schools, such as Peking Union Medical College. Since then, pharmacology has been developed as a new science in the medical area.

Since 1949, the pharmacology was developed quickly based on the

outstanding research works of Chinese pharmacologists. They researched the natural products and traditional medicines for the discovery of new drug, which is urgently needed for people in that time. Several drugs developed and used worldwide until present, for example, the antimalarial drug arteannuin.

The Chinese pharmacologists worked diligently for more than half century, and have focused on the clinical drug therapeutics and drug development. Especially in the research of traditional Chinese medicine, a lot of drugs have discovered, developed, and used clinically. During this procedure, the pharmacology science has been promoted. In the year of 2006, the 15th world congress of pharmacology held in Beijing, it is a milestone for the progress of pharmacology made in China.

Neuropsychopharmacology is an interdisciplinary science related to neuropharmacology, psychopharmacology, and fundamental neuroscience. It entails research on the mechanisms of neuropathology, pharmacodynamics, psychiatric illness, and states of consciousness. Neuropharmacology involves the study on neurons and their neurochemical interactions; it has the overall goal for developing drugs that have beneficial effects on neurological function. Psychopharmacology focuses on the study how drugs affect human mind and behavior, including the study on how drug dependence and addiction affect the human brain. Both of these fields are closely connected with each other, since both are concerned with the interactions of neurotransmitters, neuropeptides, neurohormones, neuromodulators, enzymes, second messengers, co-transmitters, ion channels and receptor proteins in nervous system. By studying these interactions, researchers are developing drugs to treat many different neurological disorders, including pain, neurodegenerative diseases, such as Parkinson's disease and Alzheimer's disease, psychological disorders, addiction, and many others.

Cardiovascular disease is the inadequacy of the heart and blood vessels because of the blood vessels narrowing, which is unable to maintain the amount of blood circulation throughout the body. In China, the cases of cardiovascular disease are continuously increasing. The disease is potentially preventable; the task for searching potential prevention targeted is carrying out.

Clinical pharmacology is a subject involving the research of interaction

and rules between drug and human body, which is an important part of pharmacology. It is mainly about clinical pharmacokinetics, clinical pharmacodynamics, adverse drug reaction, drug interaction, rational prescribing and new drug development. Although the development of clinical pharmacology in China started late, the subject has obtained the significant result with all efforts for many clinical pharmacologists.

Quantitative pharmacology (also called pharmacometrics) is the scientific discipline that uses mathematical and statistical methods to quantifying the interactions between drugs and patients. It plays an increasingly critical role in drug development and pharmacotherapy.

As a branch of pharmacology, pharmacology of traditional Chinese medicine (TCM) is an important subject that utilizes modern scientific methods to objectively evaluate the safety and efficacy of TCM. It is also an important subject involving the fusion of modern science and TCM, the introduction of TCM to the world, and the discovery and development of new drugs. In the study on traditional Chinese medicine theory, several new ideas has emerged, such as effective composition group and recombined TCM, it will promote the modernization of TCM.

Pharmacokinetics is a research subject on what the body does to a drug. Since the 21st century, pharmacokinetics has obtained rather rapid developments. In silico modeling, pharmacogenetics and epigenetics play the very important role in study of structure and function of drug metabolic enzymes and transporters as well as personalized medicine. New *in vitro* and *in vivo* models provide the effective approach for mechanism studies on drug transport. In recent years, pharmacokinetic-pharmacodynamic (PK－PD) models have been gradually applied to the studies of other chemical drugs except for antibiotics. Besides, PK－PD models have also been used in the studies on TCM in China, which was helpful for providing scientific evidence for development and rational clinical application of TCM. Driven by systematic biology, pharmaco-metabonomics has emerged as a characterization technology that is very close to the phenotype of drug response, and will further promote the development of personalized medicine.

Drug toxicology is a branch of pharmacology, which concerned with the studies on the mechanisms of the toxic effects of the pharmaceuticals and the

safety evaluation of new pharmaceutical products. The latest progresses in the drug toxicology studies in China during past five years could be summarized as follows: ①Gradually establishing an professional promotion system for drug toxicology; ②Stable and fast developing a GLP compliance system by the establishment of historical control database that contains hematology, clinical chemistry, spontaneous pathological finding, teratology, and genotoxicity, test article management and characterization, harmonization on the toxicologic pathology diagnosis, the development or adaptation of LIMS data capture system in a GLP environment, and the improvement of animal welfare in toxicology laboratories; ③Implementing the concept of whole R&D process involvement of drug toxicology and its application in the new drug safety evaluation practice; ④Comprehensively promoting the preclinical safety assessment of new drugs by the application of concurrent toxicokinetic exposure analysis, the modernization of the safety pharmacology study instruments and tools, formal adaptation of the ICH guidelines for developmental and reproductive toxicity tests, and the ICH S8: immunotoxicology studies; ⑤ Broadly applying the toxicogenomic, toxicoproteomic, and metabonomic technologies to the elucidation of the mechanisms for the toxicity of common pharmaceuticals in China; ⑥Focusing on the safety evaluation of some special pharmaceuticals, such as the injection formulations of TCM, nanomized drug delivery systems, and biopharmaceuticals.

In the recent years, the development of pharmacology has been accelerated. The government launched mega projects for drug development and medical system reformation. These projects promote the pharmacology and make it increasingly important.

21 Leprology

Leprosy is a chronic infectious disease caused by Mycobacterium leprae (M. leprae). It affects skin and peripheral nerves and can cause irreversible nerve function impairment and consequent chronic disabilities, often leading to many social and economic problems. Therefore, leprosy is one of the important major diseases in the world as well as in China. Although its transmission is still not fully understood, the upper respiratory tract is

generally considered to be the main route for the spreading of *M. leprae*. Most people have a natural resistance to the infection, and only a few have a genetically related susceptibility to it. The onset of leprosy is very insidious with a long incubation period, and it is difficult to determine the exact onset of the disease. Clinically, leprosy can simulate many kinds of skin diseases and neuropathic problems, which makes early diagnosis difficult.

In the year of 1981, an estimated 12 million leprosy cases were being treated worldwide. After the introduction of Multi-Drug Therapy (MDT) in that year, the prevalence of leprosy declined dramatically, because of the change from life-long treatment with dapsone monotherapy to treatment of fixed duration with MDT and the changes in record-keeping. After the 44th World Health Assembly resolved to eliminate leprosy by the year of 2000 and the final push toward elimination of the disease was implemented in areas where it is endemic, the number of newly detected cases further declined. In 2009, a total of 244,796 new leprosy cases were globally reported. Only four countries had not achieved the elimination of leprosy which is defined as less than 1 case in 10,000 populations. The elimination of leprosy was achieved in 1998 at national level in China which is defined as less than 1 case in 100,000 populations after more than 40 years' efforts in combating the disease. Since then, about 1,600 new cases were reported each year in China in the last 10 years. By the end of 2010, 46 counties and 276 counties did not reach at the WHO criteria and China criteria for the elimination of leprosy, respectively. Despite the great progress, changing trends in case detection should be viewed with caution, since undetected cases are not included in these statistics. Furthermore, patients with leprosy are not evenly distributed in countries where the disease is endemic. Therefore, even in the post-elimination era, the efforts are needed to further reduce the disease burden and to sustain control activities, including the detection of remaining hidden and new cases. The efforts are also needed to deal with problematic patients, such as those at high risk for disability, those with drug reactions, and those already disabled by leprosy. Furthermore, leprosy not only has a physical effect, but also has a social and economic impact.

The diagnosis of leprosy must be established as early and as accurately as possible, because both under- and over-diagnosis will lead to undesired

consequences for individuals as well as the community. Accurate diagnosis is also vitally important to all aspects of a control program, including epidemiology, chemotherapy, prevention of disability, and assessment of interventions. Three cardinal signs found on clinical examination (anaesthetic skin lesions, enlarged peripheral nerves, and acid-fast bacilli in the skin smear) form the basis of the diagnosis of leprosy. Many advanced diagnostic tools have been developed, but these are used mainly in research. Serology can't be used as a single diagnostic test because the majority of the PB patients are seronegative, and current serological tests are not specific enough to distinguish a patient with clinically overt infection from one with sub-clinical infection. Also, DNA amplification tests require trained personnel and expensive equipment, which limits their use in the field.

The diagnosis of leprosy is not straightforward because it can mimic many skin diseases, the sensory testing of a skin lesion has not been standardized, and the test result is judged subjectively rather than objectively. Therefore, several factors impact the accuracy of the testing and the palpation of peripheral nerves. Apart from the inter-examiner reliability, peripheral nerve enlargement may not be apparent in some early cases. Although a positive result on examination of skin smears has near 100% specificity in the diagnosis of leprosy, many PB patients have a negative result and skin-smear examination is usually not available in the general health services. Furthermore, ignorance of general health problems, lack of awareness for leprosy, and stigmatization in the general population may prevent persons from seeking help. In view of these factors, many patients visit general health care services/dermatologist several times before the diagnosis of leprosy is made, especially in a low endemic area. Delay in diagnosis will result in increased impairment of nerve functions. Currently in China, the proportion of WHO grade - 2 disability among newly detected cases is more than 20% in general and even as high as 40%- 50% in some provinces, where leprosy is in a low endemic. This indicates that there is a room for improving early diagnosis of leprosy.

To prevent the drug resistance that occurs when only one drug is given, MDT was introduced in 1981. In the same year, in order to guide this therapy, the World Health Organization (WHO) developed a 2 - group

classification system based on the probable number of *M. leprae* presenting in a patient. The patients with paucibacillary (PB) disease were treated daily with dapsone (100 mg) and monthly with rifampicin (600 mg), and with 6 months of supervision. The patients with multibacillary (MB) disease were treated daily with dapsone (100 mg) and clofazimine (50 mg), as well as monthly with clofazimine (300 mg) and rifampicin (600 mg), and with a minimum of 24 months of supervision or, if possible, until the skin smear became negative. In 1994, after more information was collected from the efficacy and the low risk of relapse, the duration of treatment for patients with MB leprosy was fixed at 24 months, while the regimen for those with PB disease remained at 6 months. To accelerate the elimination of leprosy in most countries where the disease is endemic, the duration of the MDT－MB regimen was further reduced to one year in 1998. In the year 2002, WHO started clinical trials to test the efficacy of Uniform MDT (WHO MDT－MB regimen, 6 months for both MB and PB). However, the long-term efficacy and the risk of relapse of this shorter regimen are unknown.

Since *M. Leprae*, the causative mycobacterium for leprosy was discovered by Armauer Hansen, a Norwegian scientist, in the year of 1873, many achievements in the research have been made. Especially, over the past decade, the developments of molecular biology in general, and the complement of Human Genome Bank in particular, provide strong tools for the study on biology of *M. Leprae* and on genetics of leprosy. For example, studies on genome sequences of *M. Leprae* have revealed the stability of the mycobacterium with little variation between strains. Studies on genome of *M. Leprae* have also elucidated the nature of strict inter-cellular parasitism and the long incubation period of leprosy. The type specific markers established from genome sequences of *M. Leprae* have been used as a tool in the study on the epidemiology of leprosy. Another development on genome of *M. Leprae* is to establish a drug resistance monitoring system for anti-leprosy drugs including rifampicin. Comparing to mouse footpad techniques, the test is simple, rapid, and less expensive.

Recently, study on susceptibility to leprosy is also one of the hot spots worldwide. It is well known that only few infected persons will eventually develop into clinical disease. Host genetic factors have been implicated in

susceptibility to leprosy in studies of familial clustering, studies of twins, complex segregation analyses, and tests of association with the HLA genes. Markers in several genes and genomic regions have been reported to be associated with susceptibility to leprosy or the development of a particular clinical form of the disease, but few of these associations have been replicated. A two-stage genomewide association study by genotyping 706 patients and 1,225 controls using the Human610 - Quad BeadChip (Illumina) was conducted in China in collaboration with more than 40 domestic institutions and Singapore Human Genetic Institute. A significant association between SNPs in the genes *CCDC*122, *C*13*orf*31, *NOD*2, *TNFSF*15, *HLA -DR*, and RIPK2 and a trend toward an association with a SNP in LRRK2 were discovered. The associations between the SNPs in C13orf31, LRRK2, NOD2, and RIPK2 and multibacillary leprosy were stronger than the associations between these SNPs and paucibacillary leprosy. Variants of genes in the NOD2 - mediated signaling pathway (which regulates the innate immune response) are associated with susceptibility to infection with *M. leprae*. The result of the study has been published in *New England Journal of Medicine*, which not only makes China a leader in the field of genomewide association study of leprosy, but also provides a base for further studies, such as pathogenesis of leprosy, relationship between phenotype and genotype of the disease, mechanism of leprosy reactions and neuritis in a collaborative way.

Leprosy is a complex condition that affects patients not only physically, but also socially and psychologically. Individuals with leprosy have been made to leave their families and communities and are forced to live as outcasts in separate colonies. The stigma attached to leprosy is very common in societies around the world and has a negative impact on a patient's health-seeking behavior, adherence to treatment, and resumption of normal life even after cure. It also affects one's entire life including marriage, employment, interpersonal relationships, leisure activities, and attendance at social and religious functions.

Although many factors contribute to this stigma, a complex mix of reasons is associated with it in each society. Disability (impairments) caused by peripheral nerve damage is one of the important factors. In the last two

decades, much progress has been made in understanding the risk factors for nerve damage. Corticosteroids are still the mainstay in the treatment of peripheral neuropathy in leprosy. Several recently published clinical trials have tested in the use of steroids to prevent immunological reactions and peripheral neuropathy prophylactically, to treat neuropathy with more than 6 months duration, and to treat mild sensory impairment.

For those disabled before the diagnosis was made or those who have developed permanent disability during the course of the disease, projects aimed at preventing secondary impairment (Prevention of Disability, POD) have been undertaken in many leprosy control programs worldwide, including China. Social and Economic Rehabilitation (SER) programs with a community-based approach are needed to target the disadvantages affected by leprosy (most of whom are elderly, former leprosy patients who have some degree of social and economic difficulty, with or without disability). By nature, these programs should be integrated into existing services and provided by communities, and should be holistic, participatory, and sustainable, sensitive to special needs, particularly those of women, and meaningful to the targeted individuals.

Since the elimination of leprosy was achieved in China (1998), maintenance of a vertical leprosy control program is no longer effective. One option for dealing with the remaining problems is to integrate the leprosy control program into general health services. This strategy has been adopted in many countries. The rationale for the integration is the development of a cost-effective and sustainable way to manage remaining leprosy problems in a low endemic situation. This includes early detection and treatment of the few incident new cases, as well as comprehensive care for the disabled and the rehabilitation of patients through the effective coverage of the population by accessible and efficient health services, which are acceptable to both the community and the patients. However, before such integration is undertaken, there must be situation analysis and careful planning. The leprosy control programs in China has not been successful for the full integration, because the health system reforms in China, which started in the late 1990's after the collapse of the well-established infrastructure of the health system in general and the rural cooperative health care system in

particular, are still underway. Without full restoration of the systems, it is difficult to begin on the integration, because a sound health care infrastructure is one of the prerequisites for the integration of a leprosy control program into the general health services.

Following research areas should be highlighted: ①Molecular tools based on strain typing of *M. leprae* are available to track the transmission of leprosy; ②Tools that assess the emergence of drug resistance should be used in order to understand the basis of transmission and to monitor the success of the control program; ③ To develop and improve diagnostic tests is very important for identifying individuals that are with disease or at high risk of developing leprosy. The efforts for finding species-specific antigens and their use in the development of immunodiagnostic tests, involving cell-based immunity and/or serology, should be intensified; ④MDT should be improved in terms of its efficacy and duration; ⑤More researches are needed in the area of prevention and management of nerve function impairment (NFI) and the underlying reactions; ⑥ Development of chemoprophylactic and immunoprophylactic tools for the prevention of leprosy is required; ⑦It is important to perform operational, epidemiological and implementation research in order to improve the sustainability and quality of leprosy services, including prevention of disability and community-based rehabilitation.

In summary, great achievements have been made in leprosy control. However, we still face many problems and challenges. More efforts are needed for improving leprosy control service and for providing the better care for people affected by leprosy.

22 Toxicology

Toxicology is the science that studies the adverse effects of chemical, physical, or biological agents on living organisms and the ecosystem, including the prevention, treatment of amelioration of such adverse effects. As an integrated discipline, toxicology has the characteristics of multivariate and integration, involves basic academic research, application research and development, and management service. Entering the 21st century, toxicology has already become an important scientific resource and technical power for

maintaining environment friendly and ecological balance, protecting life safety and health living, maintaining social economic sustainable development, and promoting social civilization and progress.

22.1 Outline of the development of toxicology in China

Toxicology has a long development history same as the development history of the traditional Chinese medicine in China. As early as the ancient period of firestorm monarch Yan Emperor, there is record about that Shennong tasted a hundred grasses, met 70 toxicants and poisonings on one day. The modern toxicology science started from 1950's in China; it has been experiencing a rapid development stage from the mid 1990's. At the present, a number of new technology theories and branch disciplines have emerged in toxicology academic system, such as toxicological genomics, poisoning metabonomics, poisoning and dynamics, nanotoxicology. There are three main fields within toxicology, i. e., descriptive toxicology, mechanistic toxicology, and regulatory toxicology. Up to now, there have developed various specialty subdisciplines under toxicology in China, they are industrial toxicology, food toxicology, drug addiction toxicology, clinical toxicology, biochemistry and molecular toxicology, feed toxicology, genetic toxicology, immunotoxicology, reproductive toxicology, environmental toxicology, ecotoxicology, biotoxin toxicology, analytical toxicology, veterinary toxicology, military toxicology, radiotoxicology, regulatory toxicology, intoxication and remedy, medicine toxicology, neurotoxicology, and Nanotoxicology.

In recent years, the strength of toxicology science and technology has been in rapid growing, the scope of scientific research, teaching and management is constantly expanding. Along with the increasing of budget invested in the field of toxicology, the ability of innovation in toxicology has boosted in China. On the one hand, toxicological basic research level is raising and the international impact is steadily increasing. On the other hand, the applied technologies and platforms of toxicology have been rapidly developed for the analytical testing and risk evaluation of chemicals including environmental pollutants, residues in all kinds of products, and medicines. The toxicology achievements have played an irreplaceable role in the evaluation of safety and risk management of exogenous environmental pollutants, industrial chemicals, medicine, food, cosmetics, health-related

products, and new materials, such as nanomaterials, etc. Especially in recent years, the knowledge and technologies of toxicology have been successfully applied to the emergency disposal and medical rescue for the prevention against the potential public emergencies of radiological, chemical, biological events, to the security of the 2008 Olympic Games in Beijing and the 2010 World Expo in Shanghai, to perform the international conventions for drug control, and to process the left chemical toxic agents by Japanese, major events of environmental pollution, etc.

22.2 Main progress and achievement of toxicology in China

22.2.1 Progress of toxicological basic research

The basic research level of toxicology is constantly upgrading in China. The quantity and quality of research articles published in international journals with good reputation by Chinese toxicologists increase year after year, and now it reaches nearly 400 SCI papers per year.

For the target organs toxicity and mechanism, in addition to the application of the traditional experimental models and methods for the research of target organs toxicities *in vivo* and *in vitro*, it also adopts and establishes a series of advanced target-organ toxicology research models and methods in recent years. The toxic characteristics, strength, and reversible mechanisms of target organs toxicities have been widely studied and elucidated in the animal models or *in vitro* cultured primary tissue cells for various exogenous chemicals, including industrial chemicals, environmental pollutants, food contaminants and biological products, Chinese and western medicines, and new materials.

For the Environmental-endocrine Disrupting Chemicals (EDCs), the increasing research data indicate that various human diseases of reproductive system are related to the exposure of exogenous chemicals or drugs. With the research strategies for the combination of in *vitro* study and whole animal study, laboratorial experimental study and population cohort study in site, Chinese investigators have systematically studied the features and related mechanisms of reproductive toxicity of multiple EDCs. It has been proved that a number of EDCs, especially some of the persistent organic pollutants (POPs), led to broad reproductive disorders, including sexual differentiation abnormalities, genital deformity, sperm defect, sexual abnormalities, birth

defect, dead fetus, and spontaneous abortion. These studied have provided important data for the risk evaluation and population intervention research of the reproductive toxicity.

Biomarker is one of the important fields in the toxicology research. In recent years, Chinese investigators have found multiple biomarkers (contact markers or effective markers) related to the exposures of a number of chemicals or toxicants. For example, 1－itrogen－6－ethylene (deoxidizing) adenine was revealed as the contact biomarker for evaluating the occupational exposure level of workers to vinyl chloride. Chinese and American investigators jointly initiated a cooperative project of molecular epidemiology study on occupational benzene exposure workers; the project aims to elucidate the complex relationship between the benzene exposure and the early changes of metabolic products and hematology index. Their data have played a direct role for promoting the Occupational Health & Safety Administration, USA to decrease the occupational benzene exposure limitation to 1ppm level. Chinese investigators also found the body contact markers or effect markers for the interaction between human and chemicals. The technology of gene analysis has also been broadly employed to the susceptibility studies of the environmental pollutants and chemicals in China.

Oxidative stress damage is a major mechanism of the acute and chronic injuries induced by a wide range of chemicals, radiation, and biological factors. In recent years, Chinese investigators have made a great progress in this field. A series of advanced platforms of oxidative stress and antioxidant research have been established. The oxidative stress damage and its mechanisms have been elucidated for some chemicals. A theory of antioxidant compound chain has been proposed. Antioxidant compounds and their activities have been screened and evaluated using the traditional Chinese medicines and nature compounds.

For the DNA damage repair, a series of progresses have been achieved in the area of DNA damage repair and cellular responses. The involvement and mechanisms of multiple DNA repair genes have been elucidated on the cellular responses to various chemicals and ionizing radiation. It has been revealed that DNA－PK complex regulates the mitotic progressing and spindle stability in response to ionizing radiation, and plays a "cross-talk" role

between the pathways of DNA repair and mitotic checkpoint. Apak (ATM and p53 - associated KZNF protein) has been demonstrated as a negative regulator of p53 - mediated apoptosis and it displays the dual role of ATM in p53 regulation after the induction of DNA damage. Axin has been found to be a critical determinant in p53 - dependent tumor suppression in which Pirh2 and Tip60 have different roles in triggering cell-cycle arrest or apoptosis depending on the severity of genotoxic stress. JWA, an oxidative DNA damage responsive gene, was shown as a novel regulator of XRCC1 in the base excision repair protein complex to facilitate the repair of DNA single-strand breaks. A series of papers based on above results have been published in the journals of *Nature Cell Biology*, *Cancer Research*, *Oncogene*, *JBC*, and *Nucleic Acids Research*.

Epigenetic is a rapidly growing research field that focuses on the heritable alterations in gene expression caused by mechanisms other than changes in DNA sequence. Recently, the epigenetic effect induced by environmental factors has become an exciting topic in the toxicology field in China. The association of epigenetic changes and the genomic instability during the progressing of carcinogenesis induced by chemicals, such as the crystallization type NiS and BaP, and ionizing radiation has been broadly studied. Epigenetic silencing of MGMT was observed in NiS-treated cells, and which is associated with DNA hypermethylation, histone modifications, and DNMT1 upregulation. Nano-particle SiO_2 was also demonstrated to induce a global hypoacetylation implying a global epigenetic response, which includes consequential decreased levels of DNMT1, DNMT3a, and methyl-CpG binding protein 2 (MBD2). The bystander effect and genomic instability induced by ionizing radiation has also been considered as an epigenetic effect. The gap junction and oxidative stress and ROS, for example NO, were demonstrated responding to bystander effect.

22.2.2 Progress of applied toxicology research

In recent years, Chinese toxicologists have made remarkable achievements on the construction of toxicological platforms and technologies which meet the social needs for safety aspects of domestic environment, food, pharmaceutical and occupational issues.

In the area of environmental safety maintenance, the achievements

reflected on the detection of environmental pollutants, determination of the metabolic, general toxicity and mechanism *in vitro* and animal experiments, and risk evaluation. The achievements also include the assessment methods and measures for early detection and early prevention of human toxicity effects for environmental pollutants. The research areas include the atmospheric environment toxicology, soil environment toxicology, and water toxicology, etc.

Toxicology achievements promote occupational safety. The main goal is to understand the health hazards of industrial chemicals, and prevent and control the occupational disease. In recent years, a great progress has been made on the neurotoxic effects and mechanism of lead, organic solvent, polymer compounds, and so on, as well as the corresponding biological markers of exposures. Multiple toxic effective markers and susceptibility markers have been found in the biomarker studies of occupational contact workers.

In the food safety aspects, Chinese government and administrative authorities have recently issued a series of administrative laws or regulation standards based on the fundamental data of food toxicology studies. For example, they include "the safety evaluation and toxicological testing requirements of food containers and packaging materials", "the safety evaluation procedures for new resource food", and "the safety detection of 90 days fed rats for the transgenic plants and their food products". A series of food safety monitoring, warning, and evaluating methods and platforms have been constructed, which have greatly improved the technology level of food safety evaluation and monitoring, and it results in that the field gradually connects and matches with the international practices.

Toxicology plays an irreplaceable role in the guarantee for drug safety. In recent years, much more efforts have been made on the toxicology research and safety supervision of western medicines and traditional Chinese medicines. It has been strengthened on the administration of animal experiments, construction and management of professional drug toxicology research organization. Many progresses have been made on the establishment and application of toxicity pathological diagnosis technology and other new technologies and methods on drugs toxicology research. Up to the year of

2010, 39 GLP centers for drug toxicology research and safety evaluation have been authorized by SFDA. The drug toxicology research and safety evaluation in China has been gradually connected and matched with the international standardization and management system.

The toxicology and safety evaluation of new materials and products, especially the nanomaterials becomes a new research field, and progresses rapidly in China, which even led to the establishment of nanotoxicology, a new specialty subdiscipline of toxicology. The nanotoxicology research in China reaches at the international advanced level in many aspects.

22.2.3 Progress of regulatory toxicology research

Regulatory toxicology is a rapidly growing and developing field of toxicology in China. In recent years, a series of policies, law, and regulatory in regard to the management of domestic public health and the environmental and ecological protection have been issued, and most of these documents are largely formulated on the basis of the basic scientific data, and the theories achieved through the solid toxicology research.

A series of tests guiding principles and standard procedures have been issued and implemented for the purposes of toxicology research and risk management of food, medicines, and chemicals. Among them, the internationalization of the standardization and management with respect to the experimental animals is the guarantee for the domestic GLP laboratory to connect with the international practice. All sorts of relevant regulations and documents have been formulated and issued, including the experimental animal classification, raise management, and environmental conditions and facilities for animal experiments, etc. The principles involving replacement, reduction, and implementation of animal use and animal welfare have been strengthened.

According to the international practices, domestic GLP centers have also established their own Institutional Animal Care and Use Committees (IACUC), and execute ethical censorship of animal testing. By the year of 2010, 27 agencies / centers have passed the certification of the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC) in China. Following the practice of SFDA-authorized GLP on the toxicology research and safety evaluation of drugs, the National Ministry

of Agriculture has launched the construction and evaluation of GLP centers for chemicals in the year of 2008. In the year of 2009, the National Ministry of Environment Protection has promulgated a list of authorized agencies for new chemicals registration and testing.

For the execution of global chemicals unified classification and labeling or Global Harmonized System (GHS), the General Administration of Quality Supervision, Inspection, and Quarantine of China released a series standards (GB 20576－2006 and GB 20602－2006) in the late year of 2006, which link to the chemicals classification, warning labels, and warming illustrate safety norms. On this basis, the specification and chemical risk evaluation norm have been issued in the year of 2008.

Toxicology is developing very fast in recent years in China, and currently is still in a period of expansive development. It has also been facing the great challenges. In order to meet the rapidly growing needs of national public health, environment safety, economic development, and social stability, toxicology discipline should continue to expand its fields, and construct its perfective science system. It is necessary to establish the Chinese National Toxicology Program (CNTP), and create a national toxicology innovation atmosphere. To pay equal attention to both basis research and application research should be further emphasized. It is suggested to establish a national toxicology industry league with the participators coming from related government agencies, universities, scientific research institutions, and enterprises in order to expand the translation research of toxicology.

附　件

2010年度与学科进展相关的主要科技成果

附件1　2010年度国家自然科学奖目录

二等奖

序号	项目名称	主要完成人
01	基于模拟关系的计算力学辛理论体系和数值方法	钟万勰，张洪武，姚伟岸
02	舒伯特簇的乘法法则	段海豹
03	电磁固体的变形与断裂	方岱宁，刘金喜，刘　彬，等
04	定量电子显微学方法与氧化钛纳米结构研究	彭练矛，陈　清，杜高辉
05	原子团簇和团簇组装的尺寸效应和奇特物性	王广厚，韩　民，赵纪军，等
06	非晶合金形成机理研究及新型稀土基块体非晶合金研制	汪卫华，潘明祥，赵德乾，等
07	BES－II DD－bar 阈上粒子 ψ(3770)非 DD－bar 衰变的发现和 D 物理研究	荣　刚，张达华，陈江川，等
08	人工结构中的波及相关奇异性质研究	刘正猷，汪国平，谭志杰，等
09	新型稀土杂化及纳米复合光电功能材料的基础研究及应用探索	张洪杰，武志坚，张思远，等
10	具有微、纳结构特征的聚合物复合光功能材料的合成与构筑	杨　柏，张俊虎，张　皓，等
11	离子液体的构效关系及其化学工程基础研究	张锁江，王键吉，张香平，等
12	具有重要生理活性的复杂糖缀合物的化学合成	俞　飚，惠永正，王来曦，等
13	复杂形态和结构的无机功能材料的构筑、自组装原理及性能研究	俞书宏，杨　剑，刘　标，等
14	环糊精的分子识别与组装	刘　育，张衡益，陈　湧
15	中国的乐平统及二叠纪末生物大灭绝研究	金玉玕，沈树忠，王向东，等
16	中国天然气成因及鉴别	戴金星，张水昌，郝　芳，等
17	亚洲风尘起源、沉积与风化的地球化学研究及古气候意义	陈　骏，郑洪波，鹿化煜，等
18	变质同位素年代学及华北与华南陆块碰撞过程	李曙光，刘贻灿，肖益林，等
19	胶质细胞新功能的研究	段树民，戈鹋平，张景明，等
20	植物钙调素的功能及其信号转导机理	孙大业，周人纲，马力耕，等
21	细胞凋亡与抗病毒反应的信号转导研究	舒红兵，翟中和，陈丹英，等
22	tau 蛋白过度磷酸化机制及其在阿尔茨海默病神经元变性中的作用	王建枝，张灼华，王丹玲，等
23	肝癌转移机理的新发现及其意义	钦伦秀，叶青海，汤钊猷，等
24	白血病细胞分化与凋亡的新机制	陈国强，赵　倩，赵克温，等
25	生物功能的飞秒激光光学成像机理研究	骆清铭，赵元弟，曾绍群，等

续表

序号	项目名称	主要完成人
26	非线性输出调节问题及内模原理	黄　捷，陈智勇，张纪峰，等
27	新型高分子光电功能材料及发光器件	曹　镛，杨伟，彭俊彪，等
28	纳米流体能量传递机理研究	宣益民，李　强
29	特大桥梁颤振和抖振精细化理论	葛耀君，朱乐东，项海帆
30	塑料的复合结构、注射成型过程与机械破坏行为的研究	解孝林，李德群，周华民，等

附件 2　2010 年度国家技术发明奖目录(通用项目)

二等奖

序号	项目名称	主要完成人
01	棉花组织培养性状纯化及外源基因功能验证平台构建	李付广，张朝军，武芝侠，等
02	人造板及其制品环境指标的检测技术体系	周玉成，程　放，井元伟，等
03	对虾白斑症病毒(WSSV)单克隆抗体库的构建及应用	战文斌，姜有声，王晓洁，等
04	环保增强增韧型皮革鞣制整饰化学品的关键制备技术	马建中，王学川，鲍　艳，等
05	黄麻纤维精细化与纺织染整关键技术及产业化	俞建勇，刘国忠，蔡再生，等
06	耐高温相变材料微胶囊、高储热量储热调温纤维及其制备技术	张兴祥，唐国翌，田素峰，等
07	脂溶性维生素及类胡萝卜素的绿色合成新工艺及产业化	李浩然，陈志荣，胡柏剡，等
08	亚胺培南/西司他丁钠化学-酶法合成关键技术及产业化	郑裕国，沈寅初，郑仁朝，等
09	催化氧化新材料——空心钛硅分子筛	林　民，朱　斌，舒兴田，等
10	典型高分子材料无卤阻燃化关键技术及应用	王玉忠，王德义，曲铭海，等
11	硫铝酸钡(锶)钙基特种水泥的制备技术及海工工程应用	程　新，芦令超，常　钧，等
12	新型微波冶金反应器及其应用的关键技术	彭金辉，张利波，郭胜惠，等
13	高强韧铸造耐磨材料制备技术及应用	邢建东，高义民，符寒光，等
14	基于测量基准时空转换技术的时栅位移传感器	彭东林，张光辉，刘小康，等
15	高速数控机床陶瓷电主轴单元	吴玉厚，张　珂，李颂华，等
16	太阳能空调与高效供热装置与应用	王如竹，代彦军，吴静怡，等
17	柴油机混合率与化学反应率协同控制技术及应用	苏万华，裴毅强，张俊红，等
18	纳米尺度硅基集成电路新器件与新工艺技术及其应用	黄　如，张　兴，张盛东，等

续表

序号	项目名称	主要完成人
19	地下水核磁共振探测与波场联合成像关键技术	林　君，段清明，王应吉，等
20	基于 SOA 的无源光网络接入扩容与距离延伸技术	刘德明，柯昌剑，张敏明，等
21	基于虚拟超市技术的大规模网络资源管理及其应用	蒋昌俊，陈闳中，闫春钢，等
22	小动物多模态光学分子影像成像方法与系统	田　捷，白　净，杨　鑫，等
23	运动汽车噪声综合识别及控制技术	连小珉，郑四发，杨殿阁，等
24	光学元件内应力、双折射和光学波片相位延迟测量的新原理和仪器	张书练，刘维新，宗晓斌，等
25	冻土路基地温调控及冻融灾害防治新技术	俞祁浩，赖远明，张明义，等
26	戊型肝炎病毒免疫优势构象性抗原决定簇的发现及其在诊断中的应用	夏宁邵，葛胜祥，李少伟，等
27	用于 2 型糖尿病防治的专利新药—太罗	李　松，郑志兵，钟　武，等
28	基于智能通道组织和共享保护方法的光层联网技术与应用	纪越峰，张　杰，叶　兵，等
29	深部煤矿高温热害治理技术及其装备系统	何满潮
30	城市客车多能源一体化混合动力系统及其系列化车型应用	欧阳明高，陈全世，卢青春，等
31	新型环保复混肥和有机肥的制备技术与应用	刘兆辉，李　彦，江丽华，等
32	基于能量转换的矿用倾斜带式输送机防抱死安全制动关键技术	寇子明，李军霞，谭鹏辉，等
33	高温高压流体和流动反应原位观测装置、方法和整合技术	张荣华

附件 3　2010 年度国家科学技术进步奖目录(通用项目)

特等奖

序号	项目名称	主要完成人或主要完成单位
01	大庆油田高含水后期 4000 万吨以上持续稳产高效勘探开发技术	大庆油田有限责任公司，等

一等奖

序号	项目名称	主要完成人或主要完成单位
01	三峡输电系统工程	国家电网公司，等
02	矮败小麦及其高效育种方法的创建与应用	刘秉华，翟虎渠，杨　丽，等
03	西气东输工程技术及应用	中国石油天然气股份有限公司，等
04	抗条纹叶枯病高产优质粳稻新品种选育及应用	万建民，王才林，刘　超，等

续表

序号	项目名称	主要完成人或主要完成单位
05	塔河奥陶系碳酸盐岩特大型油气田勘探与开发	翟晓先，焦方正，漆立新，等
06	千米级斜拉桥结构体系、设计及施工控制关键技术	张喜刚，游庆仲，张　鸿，等
07	肠功能障碍的治疗	黎介寿，李　宁，任建安，等
08	粮食储备“四合一”新技术研究开发与集成创新	吴子丹，卞　科，徐永安，等
09	地球空间双星探测计划	刘振兴，张永维，吴　季，等
10	实时三维图形平台 BH_GRAPH	赵沁平，郝爱民，王莉莉，等
11	秦岭终南山公路隧道建设与运营管理关键技术	乔怀玉，冯西宁，杨育生，等
12	遂渝线无砟轨道关键技术研究与应用	何华武，耿志修，朱　颖，等
13	中国海洋油气勘探开发科技创新体系建设	中国海洋石油总公司
14	高品质 J6 重型车及重型柴油机自主研发与技术创新	李　骏，董春波，吴碧磊，等
15	六轴 7200kW 大功率交流传动电力机车的研发及应用	孙喜运，张曙光，崔殿国，等
16	黄河调水调沙理论与实践	李国英，廖义伟，张金良，等

二等奖

序号	项目名称	主要完成人或主要完成单位
01	水稻重要种质创新及其应用	钱　前，朱旭东，程式华，等
02	枣林高效生态调控关键技术的研究与示范	王有年，师光禄，苗振旺，等
03	人工合成小麦优异基因发掘与川麦 42 系列品种选育推广	杨武云，汤永禄，卢宝荣，等
04	高产优质多抗“丰花”系列花生新品种培育与推广应用	万勇善，刘风珍，廖伯寿，等
05	枇杷系列品种选育与区域化栽培关键技术研究应用	郑少泉，江国良，黄金松，等
06	华南杂交水稻优质化育种创新及新品种选育	邓国富，粟学俊，陈彩虹，等
07	我国北方几种典型退化森林的恢复技术研究与示范	李俊清，宋国华，卢　琦，等
08	无烟不燃木基复合材料制造关键技术与应用	吴义强，彭万喜，杨光伟，等
09	东南部区域森林生态体系快速构建技术	江　波，周国模，袁位高，等
10	泡桐丛枝病发生机理及防治研究	范国强，翟晓巧，徐　宪，等
11	落叶松现代遗传改良与定向培育技术体系	张守攻，孙晓梅，李凤日，等
12	西藏藏羚羊生物生态学研究	刘务林，李炳章，吴晓民，等
13	仔猪肠道健康调控关键技术及其在饲料产业化中的应用	印遇龙，侯永清，林映才，等
14	牛和猪体细胞克隆研究及应用	李　宁，戴蕴平，李秋艳，等
15	鲁农Ⅰ号猪配套系、鲁烟白猪新品种培育与应用	武　英，郭建凤，魏述东，等
16	中华绒螯蟹育苗和养殖关键技术开发与应用	陈立侨，成永旭，王　武，等

续表

序号	项目名称	主要完成人或主要完成单位
17	海洋水产蛋白、糖类及脂质资源高效利用关键技术研究与应用	薛长湖，李兆杰，汪东风，等
18	大洋金枪鱼资源开发关键技术及应用	陈雪忠，许柳雄，蒋兴伟，等
19	猪繁殖与呼吸综合征防制技术及应用	蔡雪辉，童光志，郭宝清，等
20	母猪系统营养技术与应用	陈代文，吴　德，杨　凤，等
21	半滑舌鳎苗种规模化繁育及健康养殖技术开发与应用	柳学周，陈松林，姜言伟，等
22	李毓佩数学故事系列	李毓佩，何　龙
23	《黑龙江农业新技术系列图解丛书》	韩贵清，张相英，肖志敏，等
24	数学小丛书	华罗庚，段学复，吴文俊，等
25	追星——关于天文、历史、艺术与宗教的传奇	卞毓麟，陈鸣华，匡志强
26	钢轨焊缝双频正火设备及工艺	郭晋龙
27	一种防脱落的超薄石材复合板	郭镇义
28	高压轴向柱塞泵/马达国产化关键技术	李　斌
29	辣(甜)椒雄性不育转育及三系配套育种研究	陈炳金
30	以自主创新为核心的航天科工科技创新体系和机制创建	中国航天科工集团公司
31	三一重工工程机械技术创新平台建设	三一重工股份有限公司
32	中控以标准国际化为核心的自动化技术创新工程	中控科技集团有限公司
33	基于高效率低成本光伏发电技术的创新平台建设	无锡尚德太阳能电力有限公司
34	稀有金属材料技术创新工程	西北有色金属研究院
35	以市场为导向的武钢自主创新能力建设	武汉钢铁(集团)公司
36	烟台万华科技创新系统工程	烟台万华聚氨酯股份有限公司
37	农业装备技术创新工程	中国农业机械化科学研究院
38	三维三分量地震关键技术突破与深层致密大气田高效勘探	蔡希源，唐建明，杨克明，等
39	高含水油田优势通道定量描述与调控技术及工业化应用	戴彩丽，冯其红，赵福麟，等
40	特低渗透油藏有效开发非线性渗流理论和开发方法及其工业化应用	朱维耀，姚　军，孙玉凯，等
41	卷烟危害性评价与控制体系建立及其应用	谢剑平，刘惠民，朱茂祥，等
42	中高浓度纸浆清洁漂白技术	陈克复，李　军，应广东，等
43	聚苯硫醚(PPS)纤维产业化成套技术开发与应用	王　桦，黄　庆，蒲宗耀，等
44	簇绒地毯织机系列成套装备技术及其产业化	孙以泽，孟　婷，窦秀峰，等

续表

序号	项目名称	主要完成人或主要完成单位
45	数字化经编装备的关键技术研究与应用	蒋高明，王占洪，陈南梁，等
46	聚间苯二甲酰间苯二胺纤维与耐高温绝缘纸制备关键技术及产业化	胡祖明，陈　蕾，钟　洲，等
47	重油催化裂化后反应系统关键装备技术开发与应用	卢春喜，时铭显，徐春明，等
48	低断面抗湿滑低噪声超高性能轿车子午线轮胎	王　锋，董毛华，刘占村，等
49	大型 PTA 生产关键技术－加氢精制催化剂及反应工艺的开发与应用	畅延青，林　菘，杨毓莹，等
50	提高轻质油品收率的两段提升管催化裂化新技术	山红红，杨朝合，马　安，等
51	含烃石化尾气梯级耦合膜分离技术的研发与工业应用	贺高红，吴雪梅，李保军，等
52	钴酸镧等高性能超细氧化物催化剂的制备和应用技术	汪　信，刘孝恒，朱俊武，等
53	单系列大型化炼油技术集成开发与工业应用	刘家明，孙丽丽，李国梁，等
54	高效汽油抗爆剂 MMT 的开发及应用	廖维林，夏剑辉，许招会，等
55	骨外科用生物降解复合材料制备关键技术及商品化开发应用	李世普，闫玉华，陈晓明，等
56	钢管高强混凝土膨胀控制与制备技术及其在大跨度结构的应用	胡曙光，丁庆军，吕林女，等
57	多层陶瓷电容器用钛酸钡基介电陶瓷材料的产业化关键技术及应用	陈代荣，张　兵，唐　浩，等
58	废弃钴镍材料的循环再造关键技术及产业化应用	聂祚仁，许开华，席晓丽，等
59	大型链篦机-回转窑赤铁矿氧化球团生产的关键技术开发和应用	朱德庆，赵荣坤，舒方华，等
60	铝电解用优质炭阳极生产关键技术开发及产业化	刘风琴，路增进，周新林，等
61	大型高炉高效生产综合技术的开发与应用	张寿荣，邓崎琳，傅连春，等
62	高品质中高碳特殊钢棒线材连续生产技术与工艺开发	张文基，蒋建清，李国忠，等
63	100 米长尺钢轨在线热处理生产线工艺及装备集成技术开发	战金龙，周一平，梅东生，等
64	宽带钢热连轧生产成套关键技术与应用	徐金梧，王　岑，沙孝春，等
65	耐久型超高强度平行钢丝拉索关键技术及产业化	刘礼华，赵　军，宁世伟，等
66	高强韧耐磨铝青铜合金的研制及其应用	李元元，张卫文，罗宗强，等
67	大型宽厚板矫直成套技术装备开发与应用	黄庆学，岳普煜，曹一兵，等
68	高可靠先进液压系统新技术及其在现代军机、民机和航天器中的应用	焦宗夏，王少萍，黄　佑，等
69	特厚煤层安全开采关键装备及自动化技术	葛世荣，刘克功，赵学雷，等
70	核电站密封新技术、新产品及应用	励行根，王晓江，宋　炜，等

续表

序号	项目名称	主要完成人或主要完成单位
71	轻量化整体构件内高压成形技术	苑世剑，刘　钢，王小松，等
72	超大加氢反应器研制及工程应用	刘恩清，邵建雄，张文辉，等
73	快速热循环高光注塑成型技术开发及其产业化	赵国群，于昕世，管延锦，等
74	大型高端燃气轮机铸件研发及产业化	彭　凡，原晓雷，王向阳，等
75	弯扭叶片关键技术研究及在大型汽轮机中的工程应用	杨其国，王仲奇，王松涛，等
76	汽液两相流升压加热与液位控制关键技术及其应用	严俊杰，林万超，刘继平，等
77	复杂配电系统综合技术评价方法研究、系统开发及工程应用	王成山，肖　峻，路志英，等
78	大型企业综合电气节能关键技术及应用	罗　安，章　兢，帅智康，等
79	城市电网电灾防治关键技术与应用	程浩忠，阮前途，王　伟，等
80	7500kVA 大功率 IGCT 交直交变频系统	李崇坚，李耀华，葛琼璇，等
81	环境与灾害监测预报小卫星超光谱成像仪	相里斌，王忠厚，刘学斌，等
82	特大功率电力电子器件技术研发及推广应用	丁荣军，张　明，刘国友，等
83	新型功率半导体器件体内场关键技术与应用	张　波，李泽宏，乔　明，等
84	小型质谱仪关键技术创新及整机研制	方　向，张新荣，熊行创，等
85	网络教育关键技术及示范工程	顾冠群，罗军舟，曹玖新，等
86	百万册数字图书馆的多媒体技术和智能服务系统	庄越挺，潘云鹤，高　文，等
87	面向节能的复杂配电网监测控制与故障诊断关键技术研发及应用	张化光，杨东升，孙秋野，等
88	铜冶炼生产全流程自动化关键技术及应用	李贻煌，桂卫华，周俊武，等
89	面向大规模城域监控的流媒体关键技术及装备	陈耀武，季向阳，汪鹏君，等
90	西部低能耗建筑设计关键技术与应用	刘加平，杨　柳，王　怡，等
91	工程结构抗灾控制新技术与工程应用	李宏男，王亚勇，李云贵，等
92	大跨空间钢结构预应力施工技术研究与应用	郭正兴，肖绪文，罗　斌，等
93	岩体爆破振动效应定量评价理论与精细化控制技术及工程应用	李海波，卢文波，张继春，等
94	大型复杂结构隔震减震关键技术及工程应用	周福霖，刘伟庆，谭　平，等
95	钢纤维混凝土特定结构计算理论和关键技术的研究与应用	高丹盈，黄承逵，赵顺波，等
96	复杂环境下水力射流新理论、关键技术及应用	李行伟，唐洪武，王文平，等
97	复杂水电能源系统优化运行关键技术研究及应用	周建中，马光文，蒋传文，等
98	水布垭超高面板堆石坝工程筑坝关键技术及应用	杨启贵，孙　役，刘　宁，等
99	200m 级高碾压混凝土重力坝关键技术	冯树荣，戴　波，吴　旭，等

续表

序号	项目名称	主要完成人或主要完成单位
100	高混凝土坝整体稳定安全控制新理论及工程应用	常晓林，杨　强，张　林，等
101	水沙灾害形成机理及其防治的关键技术	倪晋仁，李义天，江恩惠，等
102	海洋工程安全与防灾若干关键技术及应用	李华军，刘德辅，张　建，等
103	核电厂地基及防护构筑物的抗震安全评价及其工程实践	孔宪京，林　皋，谢世楞，等
104	洋山深水港（外海岛礁超大型集装箱深水港口）工程建设关键技术	上海同盛投资（集团）有限公司，等
105	永久性沥青路面结构设计理论与方法、关键技术及工程应用	杨永顺，王　林，高雪池，等
106	造船重大装备机械手肋骨冷弯机的创新与应用	王呈方，茅云生，胡　勇，等
107	高原山区高速公路建设支撑技术	杨　延，张玉芳，张发春，等
108	大功率中速船用柴油机关键技术研究及产业化	吴　杰，俞小莉，冯志敏，等
109	提高运动员体能的关键技术研究	谢敏豪，陈佩杰，林炳承，等
110	新一代基于同步数字体系（SDH）多业务传送平台标准、设备研制及应用	张成良，蔡常天，袁　飞，等
111	金属压力容器和常压储罐声发射检测及安全评价技术与应用	沈功田，李邦宪，戴　光，等
112	交流高频大电流国家基准的建立	张江涛，王　磊，许　晨，等
113	重度苏打盐碱地顶级植被快速恢复核心关键技术的创新与应用	梁正伟，王志春，周道玮，等
114	区域大气复合污染研究的技术体系及在珠江三角洲的应用	张远航，胡　敏，钟流举，等
115	特大城市空气质量改善理论与技术及其应用	郝吉明，贺克斌，王书肖，等
116	有机废水碳氮硫同步脱除新技术及工程应用	王爱杰，任南琪，马　放，等
117	高原高山峡谷区大型梯级开发的环境效应及生态安全调控	何大明，晏志勇，刘　恒，等
118	中国陆地碳收支评估的生态系统碳通量联网观测与模型模拟系统	于贵瑞，周广胜，黄　耀，等
119	岩石力学智能反馈分析方法及其工程应用	冯夏庭，周　辉，樊启祥，等
120	心房颤动导管消融的临床研究与推广应用	马长生，张　澍，杨延宗，等
121	消化道智能胶囊内镜系统的研制与临床应用	王金山，李兆申，李向东，等
122	衰老的分子调控机制及个体化衰老评价的创建和应用	陈香美，蔡广研，童坦君，等
123	游离脂肪酸、乙醇在 2 型糖尿病发生机制中的作用及临床干预	赵家军，宁　光，高　聆，等
124	我国农村高血压流行趋势及低成本综合干预预防脑卒中研究	孙英贤，胡大一，张永红，等

续表

序号	项目名称	主要完成人或主要完成单位
125	冠心病血管内皮损伤机制与防治策略	黄　岚，晋　军，武晓静，等
126	宫颈癌发病生物学特征研究及早期防治措施的建立与应用	马　丁，谢　幸，王世宣，等
127	提高出生人口质量的生殖技术创建、体系优化与临床推广应用	黄荷凤，陈子江，刘嘉茵，等
128	医用生物传感器检测理论及技术体系的建立和临床应用	府伟灵，陈　鸣，张　波，等
129	高原移居人群高海拔作业低氧损伤的综合防治	吴天一，王晓勤，褚以德，等
130	抑郁症中医证候学规律的研究	唐启盛，曲　淼，朱跃兰，等
131	肾阳虚证的神经内分泌学基础与临床应用	沈自尹，王文健，俞　瑾，等
132	基于中医药特点的中药样品库的建立与新药研究	张卫东，陈万生，柳润辉，等
133	经方现代应用的临床与基础研究	王庆国，陈纪藩，李宇航，等
134	中药质量控制综合评价技术创新及其应用	王峥涛，胡之璧，俞桂新，等
135	美洛西林钠及其复方制剂的技术创新与产业化	赵玉山，苗得足，王太岭，等
136	三种妇科常见疾病超声治疗技术的研发及临床推广应用	王智彪，陈文直，汪　伟，等
137	移动通讯软基站关键技术的研究与应用	谢大雄，赵先明，卢科学，等
138	T 比特级多业务路由平台技术创新及产业化	杜文华，邓抄军，叶锦华，等
139	TD－SCDMA 及其增强型终端一致性测试技术与平台	张　平，姜　军，张　治，等
140	五十米口径天线	杨可忠，耿京朝，金　超，等
141	跨安全域隔离与信息交换技术及应用	陈　钟，杜　江，胡建斌，等
142	大型乙烯装置用裂解气压缩机关键技术及装备	王学军，汪创华，戴继双，等
143	海上重型起重装备全回转浮吊关键技术及应用	严　兵，田　洪，严云福，等
144	超超临界 1000MW 火电重大装备研制与产业化	于　龙，王为民，张素心，等
145	煤矿冲击地压预测与防治成套技术	潘一山，郎庆田，齐庆新，等
146	高瓦斯大倾角煤层开采自燃火灾防治技术研究	候铁军，文　虎，董庆利，等
147	含钒页岩高效提取在线循环资源化新技术及工业应用	张一敏，李先旺，傅连春，等
148	油藏保护性可持续开发的微生物采油调控技术及工业化应用	牟伯中，李　阳，董　范，等
149	鄂尔多斯盆地低渗透油气田含油污水回用处理技术及工程应用	张宁生，屈撑囤，吴新民，等
150	富含腐植酸的劣质煤梯级综合利用技术及其应用	田原宇，乔英云，乔　生，等
151	稠密多相流动与化学反应耦合体系的节能减排关键技术及应用	肖　睿，钟文琪，孙克勤，等
152	兆瓦级变速恒频风电机组	姚兴佳，王凤翔，杨树人，等

续表

序号	项目名称	主要完成人或主要完成单位
153	烟草物流系统信息协同智能处理关键技术及应用	赖明勇，谢高岗，姜新荣，等
154	面向现代服务业的钱塘平台软件研制及产业化应用	吴朝晖，尹建伟，吴　健，等
155	基于异构网络融合的多媒体技术研究与应用	邓中亮，王晓明，戴志军，等
156	黄淮区小麦夏玉米一年两熟丰产高效关键技术研究与应用	尹　钧，李潮海，谭金芳，等
157	数字农业测控关键技术产品与系统	赵春江，王　成，郑文刚，等
158	干旱半干旱农牧交错区保护性耕作关键技术与装备的开发和应用	路战远，赵满全，张德健，等
159	特色热带作物产品加工关键技术研发集成及应用	王庆煌，王光兴，钟春燕，等
160	农业化学节水调控关键技术与系列新产品产业化开发及应用	杨培岭，王爱勤，李云开，等
161	棉铃虫对 Bt 棉花抗性风险评估及预防性治理技术的研究与应用	吴孔明，郭予元，吴益东，等
162	细菌农药新资源及产业化新技术新工艺研究	关　雄，蔡　峻，刘　波，等
163	主要作物种子健康保护及良种包衣增产关键技术研究与应用	刘西莉，李健强，张世和，等
164	芽孢杆菌生物杀菌剂的研制与应用	王　琦，陈志谊，马　平，等
165	小麦赤霉病致病机理与防控关键技术	康振生，黄丽丽，周明国，等
166	鱼藤酮生物农药产业体系的构建及关键技术集成	徐汉虹，赵善欢，张志祥，等
167	贝类精深加工关键技术研究及产业化	朱蓓薇，董秀萍，李冬梅，等
168	大豆磷脂生产关键技术及产业化开发	谷克仁，王兴国，江连洲，等
169	青藏高原牦牛乳深加工技术研究与产品开发	任发政，甘伯中，韩北忠，等
170	食品微生物安全快速检测与高效控制技术	吴清平，张菊梅，蔡芷荷，等
171	农业食品中有机磷农药等残留快速检测技术与应用	孙远明，雷红涛，卢　新，等
172	国家土地资源遥感监测关键技术及重大工程应用	王　静，张继贤，刘顺喜，等
173	时空数据挖掘关键技术与应用	刘耀林，唐新明，李宪文，等
174	大型矿山提升装备关键技术及应用	朱真才，王继生，杜庆永，等
175	复杂破碎条件下露天-地下联合高效开采关键技术	吴爱祥，韩　斌，王春来，等
176	复杂地形长距离铁精矿固液两相浆体输送关键技术及应用	安　建，陈子刚，傅旭东，等
177	煤矿千米深部岩巷稳定控制关键技术及应用	刘泉声，薛俊华，高　玮，等
178	多平台多波段对地观测信息处理技术与应用系统	郭华东，邵　芸，范湘涛，等
179	开放式虚拟地球集成共享平台及重大工程应用	龚健雅，李志刚，徐开明，等
180	中国煤炭地质综合勘查关键技术与工程运用	徐水师，王　佟，孙升林，等

续表

序号	项目名称	主要完成人或主要完成单位
181	矿井移动与应急通信技术与系统	孙继平，田子建，胡穗延，等
182	大型露天煤矿开采新技术与应用研究	才庆祥，徐志远，车兆学，等
183	矽卡岩型极低品位难选多金属共伴生矿高效综合回收新技术	邱显扬，高文翔，胡　真，等
184	特大异型工程精密测量与重构技术研究及应用	王晏民，李广云，秦长利，等
185	口腔颌面部血管瘤与脉管畸形的临床治疗研究	张志愿，赵怡芳，周国瑜，等
186	颅脑创伤后继发性脑损害发生机理与诊治新技术应用	费　舟，章　翔，潘伟生，等
187	多模式部分肝移植关键技术研究及其临床应用	李宏为，彭承宏，沈柏用，等
188	脊柱畸形三维矫形创新理论与技术及其临床应用	李　明，白玉树，朱晓东，等
189	口腔颌面组织修复及功能重建技术的研究及应用	王松灵，胡　静，龙　星，等
190	肝移植的临床研究及应用	沈中阳，朱志军，陈新国，等
191	危重新生儿营养支持基础研究与临床应用	蔡　威，汤庆娅，陶晔璇，等
192	手与腕部组织修复与重建的系列研究及推广应用	路来金，宫　旭，刘　彬，等
193	肾结石及其慢性肾功能不全外科治疗新技术的建立与应用	苏泽轩，于立新，李　逊，等
194	重症冠心病临床评估体系和外科治疗关键技术的建立与应用	胡盛寿，朱晓东，郑　哲，等
195	青光眼临床诊治模式的转变	葛　坚，卓业鸿，刘　杏，等
196	提高我国包虫病诊疗水平的临床应用与基础研究	温　浩，刘文亚，王建华，等
197	高速铁路 900 吨简支箱梁建造成套技术与装备	娄德兰，王治斌，王清明，等

附件 4　2010 年度“中国科学十大进展”

1. 拓扑绝缘体研究取得重要进展
2. 相对论重离子对撞机上发现首个反超核粒子——反超氚核
3. 揭示三氧化二砷和全反式维甲酸联合治疗急性早幼粒白血病的分子机制
4. 中国发现 10 万年前的早期现代人化石
5. 全基因组关联研究发现银屑病、白癜风和麻风易感基因
6. 揭示水稻理想株型形成的分子调控机制
7. 大地电磁测量揭示青藏高原东部有两条地壳物质流
8. 揭示蛋白质赖氨酸乙酰化在细胞代谢中的调控作用
9. 基于超材料实现微波段三维隐身和电磁黑洞
10. 实验实现最远距离自由空间量子隐形传态