Centre for Research on Anabolic Skeletal Targets in Health and Illness (ASTHI)

The mission of the centre is to undertake cutting-edge research into the causes, treatment, and prevention of diseases of bone and joint; training of researchers to carry out this research; securing innovation through IPs; commercialization of inventions; discovering and developing affordable medicine; and dissemination of information on research progress in these diseases.

CSIR-Central Drug Research Institute

CSIR-Central Drug Research Institute, Lucknow

Contents

Prelude 1

Publication 2

Our technologies mean business 4

Early licensing and joint product development with industries 6

Clinical trials in progress 7

Industry-CDRI non-strategic partnerships now for strategic collaborations in future 8

Products pipeline 8

IP portfolio 9

State-of-the-art facilities created 10

Advancing the frontiers of knowledge 11

Preclinical disease models 12

Human resource development 12

Collaborations established 13

Participating scientists 13

Designed by- Mr. Kazim Raza

Prelude

It is now well established that Indians, in general, have poor bone health and osteoporosis is very common in India. More than 50 million Indians have been so far diagnosed with this disease however the experts feel that undiagnosed cases might be several times more than the current figure. Osteoporosis causes fragility fractures which are major causes of morbidity and mortality among postmenopausal women at an older age. Given the serious medical conditions caused by this disease and the huge disease burden which is expected to grow substantially in the near future due to increased longevity, multi-pronged research strategies are required to address this disease.

Another unique problem is that India leads the world in road accidents. Major and minor injuries from accidents total up to 0.5 million/year and an average of 75 fracture cases/day/hospital are extremely grim realities of India. Man-hour loss due to fracture is astronomical and mostly affects the disadvantaged sections of society. Bones once fractured are always compromised in quality. Furthermore, India has a huge burden of chronic inflammatory diseases including chronic obstructive pulmonary disease, arthritis, and inflammatory bowel disease for which synthetic corticosteroids are given for a long duration and corticosteroids cause bone loss and are established risk factors for fracture. In all three instances, i.e. post-menopausal osteoporosis, corticosteroid-induced osteoporosis, and fracture, sarcopenia (muscle wasting) is a frequently-observed co-morbidity.

CSIR-CDRI through a network of multi-disciplinary collaboration has developed the country's only world-class infrastructure and expertise for cutting-edge research in the field of bone biology and anti-osteoporosis drug discovery and development. Realization of these facilities has come in the form of highly cited publications, generation of knowledge portfolio (IPR), the building of a strong drug pipeline, and marketing of technologies. In addition, the centre has imparted very sophisticated training on bone biology to doctoral and post-doctoral fellows across the country to become future bone scientists.

The aim of this document is to give a glimpse of the achievements of this centre since dedicated CSIR funding began in April 2012 under the 12th five-year plan.

A Publication

The country's most impactful research articles in the field of bone biology and osteoporosis are published from CSIR-CDRI*.

- *According to **Gupta BM et al. Osteoporosis research in India: A scientometric assessment of publications output during 2007-16. *Journal of Orthopedics & Bone Disorders; DOI:10.23880/JOBD-16000135, 2017***, the papers published from CSIR-CDRI have the highest impact judged from total citations, average citations per paper, and ***h***-index when all published papers from India in this field were considered.

208 Papers Published Since 2012 (average IF - 5.1)

Selected papers since 2012

1. Tripathi JK, Pal S, Awasthi B, Kumar A, Tandon A, Mitra K, Chattopadhyay N, Ghosh JK. Variants of Self-assembling peptide, KLD-12 that show both rapid fracture healing and antimicrobial properties. ***Biomaterials*** 56:92-103, 2015.
2. Khan MP, Singh AK, Joharapurkar AA, Yadav M, Shree S, Kumar H, Gurjar A, Mishra JS, Tiwari MC, Nagar GK, Kumar S, Ramachandran R, Sharan A, Jain MR, Trivedi AK, Maurya R, Godbole MM, Gayen JR, Sanyal S, Chattopadhyay N. Pathophysiological mechanism of bone loss in type 2 diabetes involves inverse regulation of osteoblast function by PPARγ coactivator-1α and skeletal muscle atrogenes: adiponectin receptor 1 as a potential target for reversing diabetes-induced osteopenia. ***Diabetes*** 64: 2609-23, 2015.
3. Singh AK, Joharapurkar AA, Khan MP, Mishra JS, Singh N, Yadav M, Hossain Z, Khan K, Kumar S, Dhanesha NA, Mishra DP, Maurya R, Sharma S, Jain MR, Trivedi AK, Godbole MM, Gayen JR, Chattopadhyay N, Sanyal S. Orally active osteoanabolic agent 6-C-β-D-glucopyranosyl-(2S, 3S)-(+)- 5,7, 3',4'- tetrahydroxydihydroflavonol binds to adiponectin receptors, with a preference for AdipoR1, induces adiponectin-associated signaling and improves metabolic health in a rodent model of diabetes. ***Diabetes*** 63:3530-44, 2014.
4. Pal, Sayeed M, Kumar A, Verma DP, Harioudh MK, Verma NK, Porwal K, Sharma S, Kulkarni C, Bandyopadhyay A, Mugale MN, Mitra K, Ghosh JK, Chattopadhyay N. A self-assembling nano-globular peptide from human lactoferrin acts as a systemic enhancer of bone regeneration: a novel peptide for orthopedic application. ***ACS Appl Mater Interfaces*** 13: 17300-17315, 2021.
5. Gurjar AA, Kushwaha S, Chattopadhyay S, Das N, Pal S, China SP, Kumar H, Trivedi AK, Guha R, Chattopadhyay N, Sanyal S. Long acting GLP-1 analog liraglutide ameliorates skeletal muscle atrophy in rodents. ***Metabolism*** 103:154044, 2020.
6. Kuswaha P, Khedgikar V, Gautam J, Dixit P, Chillara R, Verma A, Thakur R, Singh D,

Maurya R, Mishra PR, Chattopadhyay N, Mishra DP, Trivedi R. A novel therapeutic approach with Caviunin-based isoflavonoid that en routes bone marrow cells to bone formation via BMP2/Wnt-β-catenin signaling. ***Cell Death Dis*** 2014 Sep 18;5:e1422. doi: 10.1038/cddis.2014.350.

7. Kureel J, Dixit M, Tyagi AM, Mansoori MN, Srivastava K, Raghuvanshi A, Maurya R, Trivedi R, Goel A, Singh D. miR-542-3p suppresses osteoblast cell proliferation and differentiation, targets BMP-7 signaling and inhibits bone formation. ***Cell Death Dis*** 5(2):e1050, 2014.
8. Khedgikar V, Kushwaha P, Gautam J, Verma A, Changkija B, Kumar A, Sharma S, Nagar GK, Singh D, Trivedi PK, Sangwan NS, Mishra PR, Trivedi R. Withaferin A: a proteasomal inhibitor promotes healing after injury and exerts anabolic effect on osteoporotic bone. ***Cell Death Dis*** 4(8):e778, 2013.
9. Ahmad N, Kushwaha P, Karvande A, Tripathi AK, Kothari P, Adhikary S, Khedgikar V, Mishra VK, Trivedi R. MicroRNA-672-5p Identified during Weaning Reverses Osteopenia and Sarcopenia in Ovariectomized Mice. ***Mol Ther Nucleic Acids***. 2019 Mar 1;14:536-549. doi: 10.1016/j.omtn.2019.01.002. Epub 2019 Jan 10.
10. Swarnkar G, Sharan K, Siddiqui JA, Mishra JS, Khan K, Khan MP, Gupta V, Rawat P, Maurya R, Dwivedi AK, Sanyal S, Chattopadhyay N. Identification of a rare naringenin analog from a medicinal plant having potent bone anabolic effect by acting as an osteoblast oestrogen mimic. ***Br J Pharmacol*** 165:1526-42, 2012.
11. Balaramnavar VM, Khan IA, Siddiqui JA, Khan MP, Chakravarti B, Sharan K, Swarnakr G, Rastogi N, Siddiqui HH, Mishra DP, Chattopadhyay N, Saxena AK. Identification of novel 2-((1-(benzyl (2-hydroxy-2-phenylethyl) amino)-1-oxo-3-phenylpropan-2-yl)carbamoyl)benzoic acid analogues as BMP-2 stimulators. ***J Med Chem*** 55:8248-59, 2012.
12. Sashidhara KV, Kumar M, Khedgikar V, Kushwaha P, Modukuri RK, Kumar A, Gautam J, Singh D, Sridhar B, Trivedi R. Discovery of coumarin-dihydropyridine hybrids as bone anabolic agents. ***J Med Chem***. 2013 Jan 10;56(1):109-22. doi: 10.1021/jm301281e. Epub 2012 Dec 18. PMID: 23214410.
13. Kumar Y, Biswas T, Thacker G, Kanaujiya JK, Kumar S, Shukla A, Khan K, Sanyal S, Chattopadhyay N, Bandyopadhyay A, Trivedi AK. BMP signaling-driven osteogenesis is critically dependent on Prdx-1 expression-mediated maintenance of chondrocyte prehypetrophy. ***Free Radic Biol Med*** 118: 1-12, 2018.
14. Rai R, Singh KB, Khanka S, Maurya R, Singh D. Cladrin alleviates dexamethasone-induced apoptosis of osteoblasts and promotes bone formation through autophagy induction via AMPK/mTOR signaling. ***Free Radic Biol Med*** 190:339-350, 2022
15. Kushwaha P, Tripathi AK, Gupta S, Kothari P, Upadhyay A, Ahmad N, Sharma T, Siddiqi MI, Trivedi R, Sashidhara KV. Synthesis and study of benzofuran-pyran analogs as BMP-2 targeted osteogenic agents. ***Eur J Med Chem*** 156:103-117, 2018.
16. Gupta A, Ahmad I, Kureel J, John AA, Sultan E, Chanda D, Agarwal NK, Alauddin, Wahajuddin, Prabhaker S, Verma A, Singh D. Differentiation of skeletal osteogenic progenitor cells to osteoblasts with 3,4-diarylbenzopyran based amide derivatives: Novel osteogenic agents. ***Eur J Med Chem*** 121:82-99, 2016.

17. Tyagi AM, Mansoori MN, Srivastava K, Khan MP, Kureel J, Dixit M, Shukla P, Trivedi R, Chattopadhyay N, Singh D. Enhanced immunoprotective effects by anti-IL-17 antibody translates to improved skeletal parameters under estrogen deficiency compared with anti-RANKL and anti-TNF-α antibodies. ***J Bone Miner Res***. 2014 Sep;29(9):1981-92.

18. Khan MP, Singh AK, Singh AK, Shrivastava P, Tiwari MC, Nagar GK, Bora HK, Parameswaran V, Sanyal S, Bellare JR, Chattopadhyay N. Odanacatib restores trabecular bone of skeletally mature female rabbits with osteopenia but induces brittleness of cortical bone: a comparative study of the investigational drug with PTH, estrogen and alendronate. ***J Bone Miner Res*** 31: 615-29, 2016.

19. Shukla P, Mansoori MN, Kakaji M, Shukla M, Gupta SK, Singh D. Interleukin 27 (IL-27) Alleviates Bone Loss in Estrogen-deficient Conditions by Induction of Early Growth Response-2 Gene. ***J Biol Chem*** 292:4686-4699, 2017.

20. Kushwaha P, Khedgikar V, Sharma D, Yuen T, Gautam J, Ahmad N, Karvande A, Mishra PR, Trivedi PK, Sun L, Bhadada SK, Zaidi M, Trivedi R. MicroRNA 874-3p Exerts Skeletal Anabolic Effects Epigenetically during Weaning by Suppressing Hdac1 Expression. ***J Biol Chem*** 291:3959-66, 2016.

B Our technologies mean business

I. Orally active rapid fracture healing medicine

Fracture and India's reality

Road trauma has been categorized as a killer disease by the World Health Organisation. Every year more than 1.3 lakh people die on Indian roads and 3.8 million are seriously disabled for life. The most depressing aspect is that it affects the age group 20-40 years – the most productive population in the country. In India, victims of road traffic accidents spend 22 million hospital days per year (more than cardiac & cancer patients together) leading to an estimated loss of Rs. 5200 cr. Nearly half of hospitalization cases due to road trauma represent fractures. There is no oral medication available for accelerating fracture healing so that the breadwinners of the family could return to work sooner.

CSIR-CDRI's contribution to addressing this national problem

We developed technology from the study of an Indian traditional medicine resulting in the first-in-class oral rapid fracture healing therapy named Reunion®which contains the standardized extract of Dalbergia sissoo leaves. The major bone-forming compound in Reunion is caviunin 7-O-[β-D-apiofuranosyl-(1→6)-β-D-glucopyranoside which is a new chemical entity and holds the difficult-to-infringe composition of matter patent claim and also bestows large freedom to operate. Since its pan-India launch in May 2017, the business figures of Reunion till 30th April 2022 are as follows.

“>2 million strips (10 tablets/strip) have been sold; ₹37.62 Cr. is the quantum of business; and ₹4.5 Cr. GST paid @12%: (July17-Apr22)

II. A nutraceutical intervention for the treatment of osteoarthritis

High disease burden of OA in the country and only symptomatic relief available

OA is the most common chronic condition of the joints. It afflicts mainly the weight-bearing joints such as hips and knees and causes physical disabilities. In India, 22% to 39% of people suffer from OA. Out of this 45% of women above 65y experience symptoms of OA but 70% of women over 65y have x-ray evidence of OA. Postmenopausal women with OA have a 20% increased risk of fracture and 25% higher risk of falls than those without OA thus making them more vulnerable to fracture.

There is no approved drug for OA treatment. Clinical management of OA includes awareness programs, exercise, lifestyle changes, and non-steroidal anti-inflammatory drugs (NSAIDs). The NSAIDs serve as analgesics but with prolonged use cause gastric ulcer and liver damage.

CSIR-CDRI’s contribution to addressing this problem

A standardized extract from *Spinacea oleracea* (commonly known as Palak) has been found to cure OA in pre-clinical settings. A novel oral formulation (nano-emulsion pre-concentrate) of the standardized extract has cut down the effective dose to one-third with improved efficacy in the OA model. Furthermore, this product repairs damaged cartilage.

The formulation has been marketed by the name **JOINT FRESH®** as a nutraceutical in the states of Maharashtra and Uttar Pradesh.

**“~₹15.50 Cr. is the quantum of business;
and ~₹2.8 Cr. GST paid @18%: (APR 18-MAR 22)**

C Early licensing and joint product development with industries

I. A standardized extract from Cassia occidentalis L for glucocorticoid-induced osteo-sarcopenia

An unmet medical need

Glucocorticoid-induced osteoporosis (GIO) is the leading cause of medication-induced osteoporosis (iatrogenic osteoporosis). In terms of skeletal safety, there is no "safe dose" of glucocorticoid (GC). Approximately 0.5% of the Indian population receives prolonged GC therapy for various diseases and the incidence of osteoporosis is 50% in these patients. The global prevalence of fractures in patients receiving long-term GC stands at 30–50%. In fact, synthetic GC is the mainstay of all anti-inflammatory and immunosuppressive therapy in the medical management of inflammatory states, and it has no substitute. Recipients of glucocorticoids could be of pediatric, adult, or geriatric age. In addition, GC therapy causes muscle wasting (sarcopenia) leading to a further reduction in bone biomechanical strength.

In the present therapy, bisphosphonates merely inhibit bone loss but do not increase bone formation. Rather, this drug class inhibits bone formation! In addition, high doses of glucocorticoids cause osteonecrosis (inadequate blood supply to the bone causing the death of bone-forming cells) and bisphosphonates have also been associated with osteonecrosis.

A treatment that enhances bone formation (osteoanabolic therapy) since the disease is primarily one of reduced bone formation. In addition, presently there is no therapy to prevent muscle wasting (anti-sarcopenia) in patients receiving GC therapy.

CSIR-CDRI's contribution to addressing this problem

Following nineteenth-century Indian ethnotraditional knowledge, we developed a novel formulation from the bioactive fraction from the stem of Cassia occidentalis L that protected laboratory animals from GC-induced osteo-sarcopenia and holds the potential to become the first-in-class for the treatment of this iatrogenic disease. Our technology addresses the etiology of GIO as it promotes bone formation. This technology is currently in the advanced stages of IND-enabling studies under CSIR's Phyto-pharmaceutical Mission.

This technology has been licensed to Pharmanza Herbals Pvt. Ltd., Gujarat for carrying out clinical development through DCG(I) route prior marketing.

II. S008-0399 as an osteogenic bone implant

The case of unaffordable bone implant

The bone-inducing growth factors, bone morphogenetic protein-2 & 7 (BMP-2 & 7) are ideal bone reconstructive factors approved for human use in spine surgery and for the treatment of tibial non-union. Recombinant human (rh)-BMP-2 with a collagen carrier (INFUSE, Medtronic SofamorDanek, Minneapolis) for lumbar vertebral fusion and rhBMP-7 (OP-1, Stryker, Kalamazoo, Michigan) for tibial non-union are used in patients with unsuccessful healing. High cost makes their use prohibitive in most settings in India (₹ 3.0-4.0 lakhs).

CSIR-CDRI's contribution to addressing this problem

Our technology, S008-0399 is a small molecule BMP secretagogue that stimulates BMP-2 production from pre-osteoblasts to induce differentiation and mineralization, and in the process has overcome the need for rhBMP-2. Being a small molecule that is synthesized using inexpensive raw materials and having an easy scaling up process (industrially feasible), S008-0399 has been licensed to Orthoregenics, Hyderabad who are developing it as an osteogenic bone implant.

D Clinical trials in progress

Our innovative products and preclinical findings on the skeletal safety of clinically used drugs are being assessed through clinical trials/studies.

- **Therapeutic repurposing**: IBone formation is impaired in postmenopausal osteoporosis (PMO). PMO patients with severe bone loss require stimulation of new bone formation (osteogenic). Daily injections of human parathyroid hormone (1-34, teriparatide) are the only osteogenic drug. Teriparatide treatment is expensive (Rs. 8,000/pm) and its storage requires refrigeration.

  Through a screening of a US-FDA-approved drug library, we discovered that pentoxifylline (PTX) mimicked teriparatide action. PTX is orally active and its osteogenic dose is 1/6th the dose for relieving muscle cramp-like pain in the leg (Bone, 2019; Calcified Tissue International, 2019). **Taking note of our preclinical findings, AIIMS, New Delhi is conducting the phase-II clinical trial of PTX in PMOP through DHR funding.**
- **Osteoarthritis trial**: As mentioned under the Product Development section Spinacea oleracea with other components has been launched as a nutraceutical at present by the name JOINT FRESH® for osteoarthritis, however, further studies in the form of clinical trials in three groups of Control, Spinacea oleracea extract alone and in combination with Boswellia serrata (a strong anti-inflammatory agent) are in progress in osteoarthritic subjects in Nasik, Ayurveda Seva Sangh, Ayurveda College and Hospital in 120 subjects for three months.
- **Fracture healing trial**: DCGI has approved CDRI NCE S007-1500 for conducting Phase I clinical trial at King George Medical University, Lucknow. ICMR funds have been received for infrastructural work for initiating the Clinical trial at KGMU, Lucknow.

E Industry-CDRI non-strategic partnerships now for strategic collaborations in future

Strategic partnerships have to start somewhere. In the beginning, they are usually small and non-strategic. With time, it is decided whether a partnership has the potential to go strategic, or wither and die. Keeping this in mind, we have initiated non-strategic partnerships with several Indian industries in the forms of consultancy and sponsored research. Through these, we would win trust of the industries by undertaking smaller projects before engaging in large-scale strategic collaborations. Towards the latter aim, we have made significant progress over the last five years and hope to succeed in the near future.

I. Consultancy with industries

- GSK-Consumer Health
- Glenmark Pharmaceuticals
- Kinomera Biosciences

II. Sponsored research projects from industries

- GlaxoSmithKline
- Tata Chemicals Limited
- Sphaera Pharmaceuticals
- Eurofins Advinus

F Products pipeline

I. New chemical entities

- S007-1500, an orally active BMP-2 secretagogue for rapid fracture healing
- 99/373, an anti-resorptive compound for post-menopausal osteoporosis

IND approval for Phase I clinical trial received for both

II. New biological entities

- Novel peptide derived from human lactoferrin for non-unions
- Novel peptide derived from human sclerostin for postmenopausal osteoporosis

III. Phytopharmaceutical entity

- A standardized extract of *Cassia occidentalis L.* for the treatment of glucocorticoid-induced osteoporosis

Advanced stages of preclinical development for IND filing

IV. Therapeutic repurposing

- Pentoxifylline as an oral osteoanabolic drug for the treatment of postmenopausal osteoporosis

Phase II clinical trial is being carried out at AIIMS, New Delhi

V. Novel formulations

- D-368 as a depot injection for non-unions/delayed unions (formulation of an existing drug)
- An efficient bone delivery system of osteogenic phytochemicals

G IP portfolio

We are assiduous filers of patent and stringently consider the commercial success before each filing. Below are 7 out of 44 granted patents that have been licensed/ commercialized.

I. Granted

1. Rakesh Maurya, PreetiRawat, Kunal Sharan, Jawed Akhtar Siddiqui, Gaurav Swarnkar, Geetanjali Mishra, Lakshmi Manickavasagam, Girish Kumar Jain,Kamal Ram Arya, Naibedya Chattopadhyay. *Ulmus wallichiana* Planchon derived extract and compound employed in the prevention or treatment of osteo-health related disorders. (U.S.P.T.O. 8,669,232).

   Licensed to Kemxtree, LLC, NJ, USA and as per the agreement the industry began development but was dropped due to the unfavorable preclinical toxicity profile

2. AtulGoel, SumitChaurasia, Divya Singh, Abnish Kumar Gautam, Rashmi Pandey, Ritu Trivedi, Man Mohan Singh, Naibedya Chattopadhyay, Girish Kumar Jain, Anil Kumar Dwivedi. Substituted benzfurochromenes and related compounds for the prevention and treatment of bone related disorders (U.S.P.T.O. 8,686,028).

   Licensed to Orthoregenics, Hyderabad and S007-1500 is nearing completion of IND-enabling studies

3. Maurya Rakesh, Preety Dixit, Ritu Trivedi, VikramKhedgikar, JyotiGautam, Avinash Kumar, Divya Singh, SheelendraPratap Singh, Wahajuddin, Girish Kumar Jain, Naibedya Chattopadhyay. Dalbergiasissoo derived extract and compounds for the prevention of osteo-health-related disorders designated as osteoNATURALcare. European Patent (EP2705047 B1).

   Commercialized as Reunion

4. Prabhat R. Mishra, Ritu Trivedi, Avinash Kumar, Varsha Gupta, Srikant K Rath, Kamini Srivastava, Naibedya Chattopadhyay, Anil K Dwivedi. A controlled release micro-capsule for osteogenic action. (U.S.P.T.O. 8,496,964); European Patent (EP2400957 B1).
5. Pal S, Kumar S, Eppalapally R, Kumar P, Sapana, Gayen JR, Mohammed R, Gurjar A, Mishra PR, Mittapelly N, Arya KR, Kumar B, Rath SK, Trivedi AK, Maurya R, Chattopadhyay N. and Chattopadhyay N. Bioactive extract, fraction Cassia occidentalis and formulation thereof for bone regeneration. United States Patent (11304927

Licensed to Pharmanza Herbals Pvt. Ltd. and the industry will carry out clinical trial through the DCG(I) route

Product development in progress under CSIR Nutraceutical Mission Project

II. Filed

1. Ritu Trivedi, Prabhat R. Mishra, SulekhaAdhikary, Naseer Ahmad, Dharmendra Choudhary, Naresh Mittapelly, Sudhir Kumar, Kapil Dev, Rakesh Maurya. A formulation for the prevention and treatment of bone-related disorders. Filed on 28.6.2017, application number 20180000776

   Commercialized as Joint Fresh
2. Trivedi R, Bhatta RS, Kothari P, Tripathi AK, Banala VT, Kumar S, Rai D, Sinha S, Maurya R, Mishra PR, Hingorani L. Formulation for treatment for osteoarthritis and joint-related disorders. BD-IPU/PAT/01/2018

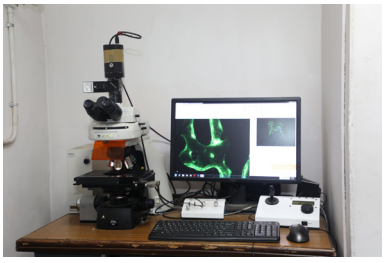
   To enhance the market opportunity of 6, a joint patent has been filed with the licensee.

H State-of-the-art facilities created

I. Micro-computed tomography

With this equipment, comprehensive static bone histomorphometry is performed in live animals and on isolated bones of laboratory rodents. This equipment has also been upgraded for finite element analysis-based prediction of bone strength in live animals. In the last five years, this equipment has been used by researchers from 26 institutes/ Universities in the country. In this way, we enable these centres via the training of students in data collection and analysis to carry out bone research.

II. Bioquant QIMAGING for bone biology



With this equipment skeletal phenotyping, human histomorphometry, cancer osteo-metastasis, cortical bone structure, osseointegration, chondrocyte proliferation, arthritis, and sarcopenia can be measured. This equipment is used by the scientists within and outside of CDRI.

III. Comprehensive Laboratory Animal Monitoring System (CLAMS)

With this equipment, indirect calorimetry is performed on live animals that allow measurement of metabolic parameters along with food intake, water volume intake, animal activity, sleep bouts, and telemetry. In addition to osteoporosis research, this equipment is routinely used by scientists involved in neurobiology, energy metabolic disorder, and toxicology research.

IV. Echo-MRI

This body composition analyser for live rats and mice enables the measurement of lean mass, fat mass, and water content.

V. Extracellular flux analyzer

This equipment measures the oxygen consumption rate and extracellular acidification rate of live cells in a multi-well plate, which allow the assessment of key cellular functions such as mitochondrial respiration and glycolysis. This equipment is extensively used by scientists within and outside of CDRI.

I Advancing the frontiers of knowledge

Under this program, we conduct innovative basic and translational research. Our world-class scientists, Ph.D. students, post-doctoral fellows, and technical staff work to gain new insights into the normal function of the bone, joints, immune system, energy metabolic system, muscles, renal system, and vascular system, and the diseases that affect them, and translate these insights into novel treatments. The currently pursued topics are given below.

- Understanding osteoblast bioenergetics
- Elucidating the role of deubiquitinases in bone formation
- Understanding the osteocyte secretome
- Delineating the immunocompetent properties of osteoblasts
- Understanding the genetics of rare skeletal diseases
- Deciphering the bone-muscle cross-talk
- Understanding the regulation of skeletal vascularization
- Deciphering the bone-kidney cross-talk

J Preclinical disease models

- Ovariectomy-induced osteopenia in rat, mouse, and rabbit
- Glucocorticoid-induced osteopenia
- Femur osteotomy model in rat and mouse
- Rat models of osteonecrosis
- Rat models of chronic kidney disease-mineral bone disease (CKD-MBD)
- Rabbit model of critical-sized defect
- Rat models of osteoarthritis
- Mouse model of rheumatoid arthritis
- Obesity-induced bone loss model in mouse

K Human resource development

Training the next generation of world-class researchers is a major focus of this program. In the last five years 46 fellows completed their Ph.D. out which eight were recognized for their high-quality research. The Dr. M.M. Dhar Memorial Distinguished Career Achievement Award in Biological Sciences is granted annually by CSIR-CDRI to the best Ph.D. thesis, and in the past 10 years, Ph.D. students from this centre have received it half the time.

1. Avinash Kumar, recipient of Dr. M.M. Dhar Memorial Distinguished Career Achievement Award in Biological Sciences, 2014
2. Abdul M. Tyagi, recipient of Dr. M.M. Dhar Memorial Distinguished Career Achievement Award in Biological Sciences, 2015
3. Jyoti Kureel, recipient of Young Investigator Award at International Osteoporosis Foundation, Orlando, USA, 2014
4. Kainat Khan, recipient of Dr. Swarn Nityanand Memorial Early Career Achievement Award for Women Research Scholar, 2015
5. Mohd. Parvez Khan, recipient of Dr. M.M. Dhar Memorial Distinguished Career Achievement Award in Biological Sciences, 2016
6. Subhasish Pal, recipient of Dr. M.M. Dhar Memorial Distinguished Career Achievement Award in Biological Sciences, 2019
7. Priyanka Kothari, recipient of Dr. Swarn Nityanand Memorial Early Career Achievement Award for Women Research Scholar, 2020
8. Krishna Bhan Singh, recipient of Dr. M.M. Dhar Memorial Distinguished Career Achievement Award in Biological Sciences, 2022

L

Collaborations established

- All India Institute of Medical Sciences, New Delhi
- Indian Institute of Technology- Kanpur
- Indian Institute of Technology- Bombay
- Indian Institute of Technology - Ropar
- National Centre for Cell Science, Pune
- Sanjay Gandhi Post-graduate Institute of Medical Sciences, Lucknow
- Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh
- King George's Medical University, Lucknow
- Centre for Biomedical Research, Lucknow
- Jamia Hamdard University, New Delhi
- National Dairy Research Institute, Karnal, Haryana
- Enem Nostrum, Mumbai
- Zydus Research Laboratory, Ahmedabad, Gujarat
- Pharmanza Herbal Pvt. Ltd., Anand, Gujarat

M

Participating scientists

Dr. Naibedya Chattopadhyay

(Endocrinology)

Dr. Jiaur R. Gayen

(Phramaceutics & PK)

Dr. Jimut K. Ghosh

(Molecular & Structural biology)

Dr. Atul Goel

(Medicinal & Process Chemistry)

Dr. Atul Kumar

(Medicinal & Process Chemistry)

Dr. Prabhat R. Mishra

(Phramaceutics & PK)

Dr. Srikanta K. Rath

(Toxicology & Experimental Medicine)

Dr. Sabyasachi Sanyal

(Biochemistry)

Dr. K V Sashidhara

(Medicinal & Process Chemistry)

Dr. Divya Singh

(Endocrinology)

Dr. Narender Tadigoppula

(Medicinal & Process Chemistry)

Dr. Ritu Trivedi

(Endocrinology)

Dr. Arun K. Trivedi

(Biochemistry)

Dr. Prem P. Yadav

(Medicinal & Process Chemistry)