Thomas Ming Swi Chang, O.C., M.D., C.M., Ph.De., FRCPC, FRS[C], FCAHS

CURRICULUM VITAE 29/1/2023

CONTENT

Two-page executive summary

Professor Thomas Ming Swi Chang, O.C., M.D., C.M., Ph.D., FRCPC, FRS[C], FCAHS

Degrees

- 1957 B.Sc. Honours Physiology McGill University (invented artificial Cells)
- 1961 M.D.,C.M. Faculty of Medicine, McGill University
- 1965 Ph.D. (on artificial cells) McGill University
- F.R.C.P.C. Fellow of the Royal College of Canada (Medical Sciences)
- F.R.S.C. Fellow of the Royal Society of Canada
- F.C.A.H.S. Fellow of the Canadian Academy of Health Sciences

Academic positions

Promoted at 3-year intervals from assistant professor to associate professor to full professor of the departments of Physiology, Medicine and Biomedical Engineering, Faculty of Medicine & Health Sciences, McGill University, Montreal, Quebec, Canada
Requested to be appointed emeritus professor so that in addition to his teaching and research activities at McGill he can also fulfill the following activities:
Director, Artificial Cells & Organs Research Centre, an international centre www.artcell.mcgill.ca/centrechart.pdf
Elected Honorary President and coordinator, Artificial Cells, Blood Substitutes & Biotechnology (an international network) www.artcell.mcgill.ca/ISABI.pdf
Editor in Chief 1980-2020, Emeritus Editor 2020- Artificial Cells, Nanomedicine & Biotechnology, an international Journal, (Taylor and Frances Publisher)
Editor in Chief 2006- Book series on Regenerative Medicine, Artificial Cells & Nanomedicine, World Science Publisher/Imperial College Press,
Editor in Chief 2023 International Journal Cell/tissue Engineering, Artificial Cell & Regenerative Medicine (World Science Publisher)
Director, " Father of Artificial Cell TMS Chang Academician Specialist Research Station" First Hospital of the Shantou University Medical School.
Honorary Professor, Peking Union Medical College, Chinese Academy of Medical Sciences, China
Honorary Professor, Blood Transfusion Institute, Chinese Academy Medical Sciences, China
Honorary Professor, Nankai University, China

Publications www.artcell.mcGill.ca/ChangPub.pdf

He has published more than 560 full papers and chapters
More than 500 invited lectures and plenary lectures

Other recognitions for his research www.artcell.mcGill.ca/ChangPub.pdf

He was awarded Officer of the Order of Canada for his invention of artificial cells
A worldwide poll voted him the “Greatest McGillian” out of 700 nominees from McGill’s 190 years history
http://www.medicine.mcgill.ca/artcell/voting%20result.pdf
Other awards www.artcell.mcGill.ca/ChangPub.pdf

He is known as the “Father of Artificial Cells”. He proposed and prepared the first artificial cells (Chang 1957 McGill, Science 1964) and continued this research for the rest of his research career to the present with 560 full papers. **In his Invited Monograph on Artificial Cells (Chang 1972)** (Charles C Thomas Publisher). he stated that:“Artificial Cell is not a specific physical entity. It is an idea involving the preparation of artificial structures ……. for possible replacement or supplement of deficient cell functions. ……. different approaches can be used to demonstrate this idea.” This area has now progressed well beyond his 1972 predictions.
His 2019 review https://www.tandfonline.com/doi/full/10.1080/21691401.2019.1577885
Titled “**ARTIFICIAL CELL evolved into** nanomedicine, biotherapeutics, blood substitutes, drug delivery, enzyme/gene therapy, cancer therapy, cell/stem cell therapy, nanoparticles, liposomes, bioencapsulation, synthetic cells, cell encapsulation/scaffold, biosorbent/immunosorbent hemoperfusion/plasmapheresis, regenerative medicine, encapsulated microbe, nanobiotechnology, nanotechnology”. The potential of artificial cells in biomedical research and clinical application is only limited by one’s imagination. An entirely new horizon is waiting impatiently to be explored.

Further details: **Public service website www.**medicine.mcgill.ca/artcell free papers, reviews, videos etc. including Monographs and books on Artificial Cells; Nanobiotherapeutic basis of blood substitutes; Hemoperfusion and others.

Comments by his peers

Greatest McGillian in the university's 190 years history *A 2011 world wide poll voted the inventor of artificial cells, Chang, as the "Greatest McGillian" out of 20 finalists from 700 nominee in McGill University's 190 years history. http://www.medicine.mcgill.ca/artcell/votingresult.pdf*

The Canadian Academy of Health Sciences "Dr. Chang's original ideas were years ahead of the modern era of nanotechnology, regenerative medicine, gene therapy, stem cell/cell therapy and blood substitutes.Evidence of his stature within the international scientific community was confirmed by 2 nominations for the Nobel Prize".

United Kingdom journal, New Scientist: In 1957, Thomas Chang was completing his final year as an undergraduate at McGill University in Montreal. … He would make the first artificial cell . has grown into a dynamic field.... worldwide artificial cells is now a sophisticated marriage of microbiology, chemistry and biotechnology, the concept remains as straightforward as Chang's original notion. Theoretically, an artificial cell can contain virtually anything: oxygen, drugs, enzymes, antibodies, cell extracts and even cells themselves. can now create artificial cells with roughly 30 different polymers, as well as several kinds of proteins. .....in 1961(Bangham) also added lipids to the list …."liposomes"

Journal of the British Royal Society of Chemistry , "Chemistry in Britain": Professor Tom Chang ……when he started work in the 1950's he was ploughing a lone furrow. Chang is credited with inventing microencapsulation, can emulate both in vitro and in vivo the behaviour of some natural cells.
"Artificial cells" already have many medical applications..chronic renal failure, drug poisoning, liver failure, enzyme therapy and metabolic function replacement. He told Chemistry in Britain: "When I first started work it was considered too far-fetched, but by 1966 when I demonstrated the value of artificial cells in hemoperfusion and detoxification there was a surge in interest and curiosity. … interest in artificial cells and especially modified hemoglobin as a blood substitute has taken off".

"American Medical News(American Medical Association)" (Mark Moran):
"For nearly 40 years, Dr. Chang has pursued the development of artificial blood, and his work has laid the foundation for products that may be available in coming years. These products, however, are not true red blood cells but modified hemoglobin molecules for short-term transport of oxygen Today, Dr. Chang is working on products that more closely resemble nature's own creation..... "

"Blood Weekly",U.S.A.: "The conference (VI International Symposium on Blood Substitutes) coincides with the 40 year anniversary of Chang's initial efforts back when he was a student at McGill University. This started … the modern approach of red blood cell substitutes… McGill University, where Chang and his colleagues have been instrumental in advancing the field of blood substitute research".

The role of artificial cells in the fight against COVID-19: deliver vaccine, hemoperfusion removes toxic cytokines, nanobiotherapeutics lower free radicals and pCO2 and replenish blood supply (Chang 2022) (Artificial Cells, Nanomedlicine & Biotechnology). 50:1, 240-251, Open access at DOI: 10.1080/21691401.2022.2126491

Modern Drug Discoveries, ACS Publications: "The first encapsulated cells were developed as far back as the 1960s, when T.M.S. Chang and colleagues first reported the microencapsulation of cells. The vision of using these cells for therapeutic purposes was present from the start Several polymeric encapsulation systems have been developed or are currently being tested in clinical trials…. Many …. are examining the use of biocompatible .. membranes to surround the encapsulated cells"

Nature Medicine, "Cell encapsulation: promise and progress" G. Orive et al
"In 1964 Chang (Chang. **Science** 146(3643):524-525) proposed the idea of using ultrathin polymer membrane microcapsules for the immunoprotection of transplanted cells and introduced the term "Artificial Cells" to define the concept of bioencapsulation. Since then …bioencapsulation has provided a range of promising therapeutic treatments for diabetes, hemophilia, cancer and renal failure".

From 50th Anniversary Special Gold Edition of the Official Journal of The American Society for Artificial Internal Organs The 1966 paper by Chang is one of the 25 landmark papers selected for this Gold edition. The editorial "…Chang is the originator of artificial cells…for medical applications such as …. Artificial kidney, artificial liver, detoxification, enzyme therapy… artificial blood field on hemoglobin type products. (Others included Kolff, inventor of artificial kidney; Scribner for chronic hemodialysis; Gibbon on heart-lung machine; Cooley first human implant of artificial heart; Kantrowitz on intra-aortic balloon pumping; Kolobow on oxygenator)

DEGREES:

1957 B.Sc. (Honours Physiology) McGill University ("invented" artificial cells while an undergraduate student on honours research project). .
1961 M.D., C.M. Faculty of Medicine, McGill University.
1965 Ph.D. (on artificial cells including blood substitutes), Departments of Chemistry & Physiology, McGill University.
F.R.C.P.C. (Medical Sciences), Royal College of Physicians and Surgeons of Canada (based on examination of research and clinical trials on artificial cells).
F.R.S.C. Fellow of the Royal Society of Canada
F.C.A.H.S. Fellow of the Canadian Academy of Health Sciences

ACADEMIC APPOINTMENTS

(1) RESEARCH APPOINTMENTS AT McGILL

1962-1965 Medical Research Council of Canada Research Fellow, Department of Chemistry then Department of Physiology

1965-1968 Medical Research Council of Canada Scholar (career development award),
1968- 1999 Medical Research Council of Canada Career Investigator, (laboratory research and clinical trials). Until MRC's Career Investigator Program ended in Dec 1999.
1975-1978 Director, Artificial Organs Research Unit, Department of Physiology, McGill University
1978-1979 Director, Artificial Organs Research Unit, Faculty of Medicine, McGill University
1979- ongoing: Director, Artificial Cells and Organs Research Centre, McGill University.

(2) ACADEMIC APPOINTMENTS AT McGILL

Physiology

1965 Lecturer of Physiology, McGill University
1966 Assistant Professor of Physiology, McGill University
1969 Associate Professor of Physiology, McGill University
1972 Professor of Physiology (tenured since l975), McGill University
2007- Emeritus Professor. In order to be more flexible in my research and international collaborative research and international scientific activities, I requested McGill to appoint me as emeritus professor

Medicine

1972-1975 Assistant Professor of Medicine and Clinical Medicine, McGill University and Royal Victoria Hospital (clinical trials)
1975-2007 Professor of Medicine (tenured), McGill University and Royal Victoria Hospital
2007—ongoing: in order to be more flexible in my research and international collaborative research and international scientific activities, I requested McGill to appoint me as Emeritus Professor of Medicine, McGill University

Biomedical Engineering (Department formed in 1990)

1990-2007 Professor of Biomedical Engineering (tenured)
2007- ongoing: In order to be more flexible in my research and international collaborative research and international scientific activities, I requested McGill to appoint me as Emeritus Professor of Biomedical Engineering.

Chemical Engineering and Chemistry

1983-2002 Associate of Chemical Engineering, McGill University (Until Biomedical Engineering Department's Ph.D. program was approved.
1985-2000 Associate of Chemistry, McGill University (Until Biomedical Engineering Department's Ph.D. program was approved)

(3) HONORARY ACADEMIC APPOINTMENTS OUTSIDE McGill University

1983- ongoing Honorary Professor, Nankai University, Tianjin, China
2007- ongoing Honorary Professor, Peking Union Medical College, Beijing, China
2011-ongoing Honorary Professor and key consultant on blood substitutes, Blood Transfusion Institute of the Chinese Academy of Medical Sciences,
2013- 2018 Honorary Professor, Shantou University Medical College
2019-ongoing. Director, "Academician TMS Chang Research station" and Clinical Research Centre, Shantou University Medical School.

(4) VOLUNTRY SERVICE AT COMMUNITY

Montreal Chinese Hospital

1966-1967 Director of Medical Board and Director of Laboratory, until Medicare started
1968-1981 Consultant
1982-1987 Honorary Consultant
1987- ongoing Honorary Staff

Chew Choa (Shantou his hometown) Association

2016-ongoing Honorary President, Province of Quebec Branch of the

EXAMPLES OF HONOURS AND AWARDS:

- Medical Research Council of Canada (MRC) Research Fellow Award 1962-65
- MRC Research Scholar Award (career development award) 1965-68
- Career Investigator Award , Medical Research Council of Canada 1968-1999
- **First Incentive Lecturer**. The Annual Incentive Lectures were instituted in Sweden in 1969. The first Incentive Lecturer was "invited to inaugurate these annual lectures". The lecture on "The Clinical Potential of Enzyme Technology" was given at: Karolinska Institute, Stockholm, University of Lund, University of Gothenberg Hospital (1969).
- **Clemson Award** for "Basic Research in the Development of the Microcapsule Artificial Kidney", World Congress of International Society for Biomaterials, Vienna, Austria. (1980)
- Honorary President IV International Symposium of Hemoperfusion and Artificial Organs, Ankara, Turkey (1982).
- Honorary President, VI International Symposium on Hemoperfusion, Mexico (1985).
- Honorary Professor, Nankai University, Tianjin, PRC. 1983-present
- Honorary President, VII International Symposium on Hemoperfusion, Kiev, USSR, sponsored by the USSR Academy of Sciences, (1986)
- Annual Award of the Education Foundation Federation of Chinese Canadian Professionals, Toronto. (for invention of "Artificial Cells including blood substitutes"), 1986
- “Ambassador by Appointment" and, AGORA Trophy, Societe du Palais des Congres de Montreal , 1986
- Honorary President, 8th International Symposium on Hemoperfusion, Sorbents and Immobilized Bioreactants, Germany, 1988.
- **Silver Medal Award** for outstanding scientific contribution from Academic Senate of University of Bologna for the 9th Centenary of University of Bologna, 1988
- Honorary President 9th International Symposium on Hemoperfusion, Sorbents and Immobilized Bioreactants, Tokyo, Japan. , 1989
- Honorary president 10th International Symposium on Hemoperfusion, Sorbents and Immobilized Bioreactants, Rome, Italy, 1990
- Congress President, VIII World Congress, International Society Artificial Organs, 1991
- **Honorary President, International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology (since 1991)**. (formed by originally group on Hemoperfusion, Sorbent and Immobilized Bioreactants)
- **Officer of the Order of Canada, for the invention of artificial cells 1992**.
- First Julius Silver Lectureship, Julius Silver Institute of Biomedical Engineering and Israel

Society for Biomedical Engineering, 1992.

- 125th Anniversary of Canadian Confederation Medal Award from Governor General of Canada, 1993
- Honorary Congress President, XI World Congress, International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology, (Congress president: Professor R.Langer of MIT who organized the congress) Boston, 1994
- **President, International Society for Artificial Organs, 1994-96**
- **Honorary member, International Society for Microencapsulation, since 1995**
- Queen Elizabeth 25th Jubilee Medal, Governor General of Canada, 2002
- Honorary Congress President XII World Congress, International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology (Congress President, is the president of the Chinese Academy of Medical Sciences that organizes the congress) co-congress president is the President of the Chinese Red Cross Society, Beijing, 1997
- **1999 ISBP Annual Award, International Society for Blood Purification** (Sir Roy Calne was winner of 1998 Award, other previous winners are Robert Rosenberg from NIH, Charles Dinarello then at Tufts and Colton from MIT)
- **"VIRAGE" AWARD FOR CENTRE OF EXCELLENCE IN BIOTECHNOLOGY**, QuebecMinistry of Higher Education, Science and Technology (1985- permanent since 1990 with salaries for 4 professors for the centre now integrated into the faculty salary budget.
- MSSS-FRSQ group on Blood Substitutes in Transfusion Medicine (2002-2008)
- Honorary President, IX International Symposium on Blood Substitutes, Tokyo, Japan 2003
- **Fellow of the Royal Society of Canada, FRSC 2004**
- Honorary President, X International Symposium on Blood Substitutes, Rhone Island, Providence, U.S.A. 2005
- Nominated for Nobel Prize in Medicine & Physiology, and also for Nobel Prize in Chemistry
- Honorary member, International Golden Key Honour Society (2005-)
- Honorary President, 2007 XI International Sym on Blood Substitutes, Beijing, (President of Symposium, Professor Liu Qian, Vice Minister of Health of China, president of Beijing Union Medical College Hospital and Vice President, Chinese Academic of Medical Sciences)
- **Special Award "50 years Outstanding Contribution on artificial cells and Blood Substitutes"** from Professor Liu Qian, Vice Minister of Health of China and President of the 2007 XI International Symposium on Blood Substitutes, Beijing, China
- Honorary President, 2009 XII International Symposium on Blood Substitutes, Parma, Italy
- **Founding President, International Academy of Nanomedicine** 2009-2010
- **First "Outstanding Research Award of the International Academy of Nanomedicine**", atthe First World Congress of the International Academy of Nanomedicine.
- Honorary President, 2011 XIII International Symposium on Blood Substitutes, Harvard Medical School, Boston, U.S.A. Symposium president, Professor Warren Zapol, Emeritus Chief of Anesthesia and Critical Care Medicine, Mass General Hospital, Harvard Medical School. http://www.medicine.mcgill.ca/artcell/536.pdf
- **2011 Voted as the Greatest McGillian in McGill University's 190 years history**.(Out of 700 nominee and 20 finalists that included Rutherford, Penfield, Osler, James McGill, Cohen and others) http://www.medicine.mcgill.ca/artcell/voting%20result.pdf
- **Honorary President, International Academy of Nanomedicine, since 2012** then continue when it was reorganized into the International Society for Nanomedical Sciences.
- **Honorary President, International Society for Nanomedical Sciences, since 2013**
- **Honorary President. 2013 XIV ISBS** International Symposium on Blood Substitutes, Institute of Blood Transfusion, Chinese Academy of Medical School, President will be vice president of the Chinese Academy of Medical Sciences.
- Queen Elizabeth Diamond Jubilee Medal 2013
- **Honorary President. 2015 XIV ISBS** International Symposium on Blood Substitutes, Lund, Sweden. President Professor Leif Bulow
- **Chinese Canadian Legend 2015**
- **Honorary President, 2017 XV ISBS** International Symposium on Blood Substitutes, Montreal

- **Honorary President, 2017 V ISNS** World Conference on Nanomedicine, Montreal
- **Honorary President, 2018 V ISNS** World Conference on Nanomedicine, Delhi, India
- **Honorary President, 2019 XVI ISBS** International Symposium on Blood Substitutes, Japan
- **Honorary President, 2022 XV ISBS** International Symposium on Blood Substitutes(Cancelled)
- **Honorary President, 2024 XVI ISBS** International Symposium on Blood Substitutes, (U.S.A)

OTHER INTERESTS:

- Continuing updating on most recent approaches in management, project control, organization, negotiation, interpersonal relationship, techniques in clear writing and speaking
- Continuing updating on new approaches in microcomputer especially word processing, database, website management, organization, project control, negotiation, graphics, clear writing, and other areas. Also in mobile communications.
- Classical music, tennis, badminton, table tennis, weight training, physical conditioning, martial arts, books on history and cultural developments and others.

ARTIFICIAL CELLS: INVENTION, INNOVATION & TRANSLATION.

Abstract:

Artificial Cell invented and developed by Chang's group has led to development by his group and other groups resulting in approval for routine clinical uses in a number of areas: For example:

- For use in COVID_19 vaccines.
- Hemoperfusion for COVID-19 cytokine storm treating poisoning, partial support of liver and renal failure, and for some immunological diseases.
- For use as first-generation blood substitute in countries with HIV contaminated donor blood. A form of blood substitute has been approved in the EU for pre-transplantation organ preservation.
- As a number of drug delivery systems.
- PEG-asparaginase for use in leukemia treatment.
- Recently approved as PEG-Phenylalanine ammonia lyase for the treatment of adult Phenylketonuria PKU

This is just the beginning of the actual routine clinical use of artificial cells since the principle of artificial cell is just beginning to be actively explored into other areas of nanomedcine, biotherapeutics, blood substitutes, targeted drug delivery, enzyme/gene therapy, cancer therapy, cell/stem cell therapy, nanoparticles, liposomes, bioencapsulation, replicating synthetic cells, cell encapsulation, biosorbent/immunosorbent hemoperfusion/plasmapheresis, regenerative medicine, encapsulated microbe, nanobiotechnology, nanotechnology and other areas. More futuristic research includes nanorobot, nanocomputer, multimodal locomotion delivery robot and others.

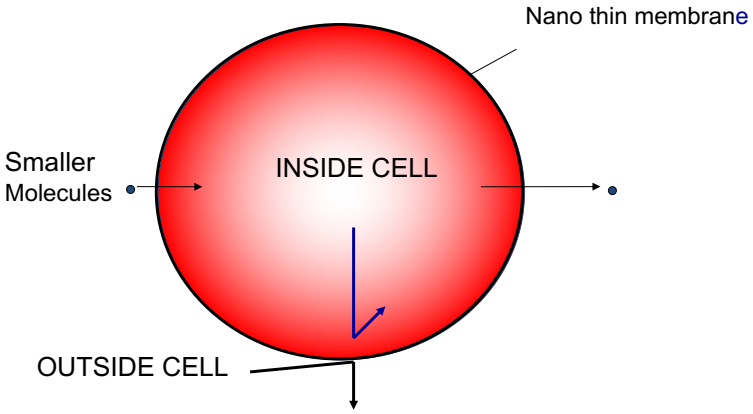
This is now a very large area, and the following is just a brief overview with emphasis on those related to his group's research. Some references are cited here, but for a complete reference of his group's research please see the Publication section of this C.V. Some typical recent reviews are as follows

(1) 2019 Chang: review on Artificial Cells: https://doi.org/10.1080/21691401.2019.1577885
(2) 2017 Opening Chapter in Book on Hemoperfusion www.medicine.mcgill.ca/artcell/hpbk_ch1.pdf
(3) 2021 Chang et al editors: Book ON Nanobiotherapeutic based Blood Substitutes www.medicine.mcgill.ca/artcell/2021book.pdf
(4)MONOGRAPH 2007 by Chang ARTIFICIALCELLS: biotechnology, nanotechnology, regenerative medicine, blood substitutes bioencapsulation and cell/stem cell www.medicine.mcgill.ca/artcell/2007%20ebook%20artcell%20web.pdf
(5) 2022 Chang: The role of artificial cells in the fight against COVID-19: deliver vaccine, hemoperfusion removes toxic cytokines, nanobiotherapeutics lower free radicals and pCO2 and replenish blood supply" https://doi.org/10.1080/21691401.2022.2126491 .

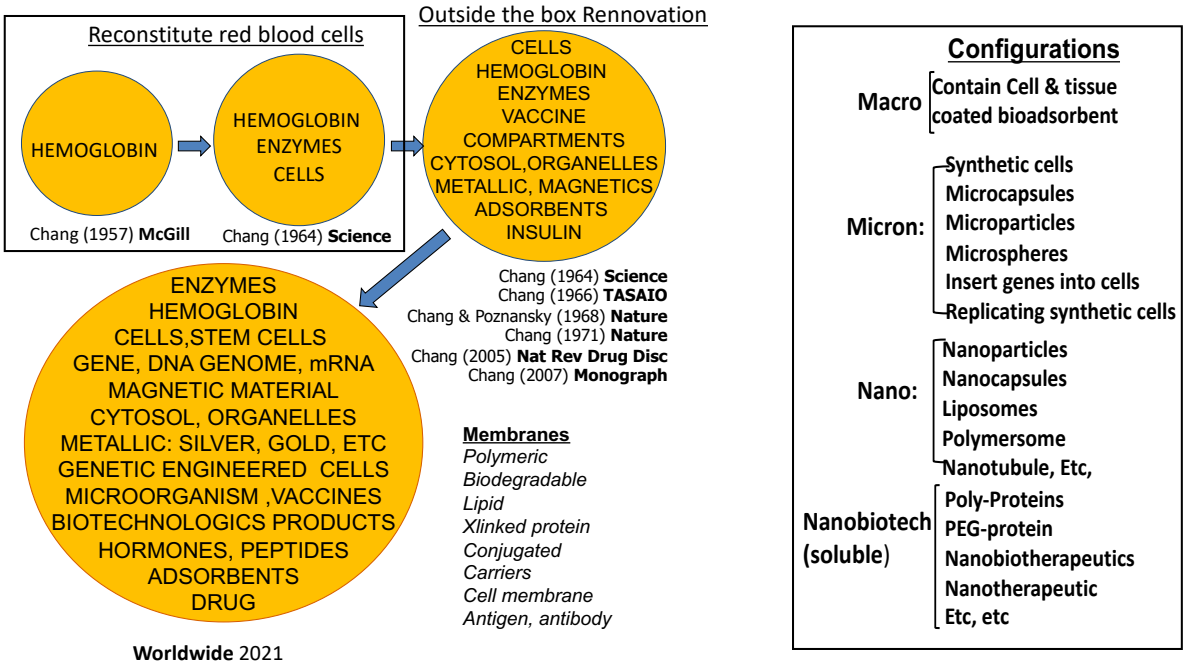
IDEA OF ARTIFICIAL CELLS

Basic Principle of Artificial Cells

(Chang 1957 McGill, 1964 Science)



The very first humble "artificial cells" reported by Chang in 1957 (1,2) is not to reproduce biological cells, but to use available basic knowledge to prepare very simple system for possible uses in medicine and other areas (Fig. 1). This author predicted in his 1972 monograph on Artificial Cells (6) that *"Artificial Cell is not a specific physical entity. It is an idea involving the preparation of artificial structures of cellular dimensions for possible replacement or supplement of deficient cell functions. It is clear that different*



approaches can be used to demonstrate this idea". There are unlimited possibilities in variations for the artificial cell membranes and contents (Fig. 2). Artificial cells can be of macro, micro, nano and molecular dimensions (Fig. 2). Each of these has unlimited variations in configurations. Each configuration resulted in a new terminology with many arbitrary subdivisions of "artificial cells" under the guise of different names. All these mean that there are many areas of application in medicine and even outside medicine (Table I)

It is only in the last 20 years that many of the original ideas on artificial cells are being increasingly applied and extended by researchers around the world. This is because many of the original ideas (2-7) were reported years before the modern era of nanotechnology, regenerative medicine, blood substitutes, biotechnology, gene therapy, stem cell therapy, cell therapy and other areas. Thus, following his 2005 review on "therapeutic applications of polymeric artificial cells" in Nature Review Drug Discovery (8), a timeline prepared by the editor shows that Chang has made 20 of the 23 major discoveries in related areas up to that time. However, since that time, other groups are making rapid and exiting progress and numerous discoveries. Each major progress in other areas has led to stepwise progress in artificial cells. First there is the coming of age of polymer chemistry and biomaterial. Then there is the recognition of the importance and developments in biotechnology. Then there is the progress in molecular biology and genomics. All these has contributed to a quantum leap in the area of artificial cells. One can expect that there will be important future progress in other areas, for example, artificial intelligence and nanorobots, that will contribute to unlimited progress by increasing number of groups world-wide in the area of artificial cells. We have only touched the surface of the potential of the extension, innovations and uses of artificial cells (Fig. 1-3). Space only allows for a general overview follows by some examples of the different configurations and their applications. More details are available elsewhere (12).

ARTIFICIAL CELLS: APPLICATIONS (2019)

Microdevice and nanodevice

Drug delivery:

Blood Substitutes and oxygen therapeutics

Biotherapeutics, Immunotherapeutics:

Enzyme and gene therapy:

Cell & Stem Cell Therapy:

Biotechnology & Nanobiotechnology

Nanomedicine

Regenerative medicine

Agriculture, Industry, Aquatic culture

Nanocomputers and nanorobatics

Nanosensors

Replicating synthetic cells etc

Other transformative possibilities

HISTORY

In 1957, while a final year honours B.Sc. Physiology student at McGill University, I came up with the idea of preparing artificial cells. I thought that since cells are the fundamental units of all organs and tissues, artificial cells should have implications for many areas of medical uses. I went around talking to students about this and even to chemistry professors thinking that they would have methods for doing this. They all gave me a funny look and the chemists even told me that this is impossible. So, I went to my dormitory room and started to try different ways to do this. After many unsuccessful attempts. I finally came up with a very preliminary method. All final year honours Physiology students have to complete an assigned research project. I gathered up my courage and went to see a young Professor Burgen who was in charge of the honours program (He shortly returned to U.K. to become Sir Arnold Burgen, FRS). He sent me the following for my 60th anniversary of the invention of artificial cells: *"……..I still recall you coming to see me and saying that you would prefer to do a different project and would like to try to make artificial red blood cells. I think I said go ahead without much expectation. The start of a life of a very successful career in science! ....."* With beginner's luck, I was able to prepare artificial red blood cells that has some of the oxygen carrying properties of red blood cells. The department asked for a sample for one of the professors to check and he also obtained the same type of oxygen dissociation curve. As a result, the honours thesis was approved as "Chang, T.M.S. (1957) Hemoglobin corpuscles. Report of a research project for Honours Physiology http://www.medicine.mcgill.ca/artcell/514.pdf

However, the department chairman did not want me to publish this rather outlandish idea. So I continued this research while finishing my medical school. After this I wanted to continue with PhD research, but the chairman was not too receptive since there was no one doing this research to direct me. After much discussion he kindly organized a PhD committee consisting of senior full professors all holding FRS: Physiology, Biochemist, Anatomy and Chemistry. Midway through my PhD the chairman with the agreement of the committee finally agreed to let me submit a paper for publication under the condition that it should not be called artificial cells and I should be the sole author. Surprisingly Science accepted it (2) (Chang 1964). After my PhD, the chairman did not have a position for this type of research. The associate dean, Professor Bates, who later became the chairman, helped me to apply for MRC career investigator awards (junior followed by senior) With research progress (Chang & Poznanski Nature 1968, Chang Nature 1971, Chang Monograph 1972 etc) and clinical trials and FDA approval (Chang et al 1973 etc), I became assistant professor, associate professor then full professor at 3 years intervals in the departments of Physiology and Medicine and later Biomedical Engineering. One advantage of being a full professor is that I immediately publish an invited monograph on "Artificial Cells" in 1972 (6)

BASIC METHODS

This review cannot cover all the important methods of the preparation of the numerous configurations of of artificial cells. Instead, we shall first look at the historical basic approaches to be followed later in more details using specific examples.

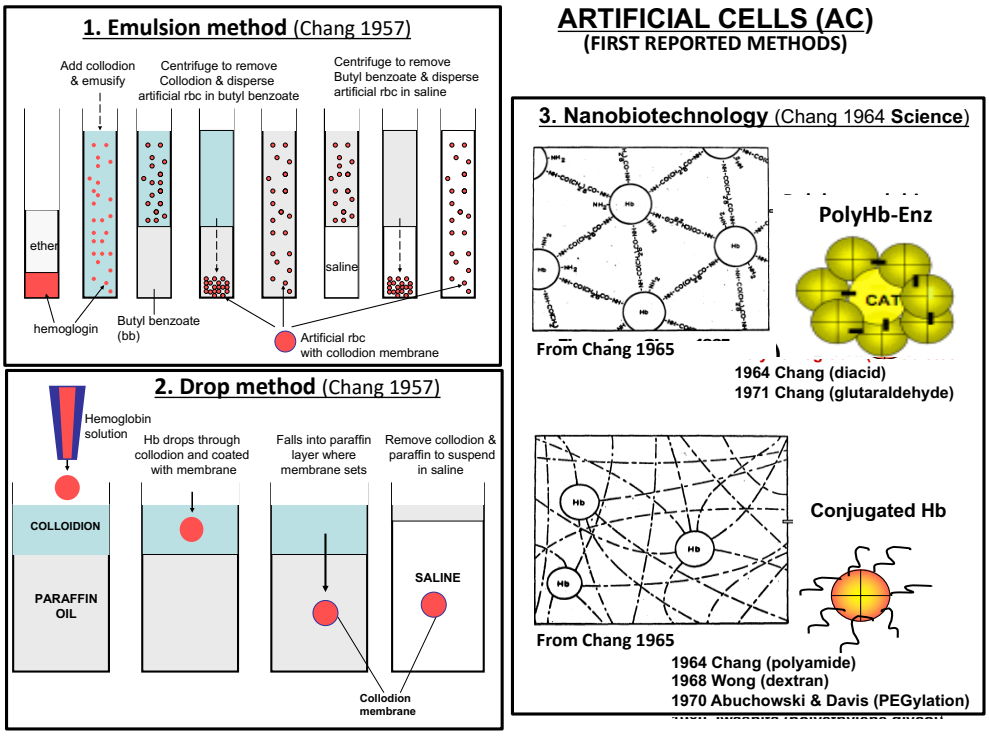


Fig.. Upper left: *Original (1)(Chang 1957) emulsion method of preparing micro-dimension artificial cells. Since extended to physical or chemical methods for microscopic and nanodimension artificial cells.* ***Lower left:****. Original (1)(Chang 1957) drop method for the preparation of large artificial cells. This has been now been extended and modified for cell/stem cell encapsulation.****lower left:*** *Basic method (Chang 1964 Science)(2,7) of bifunctional agents to assemble and crosslink hemoglobin (Hb) into PolyHb that has evolved into the preparation of soluble polyhemoglobin and other biotherapeutics.****Lower middle*** *: Basic method of conjugating hemoglobin to polymer (1)(Chang 1964 Science).that has evolved into the use of other polymers like the Pegylation (PEG-protein) Updated from Chang (8. 9, 12)*

Micro and nano dimension: The basic principle is to use emulsion followed by the use physical or chemical methods to form membrane around each micro droplet (1-2). The diameter is determined by the diameter of the emulsified micro or nano dimension droplets. Extensive novel emuslsion methods developed around the world are now available for use. This principle has since been extended using modified physical or chemical methods for the preparation of microscopic or nanodimension artificial cells that are also called microcapsules, nanocapsules, liposomes, microparticles, nanoparticles, polymersomes, etc. Microfluidizer is a new way of preparing artificial cells (10a)

Macro dimension: The drop method for the preparation of large artificial cells (1) has now been extended and modified using modified physical or chemical methods for cell/stem cell/tissue encapsulation. This will be described in more details later.

Crosslinking of proteins. The original basic method (2,7) of the use of bifunctional agents to assemble and crosslink hemoglobin (Hb) into PolyHemoglobin. has been extended into many other areas of nanobiotechnology and nanobiotherapeutics. This will be described in more details later.

Conjugation of protein. The original basic method of conjugating hemoglobin to polymer (2) has evolved into the conjugation of hemoglobin to soluble dextran or soluble (PEG) polyethylene glycol.

EXAMPLES OF ROUTES OF ADMINISTRATION

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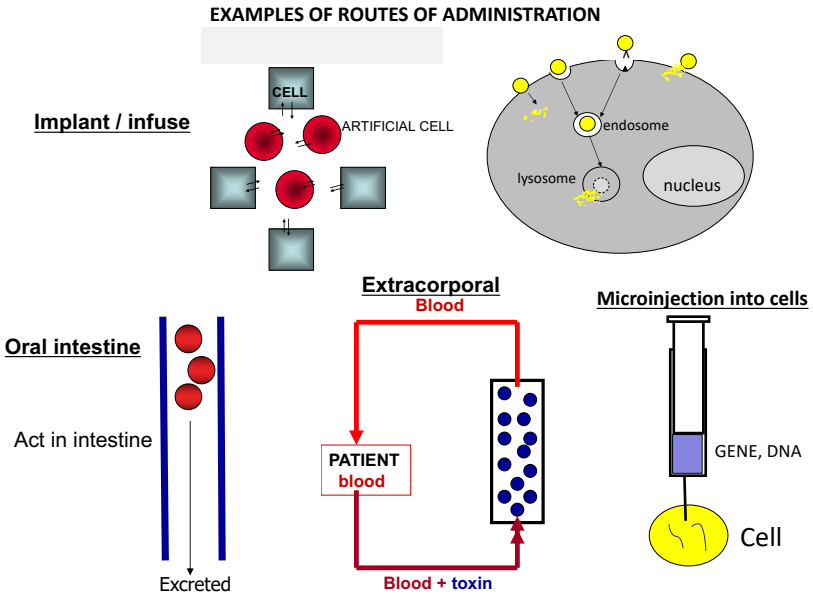


Figure contains examples of possible routes of administration for the function of artificial cells in the body. Generally speaking, regulatory agencies are less worry about the use of artificial cells that are not implanted or injected into the body. We therefore started with artificial cells that are not implanted but act in a device for the extracorporeal route. This has resulted in the early approval of the use of artificial cells in patients way back in 1980. This is in the form of a hemoperfusion device.

ARTIFICIAL CELL BASED HEMOPERFUSION

Introduction

Increasing commercial interest in this area has led to much priority claims in this area. Thus, I should disclose that I have no personal financial benefit from this research. Furthermore, it should be clearly stated that I have spent most of my research time for 16 years between 1966 and 1982 to start the whole area of the use of the principle of artificial cells for hemoperfusion. I carried out the first study to analyze the feasibility, then to prepare the system and characterized the system followed by personally carrying out animal safety and efficacy studies and then personally carried out clinical trials in patients leading to FDA approval. During all this time I published all the methods and results and organized international symposia around the world to encourage others to develop this for patient use. Thus, researchers and companies have benefited from this research. Companies needs extensive efforts and costs to develop and improve the system into different types of commercial products. This is how improvements and production of this approach can be realized. Unfortunately, there are the rare companies that try to claim priority for the whole area and to ignore what was done before. The following is just a brief overview. Please refer to the references and the CV publication section for even more details. Detaied reviews are available in Chang's 2007 artificial cell monograph http://www.medicine.mcgill.ca/artcell/2007 ebook artcell web.pdf and Chang et al's 2017 multiauthor book on hemoperfusion www.medicine.mcgill.ca/artcell/hpbk_ch1.pdf

Basic principles

It is common knowledge that for the same volume of particles the smaller the particles, the larger would be the total surface area. It is also known that the theoretical diffusion across a membrane is proportional to the total surface area and inversely proportional to its membrane thickness. However, my 1966 analysis of the implication of combining all these factors for artificial cells of micro dimension is way beyond

expectation (5). Figure shows an updated analysis (11) of the theoretical mass transfer of a fixed volume of 0.01 um membrane thickness artificial cells with different diameters. This is compared to an artificial kidney (hemodialysis) machine with a mass transfer of 1. The mass transfer increases with decreasing diameter of artificial cells so that at the micro diameter range it can increase to 100 times that of an artificial kidney. At the nano diameter range, this can increase to an amazing 1,000 times above that of an artificial kidney. Thus, artificial cells of different diameter containing different bioactive material can become efficient micro/nano dialyser/bioreactor with unlimited possibilities (Fig)

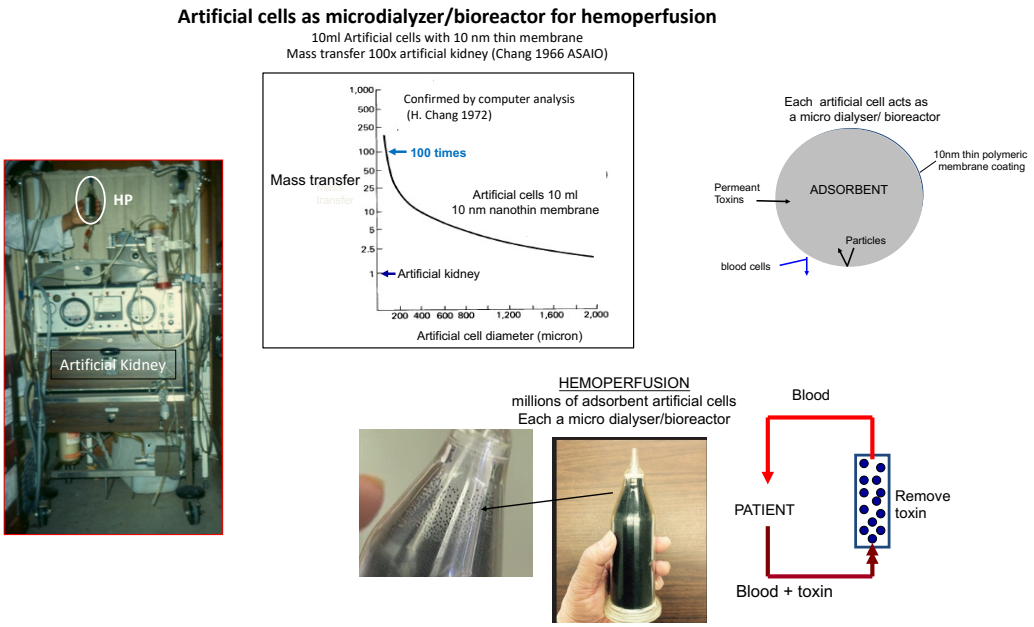


Fig. ***Center:*** *Theoretical mass transfer of 5ml 0.01 um membrane thickness artificial cells with different diameters. This is compared an artificial kidney machine with a mass transfer of 1.*
Upper right*: Thus, artificial cells containing bioactive material can become efficient micro/nano dialyser/bioreactor.*
Lower: *70 grams 90 micron diameter adsorbent artificial cells retained inside a small container by screens at either end.* ***Left:*** *Its small size is compared to an artificial kidney. Updated from Chang (5,6,8,9, 11)*

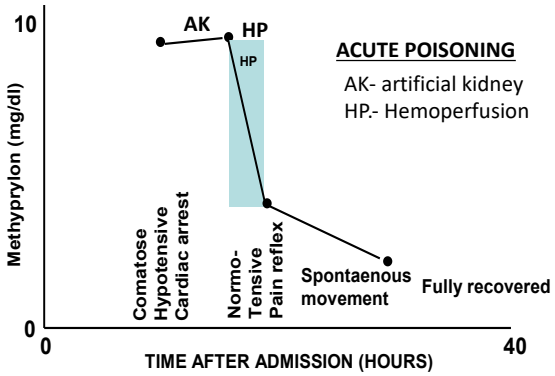
Based on this analysis, 70 grams of 90 micron diameter adsorbent artificial cells are retained inside a small container by screens at either end. The sorbent artificial cells remove toxins or drugs from the blood of patients perfusing through the column. The membrane of the artificial cells prevents the adsorbent from being released into the body and also prevents the adsorbent from damaging the blood cells (Fig. 6). This result in a cup size miniaturized hemoperfusion device with hundred times the efficiency of a hemodialysis (artificial kidney), the size of a washing machine (Fig).

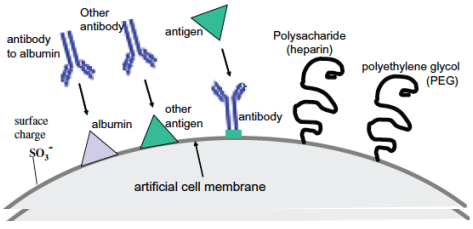
Clinical use in patients

Chang starts study on the use of artificial cells containing adsorbents for hemoperfusion. This included personally carried out scaled up, animal testing and clinical trial in patients. He shows the safety and effectiveness for using this first in animals then in patients. Figure shows the result of one of the many patients he has carried out (13). This is a suicidal patient who ingests 3 times the lethal dose of a sleep pill, methryprylon. Five hours of standard hemodialysis treatment cannot lower the drug level and the patient remains comatose, hypotensive with cardiac arrests. When the author starts hemoperfusion treatment the plasma methryprylon level decreases rapidly in 2 hours and the patient is no longer comatose nor hypotensive and shortly recovers completely.

ARTIFICIAL CELL BIOADSORBENTS
(Chang et al 2017)

(1) ACUTE POISONING
(2) SPECIFIC BIOADSORBENT
(3) ORGAN FAILURE (partial)
(4) IMMUNOLOGICAL DISEASES
(5) REMOVE SPECIFIC CELLS





ARTIFICAL CELL SURFACE LIGANDS FOR
BIOCOMPATABILITY
IMMUNOLOGICAL DISEASES
REMOVE SPECIFIC CELLS

Fig. ***Left*** *Present status of clinical uses of Hemoperfusion (from Chang et al , 2017 Book on hemoperfusion).*
Right*: Example of a sleeping pill overdose suicidal patient (Chang et al 1973). Standard dialysis (AK) is not effective but hemoperfusion (HP)*

quickly lowered the plasma level and rapid recovery.. Updated from Chang (9, 11)

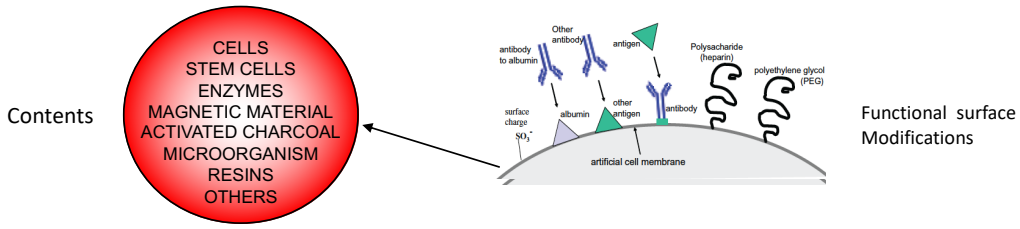
Following this first case, similar results are obtained by Chang in a number of other patients (13). He has also showed its effectiveness as partial support in patients for kidney failure and liver failure to remove toxic molecules. These results have led to FDA approval for routine clinical uses. Hemoperfusion is now an accepted routine clinical use for the treatment of patients with suicidal or accidental overdose of some medications aroundd the world. He edited a 2017 book (11) with specialists around the world showing that approach is being developed into commercial products and used extensively around the world, especially in countries where these can be manufactured with affordable costs. www.medicine.mcgill.ca/artcell/hpbk_ch1.pdf

Hemoperfusion for COVID_19 patients

Patients with very severe COVID-19 may die despite ventilator and oxygenator support due to a sudden and massive increase in certain toxic factors (inflammatory factors, cytokines storm). These can damage organs resulting in multi-organ failure and death. Artificial Cell hemoperfusion has earlier been shown to be effective for the lowering of systemic toxins and waste metabolites, www.medicine.mcgill.ca/artcell/hpbk_ch1.pdf in several medical conditions. A Chinese company has independently developed their own improved adsorbent that is coated by collodion membrane. (Chang's first hemoperfusion device also used a collodion coating). Their device shows efficacy in the treatment of severe COVID_19 patients (2020 Lancet preprint (20): Survival 47 (62%) in HP and 15 (38%) in the control group ($p<0.05$).(Zhou et al 2020 Lancet online). This is now used in Europe and Asia. Health Canada Regulatory agency has **also** approved this as an emergency treatment for COVID_19 in Canada.

Possible extensions

Possible variations: present and future: (From Chang et al 2017)



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pecific

This is now such a large area with numerous publications that please refer to the 2017 multiauthor book for more details (11).

BLOOD SUBSTITUTES

Unlike the use of artificial cells in a hemoperfusion device that is outside the body, this is an example where large volumes artificial cells have to be infused intravenously into the body. Thus, even though this is a very important and urgent lifesaving method, it needs more time before regulatory approval.

Why blood substitutes?

. Under normal circumstances, donor blood (rbc) is the best replacement for blood. HOWEVER:

- Natural epidemics (e.g. HIV, Ebola, COVID-19,etc) or man-made epidemics (terrorism, war, etc) can result in contaminated donor blood or disqualified disease contact donors. Unlike rbc, blood substitutes can be sterilized.
- Heart attack and stroke are usually caused by obstruction of arterial blood vessels. Unlike rbc particles, blood substitute is a solution and in animal studies it can more easily perfuse through obstructed vessels to reach the heart and brain.
- Severe blood loss from accidents, disasters or war may require urgent blood transfusion that cannot wait for transportation to the hospital for blood group testing. Unlike rbc, blood substitutes do not have blood groups and can be given on the spot (Fig. 8).
- Red blood cells have to be stored in refrigeration for up to 42 days thus difficult to transport and store in disaster and frontline. Blood substitutes can be stored at room temperature for more than 1 year, compared to rbc of 1 day at room temperature.
- In very severe hemorrhagic shock there is usually a safety window of 60 min for blood replacement, beyond which there could be problems related to irreversible shock. Animal study shows that one type of blood substitutes with enhanced rbc enzymes can prolong the time.

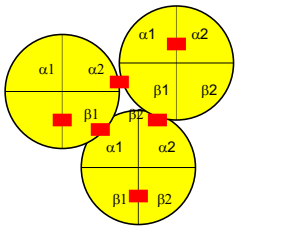
What is the present status around the world?

2021 book www.artcell.mcgill.ca/2021chapter1.pdf www.artcell.mcgill.ca/2021book.pdf

After the first report of artificial red blood cells (Chang Science 1964) (2) people felt that blood substitute is a simple matter that could be quickly developed when needed. Thus blood substitute research was put aside and only the other areas of artificial cells were extensively developed around the world for other wide spread uses. When AIDS arrived in 1989 there was no blood substitutes, and many patients were infected with H.I.V. contaminated donor blood. It is only then that intense R&D on blood substitutes was belatedly carried out around the world (20-35). It was found out too late that blood substitute requires the same long-term research as in any other medical research for cancer and other diseases. Thus, the present status is as follows (Fig.):

First generation: Oxygen carriers (HBOCs):

Red blood cells have 3 major functions: (1) transport oxygen from the lung to the tissue, (2) remove damaging oxygen radicals and (3) carry carbon dioxide CO2. from the tissue to the lung to be removed. The urgency of H.I.V. in donor blood necessitates the development of the simplest system in the shortest time. The most extensive clinical trials were based on Chang's glutraldehyde crosslinked polyhemoglobin (PolyHb) later developed by Biopure (Hemapure: bovine PolyHb) (24) and Northfield (human PolyHb) (21). They used the basic principle of glutaraldehyde crosslinked hemoglobin first reported by Chang (7) (Fig. 8).



Polyhemoglobin
Diacid (Chang 1964)
Glutaraldhye (Chang 1972)

FIRST GENERATION BLOOD SUBSTITUTE

No initial interest until H.I.V. contaminated donor blood crisis in the 1980s

Then Biopure Co prepare their glutamer-250 product , based on the 1972 published method of Chang using glutaraldehye crosslinked polyhemoglobin.

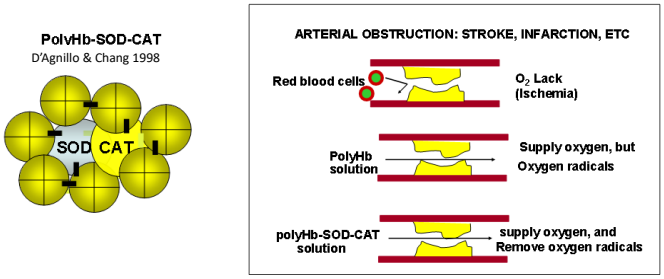
Clinical trials (24) result led to **South Africa and Russia approve the use of this product to avoid H.I.V. contaminated donor blood**. This is based on risk/benefit ratio since the avoidance of H.I.V. outweighs any possible cardiac side effect

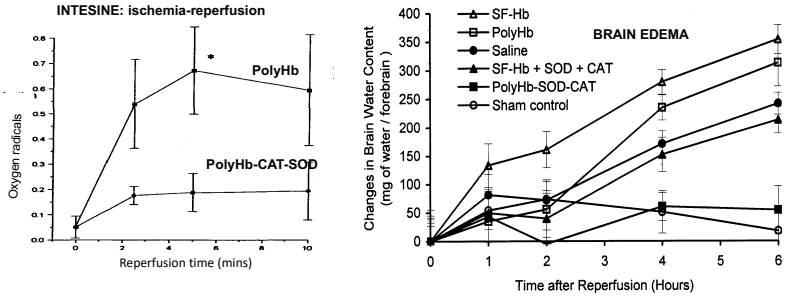
This has no blood groups and can be pasteurized to remove infective agents and can be stored at room temperature for more than 1 year. Large-scale clinical trials have been carried out including using human PolyHb in the ambulance without the need for typing or cross matching (21). Greenburg, Jahr and others have carried out clinical trials using (33) Hemapure:bovine PolyHb (23, 24). This has been approved for routine clinical use in South Africa to avoid the use of H.I.V contaminated donor blood (24). Other ongoing

research includes the use of other sources of haemoglobin by Chen's groups with porcine Hb (21), Yang's group with Placental Hb (22), and Bulow's group and others with recombinant Hb (23).

2nd Generation: Oxygen carriers + removal of oxygen radicals:

Arterial obstruction can result in stroke and heart attack. Red blood cells, being 7 to 8 microns in diameter, have difficulty flowing through partially obstructed vessels to supply the needed oxygen. PolyHb, being a solution, can perfuse through to supply the needed oxygen. However, reperfusion with an oxygen carrier can release damaging oxygen radicals (Fig. 9).

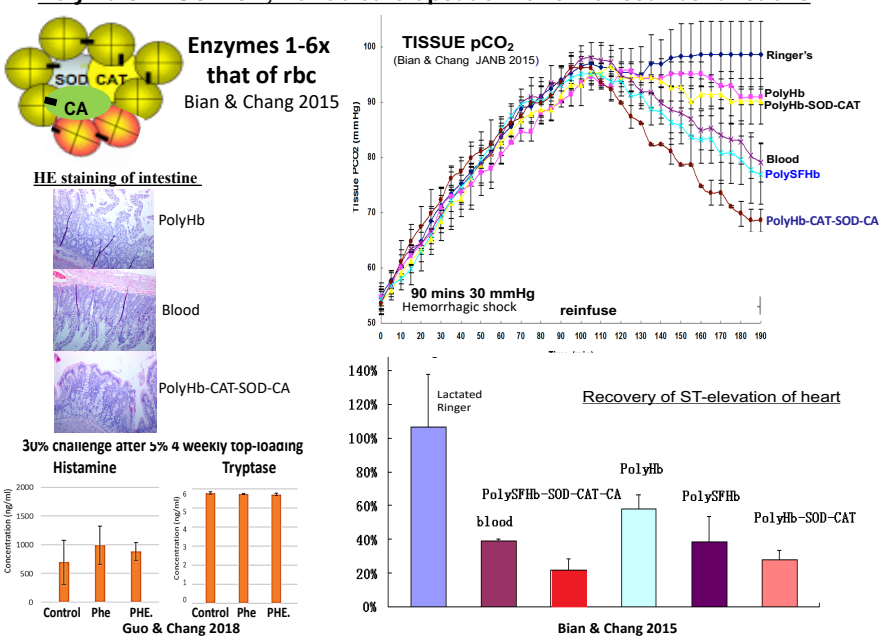




D'Agnillo and Chang has prepared a soluble complex of Polyhemoglobin containing antioxidant enzymes to remove oxygen radicals (PolyHb-SOD-CAT) (25). It has the dual function of an oxygen carrier that can also remove oxygen radicals (Fig. 9). After 90 min of combined hemorrhagic shock and brain ischemia in rats, reinfusion of PolyHb-SOD-CAT did not cause brain edema (Fig.9) (26). On the other hand, PolyHb or a solution contain free Hb, SOD and CAT causes significant increases in brain edema.

Ischemic small intestine releases damaging oxygen radicals when reperfused with PolyHb. However, PolyHb-SOD-CAT reperfusion does not increase oxygen radical release (Fig. 9). This is important during intestinal surgery or organ storage for transplantation. The work of Hsia's group using conjugated hemoglobin containing synthetic antioxidants (PNPH) is another way to solve the problem (27). Another example is that of Alayash's group based on haptoglobin(28) Others included those of Simoni, Zal and other groups (23)

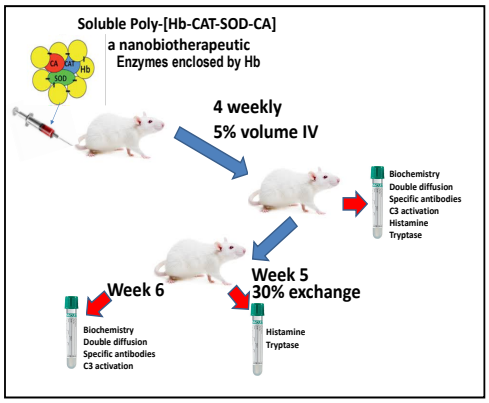
3Rd Generation: All 3 rbc functions (Carries Oxygen + removes oxygen radicals + carries CO_2



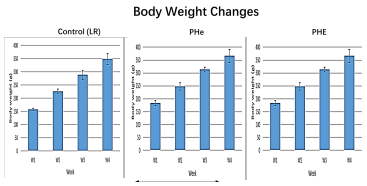
Other conditions as in sustained severe hemorrhagic shock may require all three rbc functions. We have designed a novel soluble nanobiotechnological complex (PolyHb-SOD-CAT-CA) (Fig). It not only has all 3 rbc functions, but it can have enhancement of all 3 rbc functions by increasing the concentrations of rbc enzymes in the complex (29). These rbc enzymes can be extracted from rbc inexpensively (30). This complex has no blood groups. The lyophilized preparation can be heat pasteurized at 68F for 2 h (31). This can be important if there is a need to inactivate H.I.V. virus, Ebola , COVID-19 virus, and other infective organisms. Unlike about 1 day for rbc at room temperature, this

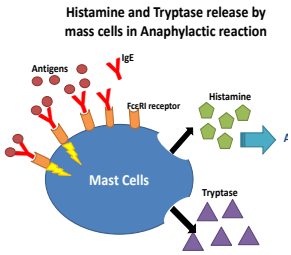
lyophilized preparation can be stored in room temperature for 320 days. Our result in a 90 minutes hemorrhagic shock animal model with 2/3 blood volume loss (Fig 10) (29) shows that it is superior to whole blood in the following ways: lowering of elevated intracellular pCO_2 , recovery of ST elevation, tropronin levels, lowering of elevated lactate, histology of the heart and intestine.

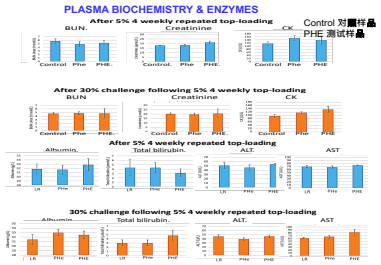
PolyHb-CAT-SOD-CA
Long term safety & Immunology
Guo & Chang 2018 JANB

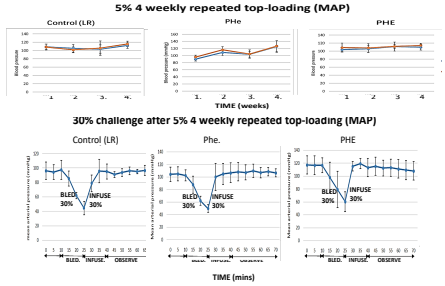


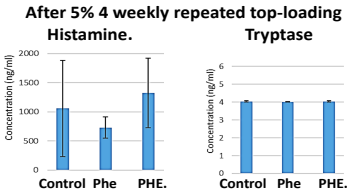
No significant differences from control in:
Body weight, biochemistry, blood pressure
IgG, IgM, specific antibodies to Hb, CAT,SOD,CA
No anaphylactic reaction nor complement activation

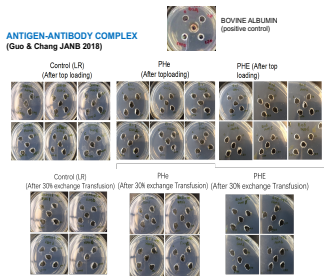


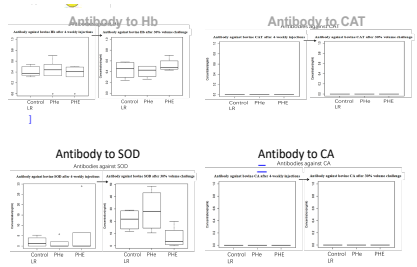


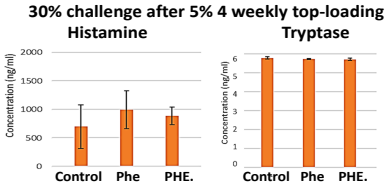












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Long term study of bovine PolyHb-SOD-CAT-CA in rats shows safety and lack of immunological problems after 4 weekly 5% blood volume infusion followed by 30% volume exchange transfusion (32). This includes the measurement of histamine and tryptase that show no anaphylactic reaction (Fig. 10). Hemoglobin has very low antigenicity. Bovine PolyHb itself shows no immunological problems in patients (23,24). For PolyHb-SOD-CAT-CA the small fraction of enzymes are nanoencapsulated inside the large excess of hemoglobin molecules (36) (Fig.10)

Nanodimension red blood cells

The original micro dimension artificial red blood cells are too large to survive in the circulation. Nanodimension artificial rbc is another way to solve this problem (33-35). Lipid membrane vesicles itself do not circulate well and the addition of PEG to the membrane to form a PEG-lipid-polymer membrane vesicle has increased the circulation time. At present, this approach at the late Tsuchida's group (35) is being continued by Sakai's group (34). In our laboratory we have been using an 80 nm mean diameter biodegradable PEG-Polylactide polymeric membrane nano rbc that contains all the rbc enzymes (Fig.11) (33). Both PEG-lipid and PEG-polylactide nano red blood cells can remain in the circulation longer than PolyHb or PolyHb-SOD-CAT-CA. However, they contain substantial amount of nonfunctional lipid or polymeric membrane. On the other hand, for soluble nanobiotherapeutic artificial rbc, PolyHb-SOD-CAT-CA, the "membrane" is functional in the form of oxygen carrying hemoglobin (Fig.11). Thus, each has its own advantage.

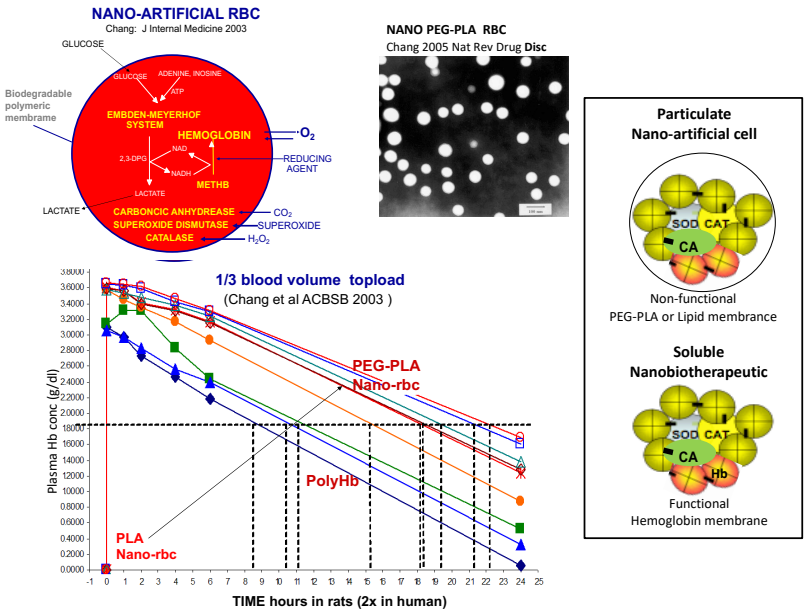

Figure 11: ***Upper left:*** *Nano artificial red blood cell (rbc) with biodegradable polymeric membrane and red blood cell enzymes.* ***Upper middle:*** *EM of PEG-PLA membrane nano artificial rbc with a mean diameter of 80 nanometer.* ***Lower left:*** *Circulation time of PEG-PLA membrane rbc in rats is 2x longer than Polyhemoglobin.* ***Right:*** *nano rbc contains substantial amount of nonfunctional lipid or polymer membrane. Soluble Hb nanoencapsulated nano rbc has functional oxygen carrying hemoglobin Updated from Chang (9, 10, 33) with copyright permission*

Future directions

International progress up to now shows that it is possible to tailor-make blood substitutes ranging from simple to complex (23). It is urgent to have these ready without again waiting until it is too late. We need to analyze the specific indications for 1,2,3 and 4 above. If a condition only needs oxygen, then there is no need to use a more complex one. On the other hand, it would be folly not to use a more complex one if indicated. We also need to intensify research on the many important ongoing research around the world. Examples include other novel approaches including novel crosslinkers; new sources of material from porcine, bovine, human cord rbc, recombinant, Arenicola marina; basic research on nitric oxide, oxidative stress, haptoglobin, rate of oxygen supply; safety and efficacy analysis and many other areas

ARTIFICIAL CELLS AS DRUG DELIVERY SYSTEM

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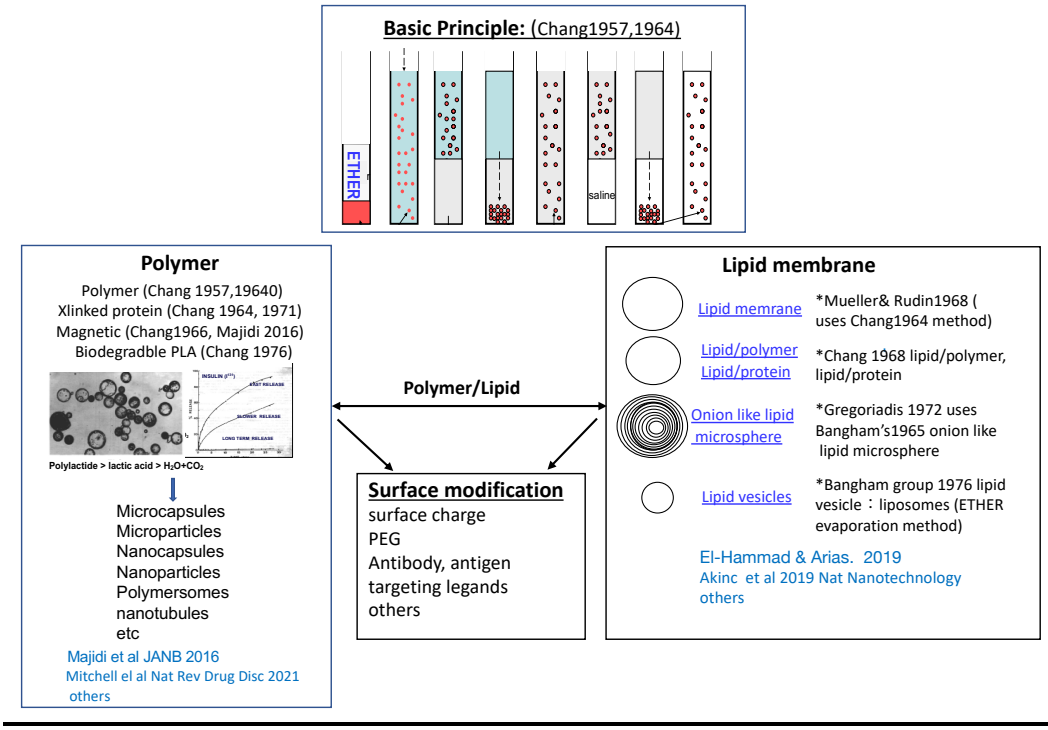


Original basic methods of preparing artificial cells (2nd figure of this paper)

Original (1)(Chang 1957) emulsion method of preparing micro-dimension artificial cells. Since extended to physical or chemical methods for microscopic and nanodimension artificial cells. Original (1)(Chang 1957) drop method for the preparation of large artificial cells. This has been now been extended and modified for cell/stem cell encapsulation.: Basic method (Chang 1964 Science)(2,7) of bifunctional agents to assemble and crosslink hemoglobin (Hb) into PolyHb that has evolved into the preparation of soluble polyhemoglobin and other biotherapeutics: Basic method of conjugating hemoglobin to polymer (1)(Chang 1964 Science).that has evolved into the use of other polymers like the Pegylation (PEG-protein) Updated from Chang (8. 9, 12)

Bilayer lipid membrane artificial cells: liposomes

In 1965 Bangham reports the use of microspheres of onion-like concentric multilamellar lipid bilayers as membrane models in basic research (43). In 1968 Meuller and Rudin (44) reported that they use Chang's method (2) to prepare single bilayer membrane vesicles. A McGill PhD graduate, Gregoriadis, visits me before leaving for his postdoctoral fellowship in England. While there he becomes the first person to start the use of liposomes as drug delivery systems (45). However, onion like multi-lamellar liposomes limit the loading of water-soluble drugs. Thus, in 1976 Deamer and Bangham (46) report the use of an "ether evaporation" method to form single bilayer lipid membrane vesicles. This "ether evaporation method" is an extension of the 1957 Chang method using ether for the preparation of artificial cells (1,2) (Fig. 4). These lipid membrane artificial cells have since been extensively studied and used as drug delivery systems around the world (47). This is now a very successful approach for drug delivery. For the delivery of larger peptides, proteins and vaccines, the emphasis is using biodegradable polymeric system.

Biodegradable polymeric membrane artificial cells

Polylactide is biodegraded in the body to lactic acid and then water and carbon dioxide (Fig. 12) and is a F.D.A. approved material for medical implantation. Thus, in 1976 Chang reported the use of polylactide prepare biodegradable membrane artificial cells containing enzymes, hormones, vaccines and other biologics (37) (Fig. 12). Variations in the molecular weight of polylactides and thickness of the membrane and configurations can result in artificial cells that release insulin at different rate (Fig. 12). This approach has been extended and developed extensively world-wide as drug delivery systems in the form of nanoparticles, polymersomes or nanocapsules (37-41). Bowerman et al reported in 2016 that Docetaxel-loaded PLGA nanoparticles improve efficacy in taxane-resistant triple-negative breast cancer (40). Ravanshad, et al. in 2017 reported the use of nanoparticles in cancer detection by Raman scattering based techniques (41). Abed et al reported in 2018 the use of Lysozyme and DNAse I loaded poly (D, L lactide-co-caprolactone) nanocapsules as an oral delivery system (42)

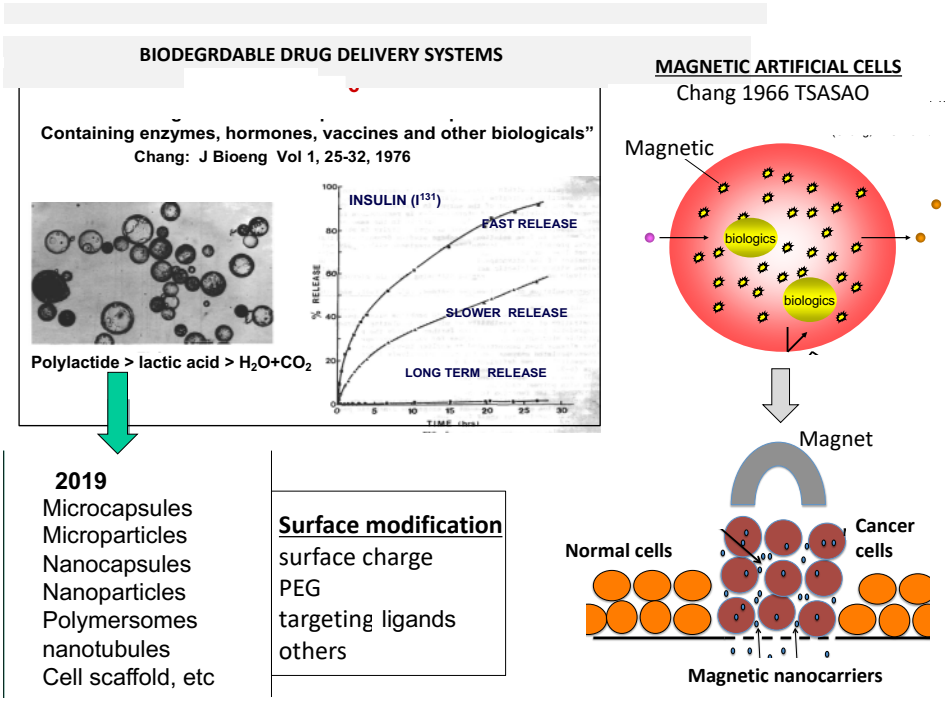


Fig. 12. ***Left:*** *Biodegradable membrane artificial cells containing enzymes, hormones, vaccines and other biologicals (Chang, 1976). Variations result in the release of insulin at different rates. Extended now to many different configurations and dimensions.* ***Right:*** *Artificial cells containing magnetic material. Updated from Chang (9, 10) with copyright permission*

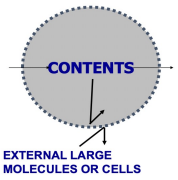
Targeting using surface ligands or magnetic properties and others

Back in the 1970, Chang's group has investigated the incorporation of surface charges, polysaccharides and protein onto the surface of polymeric artificial cells (Fig. 7) (2, 6). The most successful one is Davies of Enzon's use of Polyethylene glycol (PEG). PEG has been incorporated to both types of nano artificial cells to result in longer circulation time. Further developments lead to the incorporation of antibodies onto the polymeric or lipid membrane of artificial cells (Fig. 12), to allow for targeting to cells with the corresponding antigens. Brennick, C. A., et al. in 2017 report the use of neoepitopes as cancer immunotherapy targets (48). Artificial cells containing biological materials and magnetic materials have been prepared by Chang in 1966 (5) (Fig. 12). This way, external magnetic fields can direct their movement; remove or separate them from a mixture; retain them at specific site of action; stir or agitate them as in bioreactors, and other possibilities. This principle is now being used very extensively in bioreactors; in removing specific materials from a mixture as in diagnostics kits; in drug delivery systems; for locating radioactive material or chemotherapeutic agents at site of tumor and other areas of application. A 2016 review by Karkan et al on the use of magnetic nanoparticles for drug delivery is available. (49). A more futuristic approach is Hu et al's 2018 report in Nature of Small-scale soft-bodied robot with multimodal locomotion with potential for drug delivery (50).

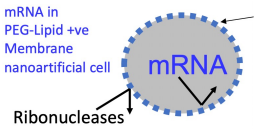
COVID_19 VACCINES

The first publication on the use of artificial cells for vaccine was in a chapter by Chang 1975 on Artificial Cells for vaccine (48) in a book edited by the late Prof Heden, Chair of Microbiology, Karolinska Institute, Sweden. It was too earlier for its time.

ARTIFICIAL CELL TECHNOLOGY.
Basic method: Chang 1957-1965Intra
Micro, nano, contents, configuration,
Membrane of polymer and protein
Surface modifications
*Polysaccharide, +ve -ve charges, antigen
(Chang 1964-e 1967)
*Polyethyleneglycol PEG
(Abuchowski & Davis 1970)
Lipid components
*Mueller& Rudin1968 (used Chang1964 method)
*Chang 1968 polymer-lipid
*Gregoriadis 1972 uses Bangham's
1965 lipid onion like membrane model
*Bangham group 1976 lipid vesicle :
liposomes (lipid evaporation method)
Biodegradable polymer
PLA (Chang 1976)
Combination of above technologies
Lipid-trace polymer, polymer trace lipid
Surface charge and PEG
PEG-Lipid, PEG-PLA,
PEG-PLA-lipid (Chang et al 2005 JANB)
PEG-+veLipid (Cullis et al 2021 Nature)
Others



2020 mRNA vaccine
Pfyzier and Moderna



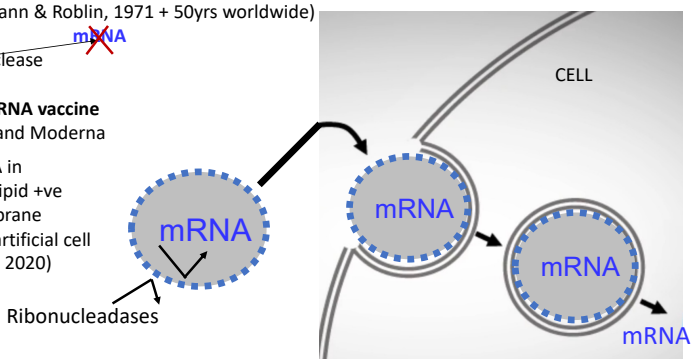
ARTIFICIAL CELLS (AC) FOR THERAPY
1957 Chang (McGill) hemoglobin
1964 Chang (Science) Hemoglobin & enzymes
1968 Chang & Poznanski (Nature)
hereditary enzyme defects (mice)
1971 Chang (Nature) suppress lymphosarcoma in mice
1973 Chang et al (TASAIO & CMAJ) adsorbent for patients
1975 Chang for **vaccine** Chapter in book (Ed Heden)
1976 Chang (J Bioeng) for **vaccine**
1985 Chang (JANB), Palmer et al (Lancet) Lesch Nyhan patient
1986 Bourget & Chang (BBA) Phenoketonuria (rat model)
(1984 mRNA synthetised in lab)
1990 mRNA in lipid AC **vaccine** (mice)
1993 mRNA **vaccine** for influenza (mice)
(2005 mRNA modified to evade immune detection
But mRNA destroyed by Ribonucleases in Body)
2012. PEG-lipid AC mRNA **vaccine**(mice)
2016 PEG-lipid AC mRNA **vaccine** influenza (human)
2020 PEG-lipid positive surface charge AC mRNA
COVID-19 **vaccine** (Emergency authorization)
2020 AC adsorbent hemoperfusion for cytokine storm
in COVID-19 patients
2021 (Emergency Authorisation in Canada)

Fortunately, we and others around the world have been developing artificial cells as carriers for other biologics and biotherapeutics. This world have been developing artificial cells as carriers for other biologics and biotherapeutics. This allows Pfzier and Moderna to place synthetic mRNA inside nano-lipid artificial cells to prevent the enzymatic destruction of mRNA (Fig below)(48a.b,c). Other confiurations and formulations of artificial cells are being explored for other types of COVID_19 vaccines. Thomas Ming Swi Chang (2022)[19]"The role of artificial cells in the fight against COVID-19: deliver vaccine, hemoperfusion removes toxic cytokines, nanobiotherapeutics lower free radicals and pCO2 and replenish blood supply" Artificial Cells, Nanomedlicine & Biotechnology). 50:1, 240-251, DOI: 10.1080/21691401.2022.2126491

Artificial Cells
1964 Chang Artificial Cells
1975 Chang AC for vaccine Chapter in
book ed. Heden. Karolinska, Sweden
1976 Chang AC for vaccine J Bioeng
(+ 60 yrs worldwide R&D on artificial cells)

Synthetic mRNA
(Friedmann & Roblin, 1971 + 50yrs worldwide)
mRNA
Ribonuclease

2020 mRNA vaccine
Pfyzier and Moderna
mRNA in
PEG-Lipid +ve
Membrane
nanoartificial cell
(Cullis 2020)



ENZYME AND GENE THERAPY
https://doi.org/10.1080/21691401.2019.1577885

Enzymes inside artificial cells can act on external permeant substrates while avoiding protein sensitization, anaphylactic reaction, or antibody production with repeated injection (2-4, 6, 8, 9) (Fig. 13). Chang's groups has been investigating the use of artificial cells for enzyme therapy since 1964 (2-10, 25,26, 29-33, 51, 54,55, 59, 60) (Fig.)

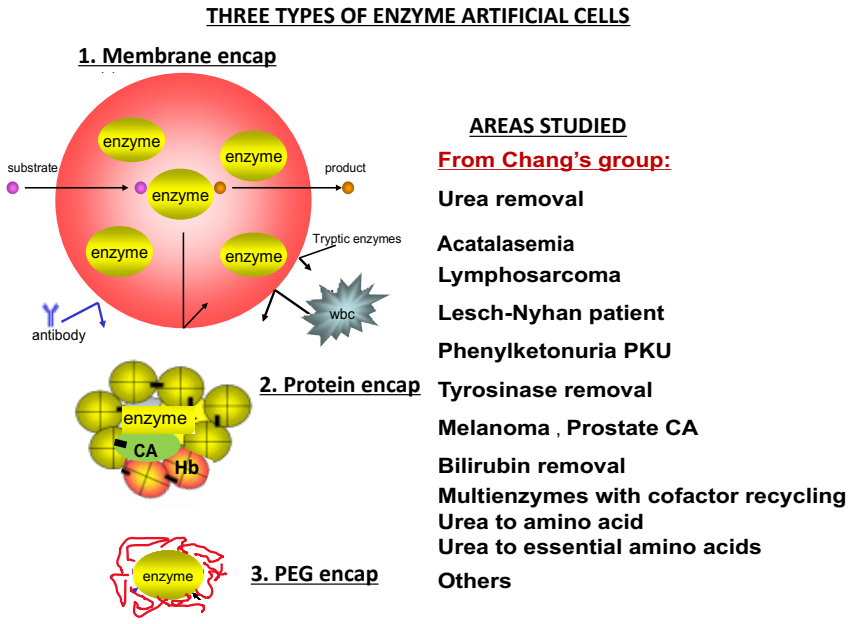
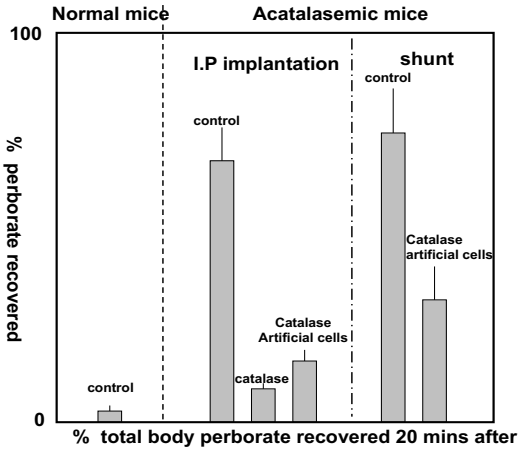


Fig. 13 **Left** *: Enzymes inside artificial cells, unlike those in free solution, do not have immunological problems. These can be in the form of membrane encapsulation, Neutral-protein encapsulation or PEG covering of the enzyme molecule.* ***Right:*** *This approaching has been studied for a number of medical applications. Updated from Chang (9, 10)*

Artificial Cells for Enzyme Therapy in Inborn Errors of Metabolism

1. Acataemsemia

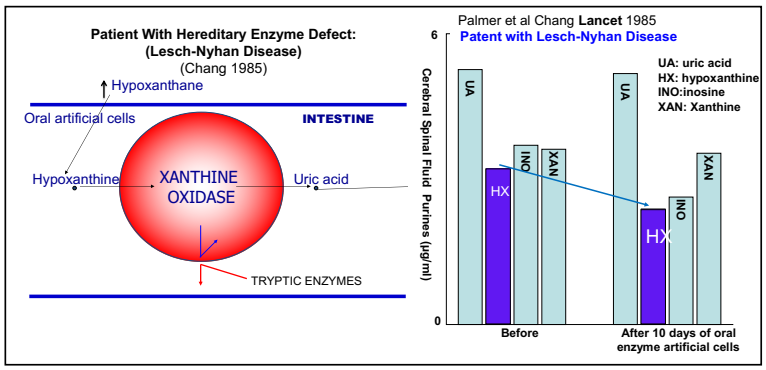
Hereditory enzyme defect: acatalasemia
(Chang & Poznansky,1968 **Nature)**



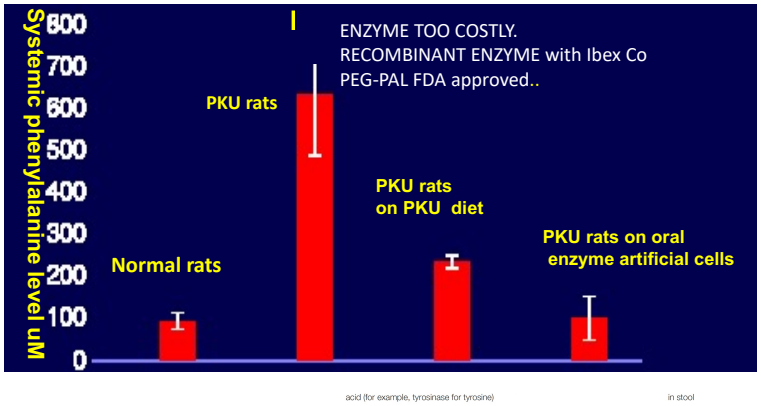
Implanted artificial cells containing catalase replaces the defective enzyme in mice with a congenital defect in catalase, acatalasemia (3). Unlike the free catalase, there is no immunological problem with repeated injections (51)

2. Artificial Cells containing Xanthine Oxidase for Lesch-Nyhan Disease patient

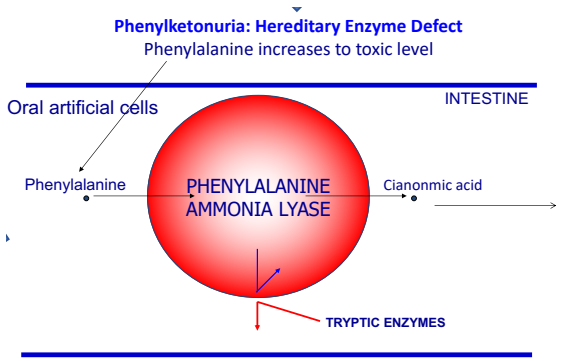
Lesch-Nyhan disease is an inborn of metabolism due to a deficient in a complex and unstable liver enzyme system. The Montreal Children Hospital contacted me that they have young child with severe symptoms due to Lesch-Nyhan Disease with elevated hypoxanthine and whether something could be done. The natural enzyme system in the liver is very complex and unstable. Fortunately, I found that there is a fermentation produced enzyme, xanthin oxidase and I was able to prepare artificial cells containing this simple stable fermentation produced enzyme, Xanthine Oxidase (Chang JABB 1985). We suspended this in jello or ice cream and the child enjoyed having this orally twice a day. After 10 days the system hypoxanthine was lowered (figure on left)(Palmer.. Chang, Lancet 1985)(55).



3. Phenylketonuria PKU is the most common inborn errors of metabolism due to hereditary enzyme defect of the very complicated and unstable multienzyme system in the liver.



We show that there is an extensive recirculation of amino acids in the intestine



(Figure) (9.56) We therefore investigated the use of oral artificial cells containing a simple and stable single enzyme prepared by fermentation, phenylalanine ammonia lyase.(57). This is placed inside artificial cells and could effectively lowered the increased systemic phenylalanine to normal level in a PKU rat model. Thus, we show that orally administered artificial cells containing phenylalanine ammonia lyase (PAL) lower the systemic phenylalanine levels in phenylketonuria (PKU) rats and improved the growth of the animals (57). We then seek a company to develop this for clinical use. They in turn collaborate with another company and develop **an injectable PEG- phenylalanine ammonia lyase that has just been approved** by **FDA for use in adult PKU patients** (58,59). In order to avoid long term injection, further development should be carried out for a formulation for oral administration (57) as we have done in the laboratory.

In the same way, our study shows that oral artificial cells containing tyrosinase when given orally lowers the systemic tyrosine level (9). Kaminsky et al use argocytes containing enzyme nanoparticles to reduce toxic concentrations of arginine in the blood (63). Abed et al reported in 2018 the use of Lysozyme and DNAse I loaded poly (D, L lactide-co-caprolactone) nanocapsules as an oral delivery system (42)

ARTIFICIAL CELLS FOR CANCER THERAPY

CANCER IMMUNOTHERAPY

This has become an explosive area. 。

But There are many problems that need to be solved.

Need for suitable delivery systems

Riley, R.S., June, C.H., Langer, R. *et al.* Delivery technologies for cancer immunotherapy. *Nat Rev Drug Discov* **18,** 175–196 (2019).
Martin, J.D., Cabral, H., Stylianopoulos, T. *et al.* Improving cancer immunotherapy using nanomedicines: progress, opportunities and challenges. *Nat Rev Clin Oncol* **17,** 251–266 (2020)

Need a less severe method especially for the less severe cases

Wang, J., Dong, R., Wu, H. *et al.* A Review on Artificial Micro/Nanomotors for Cancer-Targeted Delivery, Diagnosis, and Therapy. *Nano-Micro Lett.* **12,** 11 (2020)

Enzyme therapy using nanobiotherapeutic inside polymeric-lipid nanoartificial cells

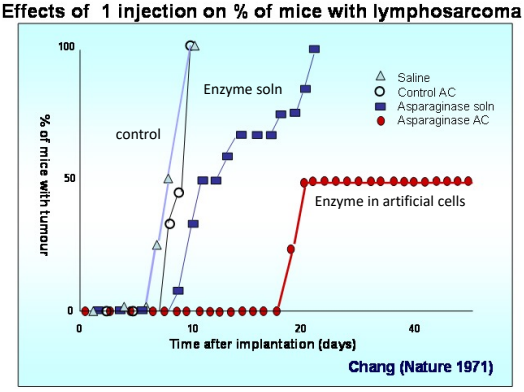
Wang & Chang JANB 2021

1. Artificial cell containing asparaginase for Lymphosarcoma in mice

Asparaginase artificial cells for lymphosarcoma.

Chang 1971 Nature

Effects of 1 injection on % of mice with lymphosarcoma

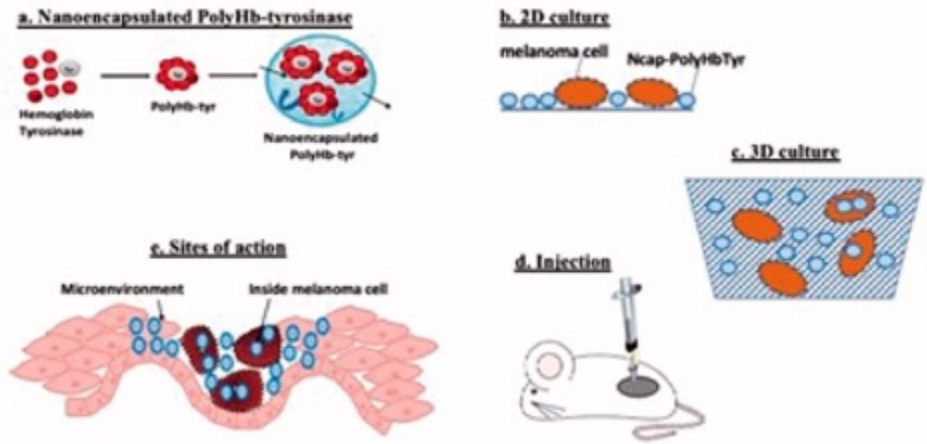


Implanted artificial cells containing asparaginase delay the onset and growth of lymphosarcoma in mice (4). This has been extended by other groups using PEG-asparaginase for the treatment of leukemia in patients (54).

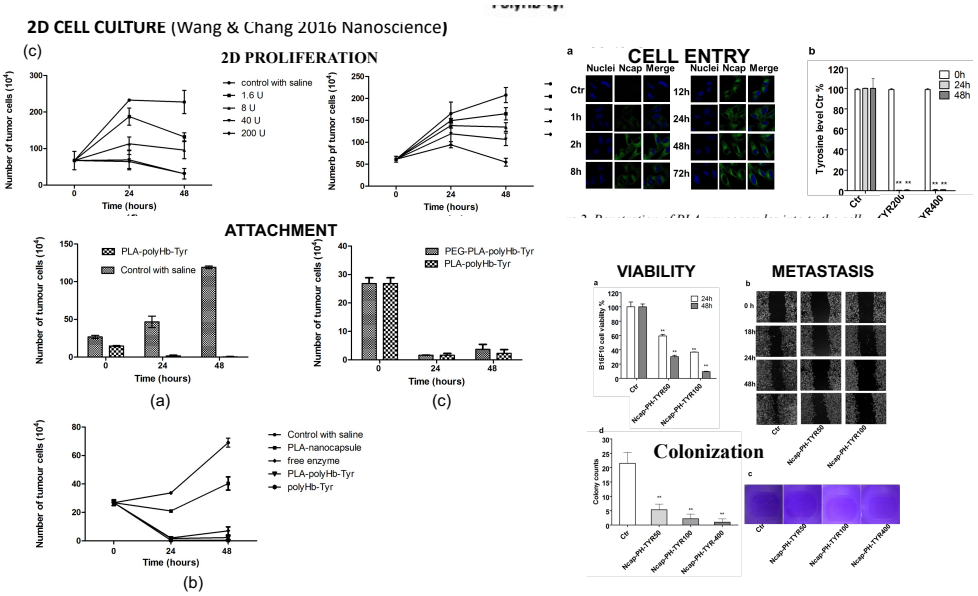
Do not require long term use
Now in clinical use by other groups as
PEG-asparaginase for acute leukemia (Wetzler et al 2007)

2. Enzyme therapy for Melanoma Based on nanobiotherapeutic artificial cells

Melanoma is a deadly skin cancer. Surgery is effective for early stages but there may be remnant cells.



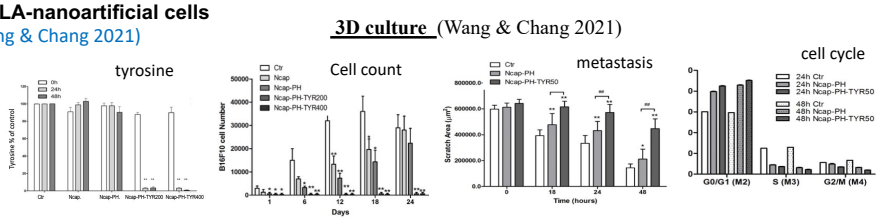
Treatments of later stages with immunotherapy and chemotherapy are very promising but are associated with severe side effects. Moreover, a dangerous type of melanoma cannot be detected early enough for surgery. There is an urgent need for treatment with less severe side effects.



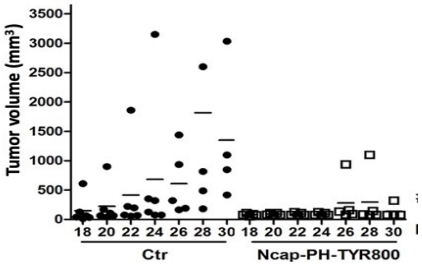
Polyhemoglobin-tyrosinase effectively lowers systemic tyrosine and delayed the growth of melanoma in mice (60). In order to suppress the growth of melanoma, we use a novel system of artificial cell polymer–lipid membrane nanocarrier containing a biomolecular nano-system of enzyme–oxygen biotherapeutic (61).We started first testing this in a 2D culture system (Fig top left) that shows its effectiveness (61)

We (Wang & Chang 2021 https://www.tandfonline.com/doi/full/10.1080/21691401.2021.1918134 show (1) its effectiveness and mechanisms in inhibiting the growth of melanoma in a 3D culture collagen medium that is more similar to that in the animal. (2) This allows us to design and carry out animal studies to successfully show that this can inhibit the growth of melanoma in an animal model. This includes following the tumour sizes and body weights every 2 days for 30 days followed by histology of the sites of injection and vital organs. We also analyze the action of the different components of the nanocarrier–nano-biotherapeutic complex. In conclusion, the results show the safety and clinical feasibility of this approach in the animal model (62)

Nanobiotherapeutic
In PLA-nanoartificial cells
(Wang & Chang 2021)



Effect on the growth of B16F10 melanoma tumor in mice
Wang & Chang (2021 JANB)



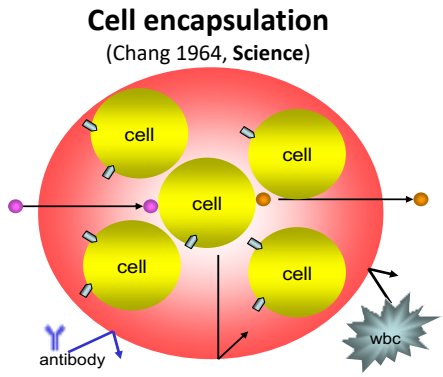
	Nodule tissue	Viable tumor % (estimate)	Necrosis % (estimate)	Hemorrhage % (estimate)	Nanoparticles visible	Granuloma reaction	Necrotic blood vessels
Ctr	Neoplastic	65	30	5	-	-	+/ -
Ncap-PH-TYR800	Granuloma	0	0	0	+	+/-	-

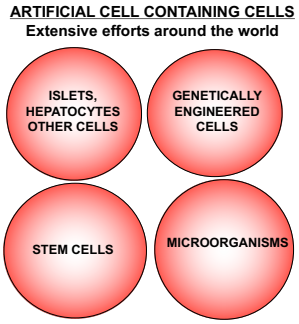
Artificial Cells Containing Biological Cells

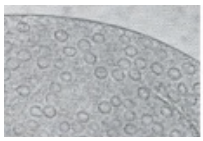
https://doi.org/10.1080/21691401.2019.1577885
www.medicine.mcgill.ca/artcell/2007%20ebook%20artcell%20web.pdf

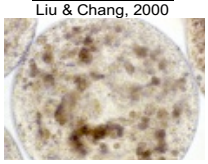
Present status

The first artificial cells containing intact biological cells were first reported by Chang in 1964 (2) using the drop method. It was proposed that “protected from immunological process, encapsulated endocrine cells might survive and maintain an effective supply of hormone” (Fig) (6).









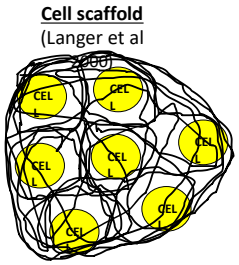
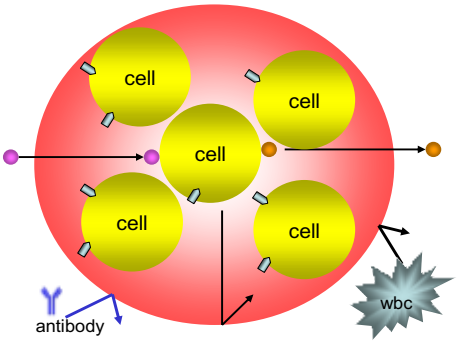


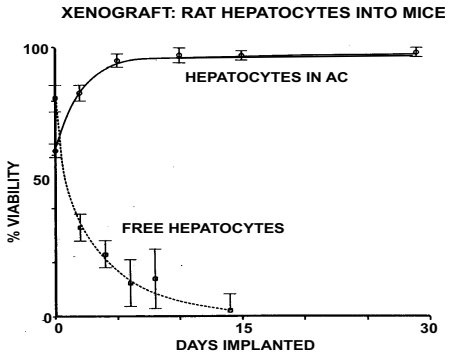
Fig.. Upper left: *Cells inside artificial cells protected from outside.*
*. **Lower**: Cells can be bioencapsulated inside artificial cell or entrapped in scaffold of fibers or nanofibers **Upper right**: Bioencapsulation of islets, cells, genetically-engineered cells.*

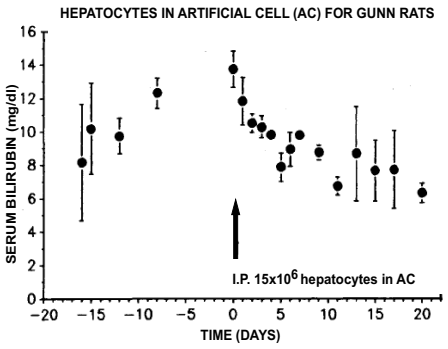
I help Conaught Laboratory to enclose islet in artificial cells for use in diabetes (64). This basic principle has been extensively developed around the world for cell therapy (8,9, 64-77). Examples include artificial cells containing endocrine tissues for instance, islets for diabetes.

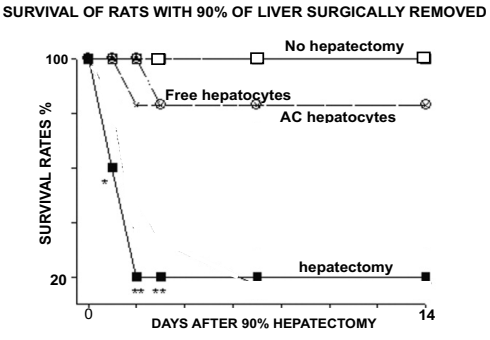
Another extensively investigated area is artificial cells containing genetically engineered cells for a number of clinical conditions. His own laboratory has investigated artificial cells containing liver cells (figure)(9, 68). result in animals have been promising. However, one implantation can only function for less than one year, and this is not practical for lon

Artificial cells containing Hepatocytes
(Chang, Wong & Chang, Bruni & Chang. Liu & Chang from Chang 2007)









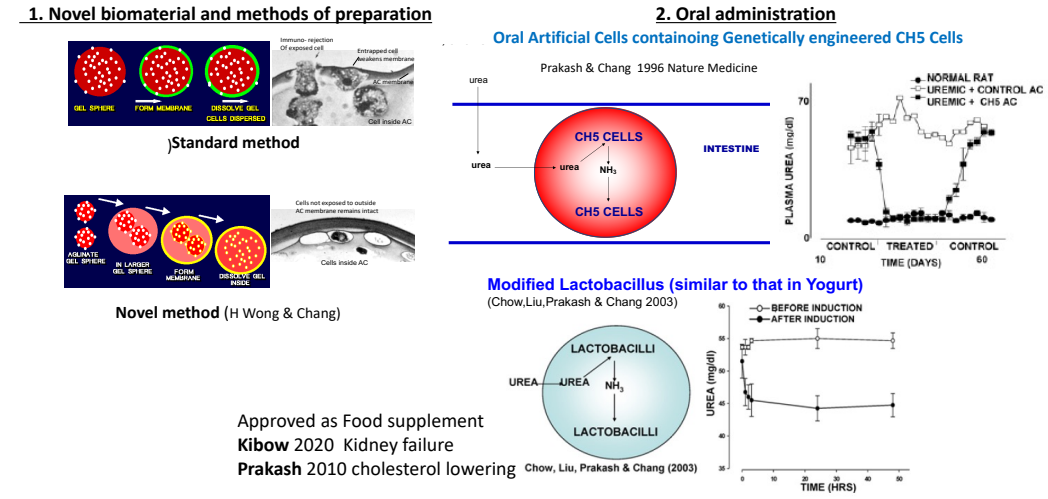
g-term illness like diabetes. Repeated injections would have retention problems.

Three ways to solve function for only one year after injection:

1. **Improve biomaterials and method** better long-term biocompatibility and improvement in the method of preparation as shown in Figure below

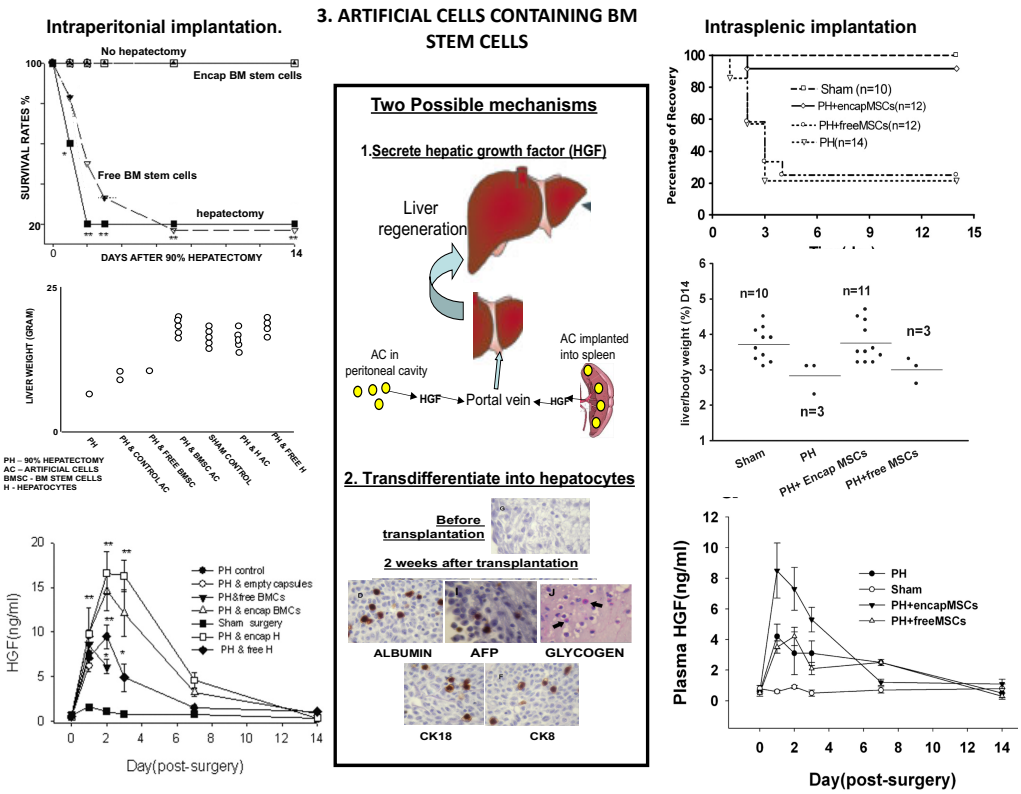
2.Oral administration of artificial cells containing microorganisms

Garofalo & Chang in 1991 show the effectiveness of artificial cells containing microorganisms for the in vitro removal of serum cholesterol (69). In 1996, Prakash and Chang (70) show that artificial cells containing genetically engineered E. coli DH5 cells given orally to kidney failure rats effectively lower the elevated blood urea level. Even though Reardon in his 2018 Nature paper (71) supports the use of genetically modified bacteria in the fight against diseases, regulatory agencies are still hesitant about the use of genetic engineered microbes. In anticipation of this **Chang asks his group in 2003 (72) to use artificial cells containing modified lactobacilli, since lactobacilli are being safely used in Yogurt. This also avoids the use of genetically engineered microbe and allows the safer use for oral administration in human**. Prakash's group has since carried out extensive research into the use of this approach for clinical use in patients (73)



3. Use in generative medicine

that only need months of function, for example the use of artificial cells containing bone marrow stem cells in liver regeneration. Liu and Chang (74,75) study this in rats using artificial cells containing bone marrow stem cells. When implanted into 90% hepatectomized rats, this increases the recovery of the rats to 100% vs 11% in the control group and 33% in the free bone marrow stem cells (Fig.). Artificial cells containing stem cell can also be implanted into the spleen to carry this function (76)



Another way not related to artificial cell is the use of biodegradable **scaffolds** started by Langer , Sefton and other groups, this is now a very popular and exciting approach. Grant's 2018 review (78) shows that this is now a very promising and active area. Biodegradable scaffolds are prepared in the shape of specific tissue or organs. The cells are seeded into the scaffold and allow to grow in the scaffold until they reach the required shape and dimension and take over the biodegraded scaffold support.*)*

TOWARDS MORE COMPLEX ARTIFICIAL CELLS

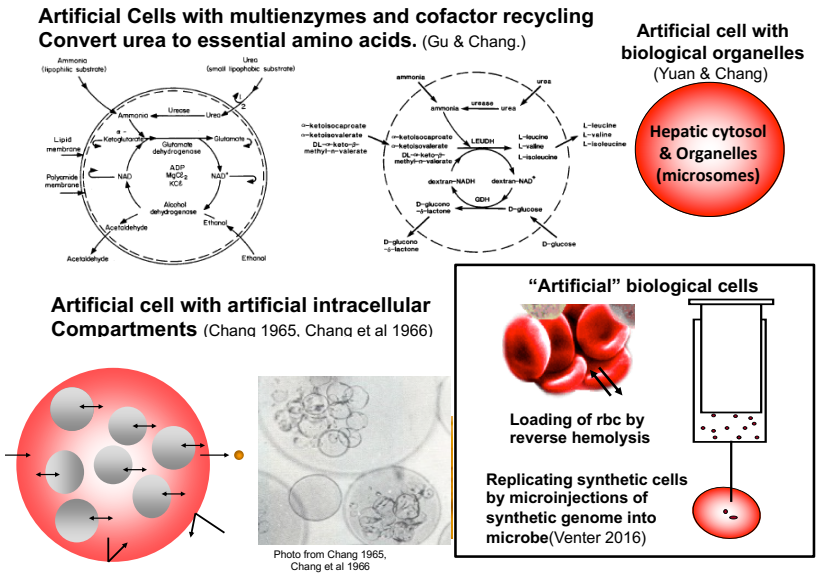


*Fig. **Upper:**. Artificial cells containing multienzyme systems with cofactor recycling can convert waste, urea, into useful essential amino acids, **Upper right:** Artificial cells that contain liver cytosol and organelles like microsomes) **Lower right:** Reverse hemolysis to load red blood cells with drugs. Microinjection to introduce synthetic DNA into microbes.*

1. Multienzyme systems with cofactor recycling

Most enzymes in the body function as multienzyme systems with cofactor recycling. Gu and Chang (79) have prepared artificial cells containing multienzyme system with cofactor recycling and show that they can be used to convert metabolic waste like urea and ammonia into essential amino acids (Fig.). The cofactor, NADH, can be retained inside the artificial cells in the form of NADH-dextran or by the use of lipid–polymer membrane. We have also included all the multienzyme system of red blood cells inside nanodimension artificial red blood cells (33).

2. Artificial Cells with Intracellular Compartments

Biological cells contain organelles that allow for more effective compartmental function. We have prepared artificial cells with intracellular compartments (6, 8,9,80) (Fig.). This can allow for more efficient stepwise enzymatic or other biological functions. This principle has been extended for possible use in therapy by Hosta-Rigau and Stadler (81).

3. Artificial cells containing microsomes, cytosol, ribosome and polymerase

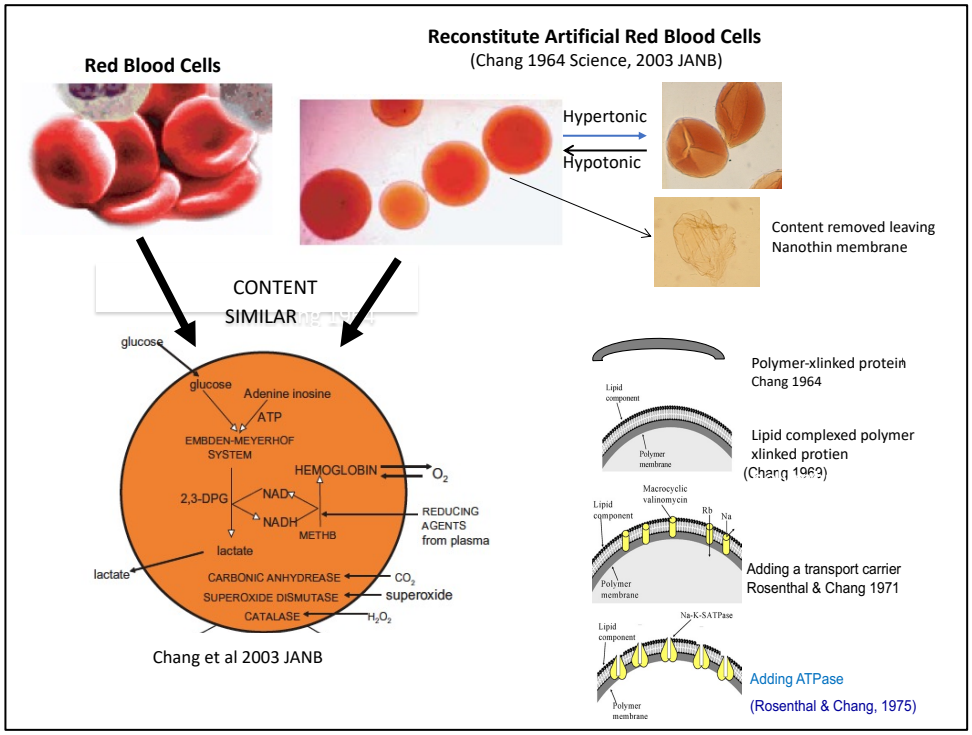
Yuan and Chang isolate microsomes and cytosol from rat liver and encapsulated into polymeric membrane artificial cells (9, 82,). 20NADPH-cytochrome C reductase and lactate dehydrogenate are used as the marker enzymes for respectively microsomes and cytosol and show retention of activities.
Monnard and Deamer (83) prepare models for primitive cellular life by encapsulating T7 RNA polymerases and templates into lipid membrane artificial cells, lipid vesicles. They can synthesize an RNA transcript from the DNA template. This is a slow process because the lipid membrane has low permeability to the needed 4 nucleoside triphosphates. Oberholzer et al encapsulate a complex polymerase system into liposomes and show that the PCR reaction could be carried out (84). The problem is again the low permeability of the lipid membrane to the needed substrates. They have also encapsulated ribosomes into liposomes and obtain some translation product. More permeable polymeric or lipid-polymer membranes may shove these permeability problems. In another study, Griffiths and Tawfik (85) use compartmentalization to load the transcription/translation system in a water-in-oil emulsion. This way each gene can occupy a separate water emulsion to carry out its function. Artificial cells containing "subcellular compartments" can be another possible way of doing this (6) Fig)

4. Synthetic genome for replicating synthetic cells

After extensive research, in 2016 Venter's group report in Science their successful preparation of a synthetic minimal bacterial genome (86). Instead of synthetic membrane, by microinjection they have ingeniously make use of the complete membrane of the microbe. By doing this, they are able to prepare replicating cells using their synthetic genome.

5.Reconstruction of complete biological cells

www.medicine.mcgill.ca/artcell/2007%20ebook%20artcell%20web.pdf



A 2018 special issue in Nature concentrates on the feasibility of constructing complete biological cells (86.87).Red blood cells are the simplest of all human cells. It is one of the most important group of cells, since without them, we cannot survive. As described above, we have already prepared complete artificial red blood cells. (Fig on left) Researchers are now interested in doing this for the more complicated types of cells as discussed by Gopfrich et al in 2018 (88)

NONMEDICAL USES OF ARTIFICIAL CELLS

There are many developments and uses of the principle of artificial cells for agriculture, bioreactors, cosmetics, food production and aquatic culture (89).
Another area is the use of artificial cells in nanorobatics and nanocomputers that in 2004 becomes the European Commission sponsored Programmable Artificial Cell Evolution (PACE) and in 2008 becomes the European Centre for Living Technology (90).

.

FUTURE OF ARTIFICIAL CELLS

The following prediction in Chang's 1972 monograph on "Artificial Cells" (6) is already out of date: *"Artificial Cell is not a specific physical entity. It is an idea involving the preparation of artificial structures of cellular dimensions for possible replacement or supplement of deficient cell functions. It is clear that different approaches can be used to demonstrate this idea*". Artificial cells have now already progressed way beyond this 1972 prediction. International efforts have led to Artificial Cell development and approval for routine clinical uses in a number of areas:

- For use in COVID_19 vaccines. Thomas Ming Swi Chang (2022) "The role of artificial cells in the fight against COVID-19: deliver vaccine, hemoperfusion removes toxic cytokines, nanobiotherapeutics lower free radicals and pCO2 and replenish blood supply" Artificial Cells, Nanomedlicine & Biotechnology). 50:1, 240-251, DOI: 10.1080/21691401.2022.2126491
- Hemoperfusion for COVID-19 cytokine storm treating poisoning, partial support of liver and renal failure, and for some immunological diseases.
- For use as first-generation blood substitute in countries with HIV contaminated donor blood.
- As a number of drug delivery systems.
- PEG-asparaginase for use in leukemia treatment.
- Recently approved as PEG-Phenylalanine ammonia lyase for the treatment of adult PKU.

Even then, we have only just touched the surface of the potential of artificial cells. One hopes that the many arbitrary subdivisions of "artificial cells" under the guise of different names can come together! When this takes place, the result of the pooling of talents, specialized know-how in this very interdisciplinary and international area will lead to progress beyond anyone's imagination [8,9,12,91].

Selected References. (Please see Publication section for my own complete list)

1. Chang, T.M.S. (1957) Hemoglobin corpuscles. Report of a research project for Honours Physiology http://www.medicine.mcgill.ca/artcell/514.pdf)., Medical Library, McGill University. (Also reprinted 1988 as part of "30th Anniversary in Artificial Red Blood Cells Research." Biomater ArtifCells Artif Organs **16**:1–9. And also in Chang, TMS (May 2007) Monograph on ARTIFICIAL CELLS: World Scientific Publisher/Imperial College Press , 435 pages. (available for free online viewing at http://www.medicine.mcgill.ca/artcell/2007 ebook artcell web.pdf)
2. Chang, T.M.S. (1964) Semipermeable microcapsules. Science **146**:524–525.
3. Chang,T.M.S., and Poznansky, M.J. (1968) Semipermeable microcapsules containing catalase for enzyme replacement in acatalsaemic mice. Nature **218**:242–245.
4. Chang, T.M.S. (1971) The in vivo effects of semipermeable microcapsules containing L-asparaginase on 6C3HED lymphosarcoma. Nature **229**:117–118.
5. Chang, T.M.S. (1966) Semipermeable aqueous microcapsules ("artificial cells"): with emphasis on experiments in an extracorporeal shunt system. Trans Am Soc Artif Intern Organs **12**:13–19.
6. Chang, T.M.S. (1972) Artificial Cells. Charles C. Thomas, Springfield, IL (out of print but available for free online viewing/download at www.artcell.mcgill.ca/1972bookcovercr.pdf
7. Chang, T.M.S. (1971) Stabilisation of enzymes by microencapsulation with a concentrated protein solution or by microencapsulation followed by cross-linking with glutaraldehyde. Biochem Biophys Res Commun **44**:1531–1536.
8. Chang, TMS (2005). Therapeutic applications of polymeric artificial cells. **Nature Review:Drug Discovery** 4:2
9. Chang, TMS (May 2007) Monograph on "ARTIFICIAL CELLS: biotechnology, nanotechnology, blood substitutes, regenerative medicine, bioencapsulation, cell/stem cell therapy" World Scientific Publisher/Imperial College Press , 435 pages. (available for free online viewing: at www.medicine.mcgill.ca/artcell/2007%20ebook%20artcell%20web.pdf
10. Abuchowski, A., Kazo, G。M。, Verhoest, C。R. Jr., et al. 1984。 Cancer therapy with chemically modified enzymes. I. Antitumor properties of polyethylene glycol-asparaginase conjugates *Cancer Biochem Biophys.***7:** 175–86..
11. Chang, Endo, Nicolaev, Tani and Zheng (editors) (2017) editors, Book on "Hemoperfusion and Plasma-perfusion and other Clinical Uses of General, Biospecific, immune and leucocyte Adsorbents" World Scientific Publisher/Imperial College Press 1004 pages www.medicine.mcgill.ca/artcell/HPBk_Ch1.pdf
12. Chang T.M.S. (2019) ARTIFICIAL CELL evolves into nanomedicine, biotherapeutics, blood substitutes, drug delivery, enzyme/gene theraphy, cancer therapy, cell/stem cell therapy, nanoparticles, liposomes, bioencapsulation, replicating synthetic cells, cell encapsulation/scaffold, biosorbent/immunosorbent haemoperfusion/plasmapheresis, regenerative medicine, encapsulated microbe, nanobiotechnology, nanotechnology, Artificial Cells, Nanomedicine, and Biotechnology, 47:1, 997-1013 https://doi.org/10.1080/21691401.2019.1577885
13. Chang, T.M.S., Coffey, J.F., Barre, P., et al. (1973) Microcapsule artificial kidney: treatment of patients with acute drug intoxication. Can Med Assoc J **108**:429–433.
14. Chang, T.M.S. (1980) Blood compatible coating of synthetic immunoadsorbents. Trans Am Soc Artif Intern Organs **26**:546–549.
15. Bensinger, W., Baker, D.A., and Buckner, C.D., et al. (1981) Immunoadsorption for removal of A and B blood-group antibodies. New Engl J Med **314**:160–162.
16. Terman, D.S., Tavel, T., Petty, D., et al. (1977) Specific removal of antibody by extracorporeal circulation over antigen immobilized in collodion charcoal. Clin Exp Immunol **28**:180
17. Hakim, R.M., Milford, E., Himmelfarb, J., et al. (1990) Extracorporeal removal of antiHLA antibodies in transplant candidates. Am J Kidney Dis **16**:423
18. Chen J, Han W, Su R, Chen J, Zong W, Wang Y & Yu Y (2017) Non-ionic macroporous polystyrene adsorbents for removal of serum toxins in liver failure by hemoperfusion. Artificial cells, nanomedicine, and biotechnology, 45(1), 174-183
19. Thomas Ming Swi Chang (2022) "The role of artificial cells in the fight against COVID-19: deliver vaccine, hemoperfusion removes toxic cytokines, nanobiotherapeutics lower free radicals and pCO2 and replenish blood supply" Artificial Cells, Nanomedlicine & Biotechnology). 50:1, 240-251, DOI: 10.1080/21691401.2022.2126491
20. Fei Zhou*, Ting Yu*, Ronghui Du*, Guohui Fan*, Ying Liu*, Zhibo Liu*, Jie Xiang*, Yeming Wang, Bin Song, Xiaoying Gu, Lulu Guan, Yuan Wei,Hui Li, Xudong Wu, Jiuyang Xu, Shengjin Tu, Yi Zhang, Hua Chen, Bin Cao (2020) Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet 2020; 395: 1054–62 Published Online March 9, 2020
21. Moore EE et al (2009) Human Polymerized Hemoglobin for the Treatment of Hemorrhagic Shock when Blood Is Unavailable: The USA Multicenter Trial. J Am Coll Surg. 208: 1-13
22. Li Wang, Fang Liu, Kunping Yan, Wencan Pan, Lijuan Xu, Huifang Liu, Chengbin Yan, Chao Chen & Hongli Zhu (2017) Effects of resuscitation with polymerized porcine hemoglobin (pPolyHb) on hemodynamic stability and oxygen delivery in a rat model of hemorrhagic shock, Artificial Cells, Nanomedicine, and Biotechnology, 45:1, 51-57
23. Chang, Bulow, Jahr, Sakai & Yang AG (editors) (2021), Nanobiotherapeutic based Blood Substitutes 1,040 pages World Scientific Publisher/Imperial College Pres9
24. Mervyn Mer, Eric Hodgson, Lee Wallis, Barry Jacobson, Lewis Levien, Jacques Snyman, Martin J. Sussman, Mike James, Antoine van Gelder, Rachel Allgaier, and Jonathan S. Jahr (2016). Hemoglobin glutamer-250 (bovine) in South Africa: consensus usage guidelines from clinician experts who have treated patients. Transfusion 56 (10,)2631–2636
25. D'Agnillo, F., and Chang, T.M.S. (1998) Polyhemoglobin-superoxide dismutasecatalase as a blood substitute with antioxidant properties. Nature Biotechnol **16**:667–671.
26. Powanda, D., and Chang, T.M.S. (2002) Cross-linked polyhemoglobin-superoxide dismutase-catalase supplies oxygen without

causing blood brain barrier disruption or brain edema in a rat model of transient global brain ischemia-reperfusion. Artif Cells Blood Substit Immobil Biotechnol **30**:25–42.
27.Ma, L and Hsia CJC, Polynitroxylated Hb As A Multifunctional Therapeutic For Critical Care And Transfusion Medicine in "Selected Topics in Nanomedicine" Editor TMS Chang, World Science Publisher/Imperial College Press, Singapore, London.2013;169-194
28.Jia YP, Alayash AI. (2013). Molecular Basis of Haptoglobin and Hemoglobin
Complex Formation and Protection against Oxidative Stress and Damage. In: Chang TMS (ed), Selected Topics in Nanomedicine, World Science Publisher/ Imperial College Press.
29.Bian Y, Chang TMS, A novel nanobiotherapeutical Poly-[hemoglobin-superoxide dismutase-catalase-carbonic anhydrase] with no cardiac toxicity for the resuscitation of a 90 minutes sustained severe hemorrhagic shock rat model with 2/3 blood volume loss Artificial Cells, Nanomedicine and Biotechnology 2015;43, 1: 1-9 http://www.medicine.mcgill.ca/artcell/2015bian&chang.pdf
30.Guo C, Gynn M, Chang, Extraction of Superoxide Dismutase, Catalase and Carbonic Anhydrase from stroma-free red blood cell hemolysate for the preparation of the nanobiotechnological complex of PolyHemoglobin-Superoxide Dismutase-Catalase-Carbonic Anhydrase, Journal Artificial Cells, Nanomedicine and Biotechnology 2015;43, 3, 157-162
31.Bian Y, Guo C, Chang TMS (2016) Temperature stability of Poly-[hemoglobin-superoxide dismutase–catalase- carbonic anhydrase] in the form of a solution or in the lyophilized form during storage at -80 °C, 4 °C, 25 °C and 37 °C or pasteurization at 70 °C. Artificial Cells, Nanomedicine and Biotechnology 2016;44,41-47
32.Guo C & Chang, TMS (2018) Long term safety and
immunological effects of a nanobiotherapeutic, bovine poly-[hemoglobin-catalase-superoxide
dismutase-carbonic anhydrase], after four weekly 5% blood volume top-loading followed by a
challenge of 30% exchange transfusion, Artificial Cells, Nanomedicine, and Biotechnology, 46:7, 1349-1363.
www.artcell.mcgill.ca/safety_immune.pdf
33.Chang, T.M.S., Powanda, D., and Yu, W.P. (2003) Analysis of polyethyleneglycolpolylactide nano-dimension artificial red blood cells in maintaining systemic hemoglobin levels and prevention of methemoglobin formation. Artif Cells Blood Substit Biotechnol **31**:231–248.
34.Sakai H. (2013) Biocompatibility of a highly concentrated fluid of hemoglobin-vesiclesas a transfusion alternative. In: Chang TMS (ed), Selected Topics in
Nanomedicine, World Science Publisher/Imperial College Press.
35.Tsuchida E, Sakai H, Horinouchi H, Kobayashi K. (2006). Artificial Cells, Blood
Substitutes and Biotechnology, an international journal 34: 581–588
36.Chang TMS (2017) Translational feasibility of soluble nanobiotherapeutics with enhanced red blood cell functions. Artificial Cells, Nanomedicine and Biotechnology 45 :671-676
37.Chang TMS. (1976) Biodegradable semipermeable microcapsules containing enzymes, hormones, vaccines, and other biologicals. J Bioengineering 1: 25–32.
38.Zhang Y, Li Y, Budak G, et al. (2013) Nanoparticles for imaging and therapy —
functionalization, endocytosis and characterization. In: Chang TMS (ed),
Selected Topics in Nanomedicine, World Science Publisher/Imperial College
Press.
39.Chandra R,Madan J, Singh P, et al. (2013) Noscapines: novel carrier systems to
target the tumour cells. In: Chang TMS (ed), Selected Topics in Nanomedicine,
World Science Publisher/Imperial College Press
40.Bowerman, C. J. et al. (2016). Docetaxel-Loaded PLGA Nanoparticles Improve Efficacy in Taxane-Resistant Triple-Negative Breast Cancer. *Nano letters*, *17*(1), 242-248.
41.Ravanshad, R. et al. (2017). Application of nanoparticles in cancer detection by Raman scattering based techniques. *Nano reviews & experiments*, *9*(1), 1373551.
42.Abu Abed I (2018) Lysozyme and DNAse I loaded poly (D, L lactide-co-caprolactone) nanocapsules as an oral delivery system Nature Scientific Reports, 03 September 2018
43.Bangham AD, et al. (1965) Diffusion of univalent ions across the lamellae of swollen
phospholipids. J Mol Biol 13: 238–252.
44.Mueller P and Rudin D) (1968) Resting and action potential in experimental bilayer lipid membranes. J Theor. Biol. 18:222
45.Gregoriadis G (ed). (1976) Drug Carriers in Biology and Medicine. Academic Press,
Inc., New York.
46.Deamer DW, Bangham AD. (1976) Large-volume liposomes by an ether vaporization
method. Biochim Biophys Acta 443: 629–634
47.Torchilin VP. (2005) Recent advances with liposomes as pharmaceutical carriers. Nat Rev Drug Discov 4: 145–160
48. CHANG TMS (1975) The one shot vaccine. in "Socio-Economic and Ethical
Implications of Enzyme Engineering" (C-G HEDEN, ed.) International Federation of
Institutes for Advanced Studies, Stockholm, Sweden, pp 17-18.
48a.Jayesh A. Kulkarni,Dominik Witzigmann , Sarah B. Thomson, Sam Chen, Blair R. Leavitt , Pieter R. Cullis and Roy van der Meel (2021) The current landscape of nucleic acid therapeutics Nature Nanotechnology 16: 630–643
48b.Anderson, E. J. et al. Safety and immunogenicity of SARS-CoV-2
mRNA-1273 vaccine in older adults. New Engl. J. Med. 383, 2427−2438
(2020).
48c.Sahin, U. et al. COVID-19 vaccine BNT162b1 elicits human antibody and
TH1 T-cell responses. Nature 586, 594−599 (2020).
49.Karkan S, Mohammadhosseini M, Panahi Y,Milani M, Zarghami N, I Akbarzadeh A, Abasi E, Hosseini A & Davaran S (2016) Magnetic nanoparticles in cancer diagnosis and treatment: a review, Artificial Cells, Nanomedicine, and Biotechnology, 45:1, 1-5
50.Hu et al (2018) Small-scale soft-bodied robot with multimodal locomotion, Nature, Volume 554, February
51.Poznansky, M.J., and Chang, T.M.S. (1974) Comparison of the enzyme kinetics and
immunological properties of catalase immobilized by microencapsulation and
catalase in free solution for enzyme replacement. Biochim Biophys Acta **334**:103–
115.
52.Kjellstrand, C., Borges, H., Pru, C., Gardner, D., Fink, D. 1981。On the clinical use of microencapsulated zirconium phosphate-urease for the treatment of chronic uremia. *Trans. Am. Soc. Artif. Intern. Org*; **27**:24-30

54.Wetzler M, Sanford BL, Kurtzberg J, et al. (2007) Effective Asparagine Depletion with Pegylated. Asparaginase Results in Improved Outcomes in Adult AcuteLymphoblastic Leukemia: Cancer and Leukemia Group B Study 9511. Blood109.10: 4164–4167.
55.Palmour, R.M., Goodyer, P., Reade, T., and Chang, T.M.S. (1989) Microencapsulated xanthine oxidase as experimental therapy in Lesch-Nyhan disease. Lancet **2**:687-688.
56.CHANG TMS, CW LISTER (1988/1989) Plasma/Intestinal concentration patterns suggestive of entero- portal recirculation of amino acids: Effects of oral administration of asparaginase, glutaminase and tyrosinase immobilized by microencapsulation in Art
57.Bourget, L., and Chang, T.M.S. (1986) Phenylalanine ammonia-lyase immobilized in microcapsules for the depleture of phenylalanine in plasma in phenylketonuric rat model. Biochim Biophys Acta **883**:432–438.
58.(FDA), U.S.F.D.A., *FDA approves a new treatment for PKU, a rare and serious genetic disease.* 2018.
59. Karlie C. Mahan, Mona A. Gandhi & Sridhar Anand (2019) Pegvaliase: a novel treatment option for adults with phenylketonuria, Current Medical Research and Opinion, 35:4, 647-651, DOI: 10.1080/03007995.2018.1528215
60.Yu, B.L., and Chang, T.M.S. (2004) In vitro and in vivo effects of poly Hemoglobin-tyrosinase on murine B16F10 melanoma. Melanoma Res J **14**:197–202.
61.Wang Y & TMS Chang (2016) Biodegradable Nanocapsules Containing A Nanobiotechnological Complex for the In-vitro Suppression of A Melanoma Cell Line B16F10 Journal of Nanosciences: Current Research 1:1-6 www.medicine.mcgill.ca/artcell/2016 Wang & Chang.pdf
62.Wang & Chang(2021) A polymer–lipid membrane artificial cell nanocarrier containing enzyme–oxygen biotherapeutic inhibits the growth of B16F10 melanoma in 3D culture and in a mouse model**.** Artificial Cells, Nanomedicine & Biotechnology.49: 461-470 https://www.tandfonline.com/doi/full/10.1080/21691401.2021.1918134
63.Kaminsky YG, Kosenko EA. (2012) Argocytes Containing Enzyme Nanoparticles. Reduce Toxic Concentrations of Arginine in the Blood. Bulletin of Experimental Biology and Medicine, 1–3
64.Lim, F., and Sun, A.M. (1980) Microencapsulated islets as bioartificial endocrine pancreas. Science **210**:908–909.
65.Wong, H., and Chang, T.M.S. (1986) Bioartificial liver: implanted artificial cells microencapsulated living hepatocytes increases survival of liver failure rats. Int J Artif Organs **9**:335–336.
66.Hunkeler, Dl. (2003) Bioartificial organ grafts: a view at the beginning of the third millennium. Artif Cells Blood Substit Immobil Biotechnol **31**:365–382.
67.Rokstad, A., Lacík, I., de Vos, P. and Strand, B. (2014). Advances in biocompatibility and physico-chemical characterization of microspheres for cell encapsulation. Advanced Drug Delivery Reviews, 67-68, pp.111-130
68.Wong, H. and T.M. Chang (1991) A novel two step procedure for immobilizing living cells in microcapsules for improving xenograft survival. Biomater Artif Cells Immobilization Biotechnol, 1991. 19(4): p. 687-97.
69.Garofalo & Chang (1991) Effects of mass transfer and reaction kinetics on serum cholesterol depletion rates of free and immobilized Pseudomonas-pictorum Applied Biochemistry and Biotechnology 27:75-91
70.Prakash, S., and Chang, T.M.S. (1996) Microencapsulated genetically engineered live E. coli DH5 cells administered orally to maintain normal plasma urea level in uremic rats. Nature Med **2**:883–887.
71.Reardon, S. (2018) *Genetically modified bacteria enlisted in fight against disease.* Nature, 2018. **558**(7711): p. 497-498.
72.Chow,KM, Liu ZC, Prakash S and Chang TMS (2003) Free and microencapsulated Lactobacillus and effects of metabolic induction on Urea Removal Artificial Cells, Blood Substitutes & Biotechnology. 4: 425-434
73.Iqbal, U., Westfall, S. and Prakash, S. (2018). Novel microencapsulated probiotic blend for use in metabolic syndrome: design and in-vivo analysis. Artificial Cells, Nanomedicine and Biotechnology, pp.1-9.
74.Liu, ZC, TMS Chang (2006) Transdifferentiation of bioencapsulated bone marrow cells into hepatocyte-like cells in the 90% hepatectomized rat model. **Journal of Liver Transplantation** 12: 566-572, 2006.
75.Liu ZC & TMS Chang (2010) Artificial Cell microencapsulated stem cells in regenerative medicine, tissue engineering and cell therapy **Advances in Experimental Medicine and Biology. 670:**68-79.
76. Liu, ZC and TMS Chang (2012) Intrasplenic transplantation of bioencapsulated mesenchymal stem cells enhances the regeneration of remnant livers and improves the recovery rates of 90% partial hepatectomized rats" Stem Cells International Volume 2012 (2012), Article ID 697094, 6 pagesdoi:10.1155/2012/697094 PMC3515999 http://www.hindawi.com/journals/sci/2012/697094/
77.W. Song, Y.-C. Lu, A. S. Frankel, D. An, R. E. Schwartz, and M. Ma (2015) "Engraftment of human induced pluripotent stem cell-derived hepatocytes in immunocompetent mice via 3D co-aggregation and encapsulation," Scientific Reports, vol. 5, p. 16884, Nov. 2015
78.R. Grant, D. Hay, and A. Callanan (2018)"From scaffold to structure: the synthetic production of cell derived extracellular matrix for liver tissue engineering," Biomedical Physics & Engineering Express, vol. 4, no. 6, p. 065015, Oct. 2018.
79.Gu, K.F., and Chang, T.M.S. (1990) Production of essential L-branched-chained amino acids, in bioreactors containing artificial cells immobilized multienzyme systems and dextran-NAD+. Appl Biochem Biotechnol **26**:263–269.
80.Chang, T.M.S., Macintosh, F.C., and Mason, S.G. (1966) Semipermeable aqueous microcapsules: I. Preparation and properties. Can J Physiol Pharmacol **44**: 115–128
81.Hosta-Rigau L, Stadler B. (2013) Subcompartmetalized systems toward therapeutic cell mimics. In: Chang TMS (ed), Selected Topics in Nanomedicine, World Science Publisher/Imperial College Press

82.Yuan, Z.Y., Chang, T.M.S., (1986) Rat microsomes and cytosol immobilized by microencapsulation in artificial cells. Int J Artif Organs 9(1):63-68, 1986.
83.Monnard, P.A., and Deamer, D.W. (2001) Nutrient uptake by protocells: a liposome model system. Orig Life Evol Blosph 31:147–155.
84.Oberholzer,T. et al. (1995) Polymerase chain reaction in liposomes. Chem Biol 2:677–682
85.Griffiths, A.D., and Tawfik, D.S. (2000) Man-made enzymes—from design to in vitro compartmentalization. Curr Opin Biotechnol 11:338–353.
86.Hutchison CA, Chuang RY, Noskov VN, Assad-Garcia N, Deerinck TJ, Ellisman MH, Gill J, Kannan K, Karas BJ, Ma L, Pelletier JF, Qi ZQ, Richter RA, Strychalski EA, Sun L, Suzuki Y, Tsvetanova B, Wise KS, Smith HO, Glass JI, Merryman C, Gibson DG, Venter JC (2016)
Design and synthesis of a minimal bacterial genome.Science 2016-03-25; 351.6280: aad6253.PMID: 27013737
86.Editorial (2018): Focus on the benefits of building life's systems from scratch. Nature 563, 155 (2018)
doi: https://doi.org/10.1038/d41586-018-07285-1
87.Dan Fletcher (2018) Which biological systems should be engineered?. 8 NOVEMBER 2018 | VOL 563 | NATURE | 177
88.Göpfrich, K., I. Platzman, and J.P. Spatz (2018), *Mastering Complexity: Towards Bottom-up Construction of Multifunctional Eukaryotic Synthetic Cells.* Trends in Biotechnology, 2018. **36**(9): p. 938-951.
89.Poncelet D, Neufeld R. (2012). 20th Bioencapsulation Conference
90.Bedau MA, McCaskill JS, Packard NH, Rasmussen S. (2010) Living technology: exploiting life's principles in technology. Artificial Life 16: 89–97. doi:10.1162/artl.2009.16.1.16103
91.Chang, TMS (2022) Artificial Cells, Blood Substitutes and Nanomedicine website containing reviews and monographs for free online viewing or download www.artcell.mcgill.ca

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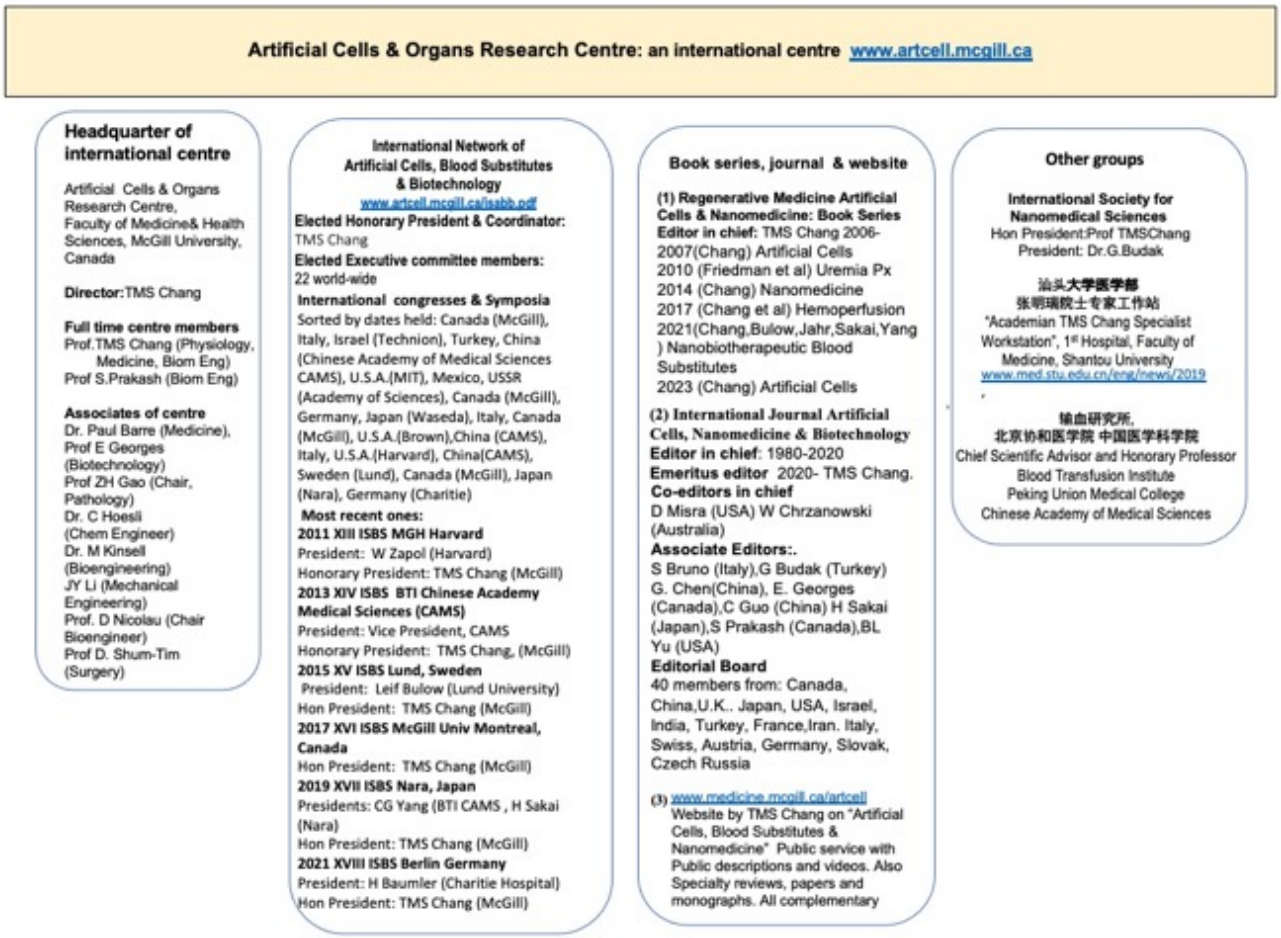
ORGNAIZATION OF INTERNATIONAL CENTRE

Artificial cell was invented at McGill by Chang (Chang McGill 1957, Science 1964). Right from the beginningI realizes that this is such a large area that it will not be possible or ethical for one laboratory, one center, one university or even one country to do everything. As a physician researcher with the aim to do what is best for the patients, my plan has been to continue to do frontier innovative research of the future and at the same time to encourage others around the world to develop his ideas for patient use. This is by publishing all the reproducible details and methods; by encouraging and helping others to do this research; by sending researchers to help others to start research in this area; by organizing international network, international meetings, international journals, books and a public service website containing complementary papers, books and videos for free access by all www.artcell.mcgill.ca

ORGANIZATION CHART FOR THIS INTERNATIONAL EFFORT



1. AT McGILL

Placed our emphasis on innovative ideas that depends on original ideas of individuals rather than extensive staff or facilities. This way, we have been more than competitive with the much larger international centers. Most of the original ideas in this area come from the director's laboratory.

Associate members from McGill:

They come from departments of Physiology, Biomedical Engineering, Experimental Medicine, Medicine and Surgery. Others come from the departments of Bioengineering , Chemical Engineering and Mechanical Engineering and also McGill's Biotechnology program .

Collaborate with other universities:

The director holds a number of non-salary voluntary positions as honorary professor of Nankai University, China; Honorary Professor of Peking Union Medical College of the Chinese Academy of Medical Sciences (CAMS), Honorary Professor and key consultant of the Blood Transfusion Institute of the Chinese Academy Medical Sciences; and honorary professor of the Shantou University Medical College in his hometown. In 2019 his hometown Shantou university formed the "Father of Artificial Cells: Chang Ming Swi Academia Specialist Research Station" for their newly built Clinical Research Centre building.

Some examples of Chang helping other groups:

- Way back in 1964, the late Harvard Professor Folkman of angiogenesis fame phoned me for the detail procedure of my 1964 Science paper for his PhD student, the now well-known Professor Robert Langer of MIT. For many years Langer has interacted with me in organizing meetings and was a member of editorial board of our journal
- Connaught Laboratory: I helped the director of Connaught start a research project on artificial cells containing islet. His research associate there, Professor A Sun did some excellent research.
- The late Professor Sam Sideman, Chair of Biomedical Engineering, Israel Institute of Technology, Technion, has collaborated in hemoperfusion and blood substitutes and coeditor with me 2 books.
- Help Professor Neufeld of McGill's Chemical Engineering and his postdoc Dr Poncelet start their research in this area. Prof Neufeld later become Chairman of Chemical Engineering at Queens and works full time in this area. They have organized annual meetings on Bioencapsulation, especially in Europe.
- Help Professor Mason of Chemistry at McGill and his postdoc Dr Kondo start a program on AC
- Help a Professor in Polymer chemistry at McGill to start research on AC
- Help Professor Charles Scriver at McGill to start a research project on the use of AC for PKU

- Help Dr Paul Barre establish the Hemoperfusion procedure in McGill teaching hospital. He becomes the director of dialysis at McGill
- Professor C Yang, has collaborated in blood substitutes for many years – was director and now emeritus director of the Blood Transfusion Institute of Peking Union Medical College and Chinese Academy of Medical Sciences
- In 1968, Muller and Rudin reported that they used the method from Chang Science 1964, to prepare lipid membrane artificial cells. I "brain washed" a McGill Biochemistry PhD graduate, Gregoriadis, to study lipid membrane artificial cell for drug delivery for his postdoc in England with Bangham using their onion like multilaminar lipid microspheres. This has resulted in liposomes now used commonly for drug delivery.
- D'Agnillo, (PhD with me in Physiology) to help Dr Alayash head of division of FDA/NIH to start a research program on blood substitutes. (He is now a senior staff there)
- BL Yu (PhD with me in Biomed Eng) to help the late Dr. Zapol, Chief Anesthesiology, MGH Harvard start a research program on blood substitute (She is now an assistant Professor there)
- Keipert (PhD with me in Physiology) to help start the blood substitute program for the late Professor Winslow at Letterman Institute and UC San Diego, he then become VP of Winslow's company on blood substitutes
- Prakash (PhD with me in Physiology) now professor at McGill Biomedical Engineering with his companies.
- Poznanski (My first PhD graduate, Physiology) is director emeritus of Robert Research Institute.
- Chawla, Daka & Ning join as staff at Health Canada Regulatory division.
- Piskins both return to Turkey as professors.
- YT Yu helps to start a successful hemoperfusion company in China.
- KF Gu (PhD with me Chemical Enginering) helps Montreal IBEX Co on recombinant enzyme production.
- The late Vivek Dixit (PhD with me in Physiology) professor and head of the artificial liver unit at UCLA
- Wang (PhD with me in Expt Med) now associate Professor and director of a program at the 3rd affiliated hospital of Beijing University Medical School.
- Bian (PhD with me in Biomedical Engineering and coinventor with me), is now senior administrator of the 3rd Generation Blood Substitute Co, Proheme in China. CHEN Gang (postdoc with me) is their manager. Jing (PhD with me in Physiology) is their representative in Canada. Guo (PhD with me in Expt Medicine) and Gu (PhD with me in Chemical Engineering) are their consultants.
- others include those from Saudi Arabia, Israel (Technion & Wiseman Institute), Japan (Tabata) and others.

2. INTERNATIONAL NETWORK FOR ARTIFICIAL CELLS, BLOOD SUBSTITUTES & BIOTECHNOLOGY (ISABB)

www.artcell.mcgill.ca/isabi.htm

Aims

This international network was formed in 1976 to encourage research, development and clinical applications in artificial cells, blood substitutes, nanomedicine, regenerative medicine, tissue engineering, cell/stem cell therapy, immunotherapy, hemoperfusion, bioencapsulation, and related areas.

We have avoided a tight and restrictive organizational structure. Instead responsibilities are widely distributed to committees and organizers of congresses and symposia. This allows this society to benefit from fresh ideas and novel approaches and to move with the frontier of research. This, plus the enthusiastic participation and voluntary contribution of members of the society, has allowed us to continue this international network for more than 40 years without charging membership fees – this allows for world-wide participation with no restrictions related to nationality, age, experience, financial status. This also avoid any one group or groups from controlling the network or preventing it from moving in the frontier of research.

Officers

Elected Honorary President & coordinator : T.M.S.Chang (McGill, Canada)

Elected executive committee (Elected Past-Presidents of ISABI congresses and/or symposia): V.Bonamini (Italy)1978; L.Bulow (Sweden), 2015; C.U.Casciani(Italy)1990; T.M.S.Chang(Canada)1976, 1987,1991,1996, 2017 ; K. Kobayashi (Japan) 2003; R.Langer (USA) 1994; Qin Liu (China) 2007; A. Mozzarelli (Italy) 2009;. Nikolaev(USSR) 1986; E.Piskin (Turkey)1982,2001; H. Sakai (Japan) 2019, A.Trevino Becerra(Mexico)1985, C.M.Yang(China), 1997, 2019;: Zheng/Yang/Liu (China) 2013[Late Prof D. Falkenhagen (Austria); Late Prof. AG.Greenburg (USA) ;Late Prof M.Odaka (Japan); Late Prof S.Sideman(Israel); Late Prof E.Tsuchida (Japan); Late Prof R.Winslow (USA)]: Late Professor Y.T.Yu(China); Late Prof WM Zapol (USA) 2011

Subcommittee of ISABB: International Committee on Blood Substitutes:ISBS

Elected executive board members ISBS (past elected ISBS presidents or their representatives):

1987: Chang (1987, 1991,1996)
1993: Keipert (for late Winslow 1993, 1999)
1997: Yang/Yu YT (1997)
1997: Sakai (for late Tsuchida 1997)
2003: Kobayashi (2003)
2005: Greenberg (2005)
2007: Liu/Xiu (2007)
2009: Mozzarelli (2009)
2011: Zapol (2011)
2013: Zheng/Liu/Yang (2013)
2015: Leif Bülow (2015)
2017: Chang (2017)
2019: CM Yang, H Sakai (2017)
2023: Leif Bulow (2023)

Scientific Advisory Board ISBS

Alayash A, Abuchowski A. H Beumler, Bian Y,Biro B, Bucci E, Bülow L, Burhop K, Chan G, Chang TMS, Chen C, Cooper C, D'Agnillo F, Estep T, Feola M, Gould S, Han JQ, Hong Z, Intaglietta M, Jahr S, Keipert P,Kim HW, Kluger R, Kobayashi K, Krafft MP, Liu Q, Liu JX, Ma L, Meßmer K, Mozzarelli A, Palmer A, Privalle C, Pugach I, Rausch C, Riess JG, Sakai H, Simoni, Selivanov E, Su ZG, Tsai AG, Wei G, Wong B, Wong JT, Xiu RJ, Yang CM, Yu BL, Zafiris G , Zal . Zapol W, ZhangY, Zhao L, Zhu YJW

Conferences

The emphasis is to concentrate on 1 or 2 areas that need extensive effort towards routine clinical uses. Once the area is in routine clinical use, the area is left to other groups to look after and we then concentrate on another 1 to 2 areas that needs major effort. Each congress or symposium president in consultation with his local organizing committee, makes the final decision and has the final responsibilities including financial responsibilities. After each congress or symposium, the president or appointed representative becomes a member of the executive committee of the ISABI.

1976 ISABI (I HPS) President: TMS Chang (McGill, Canada)
1978 ISABI (II HPS) President: V Bonamini (Bologna U, Italy) co-chair TMS Chang (McGill Canada)
1980 ISABI (III HPS) President: S. Sideman (Technion, Israel) co-chair TMS Chang (McGill Canada)
1982 ISABI (IV HPS) President: E. Piskin (Ankara U, Turkey) Honorary President: TMS Chang(Canada)
1983 ISABI (V HPS) President: C Z Huang (President, Chinese Academy of Medical Sciences), co-chair TMS Chang (McGill Canada)
1985 ISABI (VI HPS) President: A. Trevino Becerra (Mexico). Honorary President: TMS Chang (Canada) VII 1986 ISABI (VII HPS) President: V.Nikolaev(USSR Academy of Sci), Honorary President: TMS Chang VIII 1987 ISABI (III ISBS) President: TMS Chang (McGill, Canada), Cochair: R.Geyer (Harvard) 1987
1988 ISABI (VIII HPS) President: D.Falkenhagen & Klinkmann(Germany) Honorary President:TMS Chang
1989 ISABI (VIV HPS) President: M.Odaka(Chiba U, Japan), Honorary President: TMS Chang
1990 ISABI (X HPS): President: C.U.Casciani(Rome U, Italy), Cochiar: G Splendiani (Rome U, Italy) Honorary President TMS Chang (McGill, Canada)
1991 ISABI (IV ISBS) President: T.M.S.Chang(McGill, Canada) Cochair R.Geyer (Harvard, USA)
1993 ISABI (V ISBS) President: R.Winslow(Letterman, USA) Cochairs: TMS Chang (McGill, Canada) & R.Riess (France), 1993
1994 ISABI Congress President: R. Langer (MIT, U.S.A.), Honorary president: TMS Chag (McGill)
1996 ISABI (VI ISBS) President: TMS Chang (McGill, Canada) Cochairs: A.G.Greenberg (Brown U, U.S.A) & E.Tsuchica (Waseda U, Japan)
1997 ISABI Congress President: Denian Ba (President,Academy of Med Sci, China) & C.M. Yang (CAMS, China), Honorary President TMS Chang (McGill, Canada)
1997 ISABI (VII ISBS) President: E.Tsuchida (Waseda U, Japan) Cochairs: S.Sekiguchi (Red Cross, Japan) & TMS Chang (McGill, Canada)
1999 ISABI (VIII ISBS) President: R.Winslow (UC at San Diego, U.S.A.) Cochairs: TMS Chang (McGill, Canada), M.Intaglietta(UC at San Diego, U.S.A.) & E.Tsuchida (Waseda U, Japan)
2001 ISABI Congress President: E. Piskin (Ankara U, Turkey) Honorary President: TMSChang (McGill)
2003 ISABI (IX ISBS) President: K. Kobayashi (Keio U, Japan), Cochair: E.Tsuchida (Waseda U, Japan), Honorary President: TMS Chang (McGill, Canada)
2005 ISABI (X ISBS) President: G. Greenberg (Brown U, U.S.A.) HonoraryPresident: TMS Chang
2007 ISABI (XI ISBS) President: Q. Liu (Vice-president, Chineswe Academyof Medical Sci., China) Executive President: R Xiu (Academy of Medical Sci, China), Honorary President: TMS Chang (McGill)

2009 ISABI (XII ISBS) President: A. Mozzarelli (University of Parma, Italy), Vice Presidents Professor Enrico Bucci (University of Maryland) and Professor Clara Fronticelli (Johns Hopkins University, U.S.A.), Honorary President: Professor TMS Chang (McGill University, Canada)
2011 ISABI (XIII ISBS) President: Professor W Zapol (Harvard Medical School, U.S.A.) Honorary President: Professor TMS Chang (McGill University, Canada)
2013 ISABI (XIV ISBS) President: Professor Zheng (BTI China), Vice presidents Professor Liu (BTI China) & Professor Yang (BIT China), Honorary President, Professor Chang (McGill, Canada)
2015 ISABI (XV ISBS) President: Professor L Bulow (Lund, Sweden), Honorary President, Prof TMS Chang
2017 ISABI Congress (XVI ISBS, V ISNS) Professor TMS Chang, 60th anniversary Conference on Artificial Cells in conjunction with XVI ISBS and V ISNS (McGill, Canada)
2019 ISABI (XV ISBS) China/Japan: Presidents Prof CM Yang/Prof H Sakai; Hon President: TMS Chang
2022(cancelled because of pandemic) ISABI (XVI ISBS) Berlin, Germany President:Prof H Beumler, Hon President Prof TMS Chang
2023 ISABI (XVI ISBS) President:Prof Leif Bulow, Lund. Sweden Honorary President:TMS Chang
2024 ISABI (XV ISBS) Presidents: Prof Jahr, Prof Doctor, U.S.A, Hon President TMS Chang

ARTIFICIAL CELLS, NANOMEDICINE AND BIOTECHNOLOGY, an international journal (IF 6.355 2021) Publisher: Frances & Taylor,

This is a peer review journal that is the oldest journal in the field having started in 1972 "Biomaterial, Medical Devices & Artificial Organs, an international journal".
1979: Chang became the editor in chief and allows the name of the journal to change with time to reflect the frontier of research in the area. Before 2003 this journal was "Artificial Cells, Blood Substitutes and Immobilization Biotechnology").
2003: Starting in 2003 it was "Artificial Cells Blood Substitutes and Biotechnology.
2012 it became Artificial Cells, Nanomedicine and Biotechnology. Its demand is such that in 2016 the publisher has increased the issues from 6/year to 8/year with corresponding increase in the total pages. In 2019 the submission increased to 2,400 that required too much time for the editor in chief. He thus becomes emeritus editor to be free from day-to-day functions and looking after major matters.
Editor in chief 1980-2020 Emeritus Editor 2020- TMS Chang (McGill, Canada);
2020- Two coeditors in chief and 1 review editor

BOOK SERIES ON REGENERATIVE MEDICINE, ARTIFICIAL CELLS AND NANOMEDICINE http://www.medicine.mcgill.ca/artcell/1%20book%20series.pdf

(World Science Publisher/Imperial College Press)
Editor in chief: TMS Chang (McGill,Canada)
Volume 1: Monograph “ARTIFICIAL CELLS: Biotechnology, Nanomedicine, Regenerative Medicine, Blood Substitutes, Bioencapsulation and Cell-Stem Cell Therapy” Chang 2007 454 pages with full text now available free on http://www.medicine.mcgill.ca/artcell/2007%20ebook%20artcell%20web.pdf
Volume 2: Present and future Therapies for End-Stage Renal Failure. Editors: Eli Friedman & MC Mallappallil (2010)
Volume 3: Selected Topics in Nanomedicine. Editor: TMS Chang (2013)
Volume 4: Hemoperfusion and plasma-perfusion: general, selective, immune and leucocyte adsorbents. Editors: TMS Chang, Y Endo, VG Nikolaev, T Tani, YT Yu and WH Zheng (2017)
Volume 5: Nanobiotherapeutic Blood Substitutes: Editor in chief: TMS Chang, Co-editors: Bulow, Jahr , Sakai and Yang 2021
Volume 6: TMS Chang: 3rd edition of Monograph “ARTIFICIAL CELLS” Chang for 2023:

WEBSITE

The Web Site of this international network: www.medicine.mcgill.ca/artcell or www.artcell.mcgill.ca or www.artificialcell.info or www.artificialcell.org

KEY OFFICIAL POSITIONS

- Honorary President, International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology (1991- ongoing).
- Honorary President, International Society of Nanomedical Sciences (2012-ongoing)

- President (1994-1996), President-elect (1992-1994), Immediate-past president (1996-98) International Society for Artificial Organs.
- Honorary member, International Society for Microencapsulation, (1995-ongoing).
- Senior Member, Society of Biomedical Engineering, since 1989.
- Honorary presidents, Chairman and co-chairman of International Symposia on Hemoperfusion, Sorbent and Immobilized Bioreactants. I (Montreal), II(Italy), III(Israel), IV(Turkey), V(PR China), VI (Mexico), VII (USSR), VIII(Germany), IX (Japan), X (Italy),
- Congress President, 7th World Congress, International Society for Artificial Organs and 4th International Symposium on Blood Substitutes, Montreal, 1991.
- Honorary Congress President, XI Congress, International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology, organized by MIT with Professor R. Langeras Congress President, Boston, 1994.
- Honorary Congress President, XII Congress, International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology, Congress president: President of the Chinese Academy of Medical Sciences & Peking Union Medical College; Congress co-president: is President of the Chinese Red Cross Society, Beijing, 1997.
- Chairmen of III(87,Montreal), IV(91,Montreal), VI (96,Montreal) and Co-Chairman of V(93,San Diego, USA), VII(97,Toyko,). VIII (99, San Diego) International Symposia on Blood Substitutes.
- Honorary President, 2003 IX International Symposium on Blood Substitutes, Tokyo, Japan 2003
- Honorary President 2005 X International Symposium on Blood Substitutes, Brown University, Providence, U.S.A.
- Honorary President, 2007 XI International Symposium on Blood Substitutes, Beijing, China 2007 organized by the Chinese Academy of Medical Sciences and Union Medical College. The symposium chairman was Professor Liu Qin vice-president of the Chinese Academy of Medical Sciences and President of the Union medical College Hospital – now vice premier of Health of China.
- Honorary President, 2009 XII International Symposium on Blood Substitutes, Parma, Italy. Symposium president was Professor Mazarrilli of University of Parma, Parma, Italy.
- Honorary President, 2011 XIII International Symposium on Blood Substitutes, Harvard Medical School, Boston, U.S.A. The symposium chairman was Professor Zapol, Professor and Chief of Anesthesia and Critical Care Medicine, Mass General Hospital, Harvard Medical School. http://www.medicine.mcgill.ca/artcell/536.pdf
- Honorary President, 2012 III Congress of the International Academy of Nanomedicine, Ankara, Turkey
- Honorary President. 2013 XIV International Symposium on Blood Substitutes, Institute of Blood Transfusion, Chinese Academy of Medical School, President was the Director of the Institute.
- Honorary President. 2015 XV International Symposium on Blood Substitutes, President will be Professor Leif Bulow, University of Lund, Lund, Sweden
- Honorary President 2015 IV ISNS World Nanomedicine Congress, Turkey.
- Honorary President 2017 V ISNS World Nanomedicine Congress, Montreal
- Honorary President. 2017 XV International Symposium on Blood Substitutes, Montreal
- Honorary President 2018 V ISNS World Nanomedicine Congress, Delhi, India
- Honorary President. 2019 XV International Symposium on Blood Substitutes, Nara, Japan
- Honorary President. 2023 XVI International Symposium on Blood Substitutes, Lund, Sweden
- Honorary President, 2014 XVII International Symposium on Blood Substitutes, U.S.A.

EDITORIAL BOARDS:

Editor-in-Chief (1986 - 2020), **Emeritus Editor** (2020-) Artificial Cells, Nanomedicine and Biotechnology, An International Journal, Informa Publisher now Tayor & Francis, UK.
(In 1986 invited to take over and modernize and reorganize the oldest journal in the field originally "Biomaterials, Medical Devices and Artificial Organs", an International Journal. In order to keep

updated with the rapid progress in this area it has evolves into Artificial Cells, Blood Substitutes and Biotechnology, An International Journal and then its present name starting in 2013. Submissions increased from 300-400 to 1300 in 2018 and > 2400 for 2019. Despite high rejection rate, annual issues increased from 4 issues in 2015 to 6 issues in 2016 and 8 issues in 2017 and 8 issues with 3 supplementary issues in 2018. As a result, starting in 2019 it has become an Open Access journal in order to accommodate the increasing number of papers. 2019 Reuter Impact Factor: 4.462. With an increase in submissions >2,400 in 2019, It became more than a full-time position. With his many other research related responsibilities, Chang resigned but was asked to continue as emeritus editor in May 2020.

tor in chief (2023-): International Journal of Cell/tissue engineering. Artificial cells & Regenerative
dicine
2023, World Science Publisher (Official publisher of all the Nobel Prize Lectures since the
ginning) started this new journal with hybrid Open Access so authors can decide whether they want
ay a fee for their papers to be open access. They invited me to be editor in chief of this new journal
ccepted this because it is important not to restrict those who cannot afford the high open access
). I am already the editor in chief for their book series on REGENERATIVE MEDICINE, ARTIFICIAL
LLS AND NANOMEDICINE since 2006 and know them well

Editor-in-chief of a book series on "Regenerative Medicine, Artificial Cells and Nanomedicine", World Scientific Publisher/Imperial College Press (official publisher of Nobel Prize Award Lectures since1921)..

(1) TMS Chang 2007 monograph "ARTIFICIAL CELLS: biotechnology, nanomedicine, regenerative medicine, blood substitutes, bioencapsulation, and cell/stem cell therapy" started this series. Now available for free access by all on his McGill University public service site: http://www.medicine.mcgill.ca/artcell/2007%20ebook%20artcell%20web.pdf
(2) Second in this series is the 2011 book on Novel Therapies in Terminal Renal Failure edited by Professor Eli Friedman's group
(3) Third in this series is the 2013 book on Selected Topics in Nanomedicine edited by Chang
(4) Fourth in this series is a 2017 book on "Hemoperfusion and Plasma-perfusion and other Clinical Uses of General ,Biospecific, immune and leucocyte Adsorbents" Editors: Chang, Endo, Nicolaev, Tani and Zheng Total 1004 pages www.medicine.mcgill.ca/artcell/HPBk_Ch1.pdf
(5) Nanobiotherapeutic based Blood Substitutes (Editor: Chang, Associate editors: Bulow. Jahr. Saki and Yang (in press for 2021)
(6) 6th in this series will be the 2nd edition of the monograph by Chang 2017 on "ARTIFICIAL CELLS: biotechnology, nanomedicine, regenerative medicine, blood substitutes, bioencapsulation, and cell/stem cell therapy" 650 pages

- **Editorial Board**, Journal of Microencapsulation, London, UK.(1990-)
- **Editorial board**. International Journal on Theoretical and Applied Nanotechnology (IJTAN) of The International Academy of Science, Engineering and Technology (2012-)
- **Honorary Editor**. Journal of Hepato-renal and artificial detoxication(2003-)
- **Associate editor**, Nanomedicine Journal (2014-)
- **Editorial Board**, Journal Biotherapy (2014-)
- **Editorial Board** ,J Biotechnology Bioengineering (2014-)
- **Associated editor**, Nanomedicine Research J (2014-)

Previous editorial boards

- Section Editor on Detoxification, International Journal of Artificial Organs, Official Journal of European Society of Artificial Organs. Wichtig Editore Publisher. (1985-2005)
- Section Editor on New Technology then editorial board, TASAIO, Official Journal of the American Society of Artificial Internal Organs. Lippincott Press, U.S.A. (1991-2003)
- Associate Editor, Biotechnology Annual Rev, Elsevier Science, Netherlands.(1995-2011)
- Editorial Board, Journal of Cell Transplantation. Pergamon Press, USA (1999- 2011)
- **Editorial Board**, New Biotechnology. 1990-2021

BIBILOGRAPHIES:

1. Who's Who in Artificial Organs , International Society for Artificial Organs 1977
2. Marquis Who's Who in the East (1977,1978)(1995, 1996 Silver aniversary 25th 2014
3. Marquis Who's Who in America (1978 - ongoing).
4. Marquis Who's Who in the World, (1984 - ongoing).
5. Canadian Who's Who (1983 - ongoing).
6. Marquis Who's Who in Frontier Science and Technology, (1984 - ongoing).
7. American Men and Women of Science (ongoing)
8. Marquis Who's Who in Science and Engineering (1992 - ongoing)
9. International Who's Who in Medicine (1995 - ongoing)
10. American Biographical Institute "Five Hundred Leaders of Influence" (1995)
11. Marquis Who's Who in Medicine and Healthcare (1996 - ongoing)
12. Top 100 Scientists, International Biographical Centre, U.K. (2005)

GRADUATE STUDENTS SUPERVISED by CHANG

Before 1985 (one example given):

Ph.D. (Physiology): **Mark Poznanski** was Professor Chang's first Ph.D. graduate in Physiology. He has recently been honoured with the Order of Ontario and Order of Canada. He has been for a number of years the president of University of Western Ontario's "Robart Institute for Medical Research" and has built up the institute to "600+ people with an average of $600,000+ per investigator" (www.robarts.ca). He is a founding member and past chair of the Council for Health Research in Canada, a research advocacy group in Ottawa, and also chairs the Scientific Advisory Board of the Canadian Medical Discoveries Fund,and Director of the Ontario Genomics Institute, he also founded London Biotechnology Incubator Inc., in addition to being on many biotechnology-industry related boards. He is now president of his own consulting firm.

After 1985 (complete list):

1986 Ph.D. (Physiology): **Peter Keipert** , was Senior Director, Blood Substitutes, Alliance Pharmaceutical Co., Calif., USA until 2004; 2005-2013 V.P. of Research in Blood Substitutes, Sangart Co. San Diego). Now part owner of the renewed Sangart Co.
1986 M.Eng. (Chem.Eng.): **Maurice Cattaneo** (continued for Ph.D. with Chang)
1986 Ph.D. (Expt. Med.): **Zhi Qing Shi**, M.D. Vice President REMD Biotherapeutics Inc, CA, USA. Was Medical Director, Genzyme Co, US, and Research scientist at Amgen Biotechnology Co.in U.S.A. after Assistant Professor in Physiology, University of Toronto
1987 Ph.D. (Physiology): **Louis Bourget** (then dentistry at McGill, now a dental surgeon)
1987 Ph.D. (Physiology): **Vivek Dixit** (retired Professor and Director, Laboratory of Artificial Liver Support, Department of Medicine, University of California at LA
1987 M.Sc. (Physiology): **Andrew Budning** (completed McGill University M.D., physician)
1987 M.Eng. (Chem.Eng.): **Flavio Garofalo** (continued for Ph.D. with Chang)
1987 M.Eng. (Chem.Eng.): **David Morley** (completed Law at McGill University and Oxford)
1989 Ph.D. (Physiology): **Soudabeh Aghazaman Kashani**, M.D. (now in clinical medicine)
1990 Ph.D. (Chem.Eng.): **Maurice Cattaneo**, Consultant (Previously Director, Technology Development, Cambridge Scientific Inc. Cambridge, MA.Adjunct Professor, Northeastern University, Boston. (Previously Research Scientist, NRC, Biotechnology Research Institute, Montreal)

1990 Ph.D. (Chem.Eng.): **Flavio Garofalo** (Research Scientist, in the Biotechnology Co. Microlife Technics in Florida)
1990 Ph.D. (Ad Hoc) **Kang Fu Gu** retired Senior scientist of a Biotechnology Company in China (Was senior Scientist, U.S. Biotechnology before this he was Senior Research Scientist of IBEX Technology, a Montreal biotechnology company)
1991 Ph.D. (Physiology): **Jing Ning**, M.D. (She was Research Scientist at Hemosol Inc., Etobicoke, Ontario, a blood substitute company. Retired from Health Canada Regulatory division)
1991 M.Eng. (Chem.Eng.): **Vaia Coromili** (continued to Ph.D. with Chang)
1991 M.Eng. (Chem.Eng.): **Maryam Mobed** (continued to Ph.D. with Chang)
1991 M.Eng. (Chem.Eng.): **Daniel Duguay** (continued to Ph.D. in Ottawa)
1992 Ph.D. (Chem.Eng.): **Khaled Alsugair** (started as assistant Professor in Saudi Arabia)
1993 Ph.D. (Chem.Eng.): **Ian Lloyd George** Manager, Research & Development, Polychem Product Ltd., Montreal (awarded NSERC Research Fellowship at Bureau of Medical Device, Ottawa)
1994 Ph.D. (Physiology): **Silvia Bruni**, M.D. (returned to Italy in clinical practice)
1996 M.Eng (Chem.Eng.): **Sarah Safos** (continued her Ph.D. with Dr. Scriver on use of artificial cells in PKU mice)
1996 Ph.D. (Biomed.Eng.): **Satya Prakash** now a Full Professor of Biomedical Engineering, McGill (Came to me as International scholar in Biotechnology from India)
1996 M.Sc. (Biomed.Eng.): **Elizabeth Quebec**
1997 Ph.D. (Chem.Eng.): **Maryam Mobed** , was Endowed Chair in Bioengineering, Davidson College of Engineering, U.S. (previously Research scientist, Bioscience Products Division, Agilent Technologies, a California Biotech company.)
1997 Ph.D. (Physiology): **Felice D'Agnillo** Graduated on dean's honours list (was N.I.H. International Forgarty Fellow, Bethesda, USA) , Now Senior Staff Scientist at FDA-NIH
2000 Ph.D. (Chem Eng): **Vaia Coromili** - no communication after graduation
2002 M.Sc (Physiology): **Douglas Powanda** (FCAR Scholarship) Continuned to compete his Master of Management at Concordia University
2004 Ph.D. (Biomed.Eng) **Binglan Yu** graduated on Dean's honours list with Geddes Award for best graduate student in Biomedical Engineering. Research fellow with Professor Zapol, previously Chief of Anesthesiology, Mass General Hospital, Harvard Medical School, then instructor, and now assistant professor.
2004 M.Sc. (Biomed Eng) **Noami Wong** (NSERC studentship). Then was a staff engineer, Merck Frosst Co. Montreal. Now home as house wife
2005-2007 M.Sc (Biomed Eng) **Caroline Fustier** (scholarship student from Paris, France) Now a research scientist in a French Company.
2006- 2007 M.Sc. (McGill Program on Biotechnology) **Jessie Rong**. Continued to Medical School at University of Montreal
2007- 2008 M.Sc. (McGill Program on Biotechnology) **Wei He** after graduation continued work in a research lab.
2008-2009 M.Sc (McGill Program on Biotechnology) **Qianqian DU**, completed her M.Sc.and continued as research assistant in this laboratory for 1 year
2010-2014 Ph.D. (Biomedical Engineering) **Yuzhul BIAN**. Came with M.Sc. from Tsinghua University, Beijing. Graduated in June 2014. Now staff in a consulting company in Beijing, China.
2011- Feb 2015 Ph.D. (Experimental Medicine) **Yun WANG** came with M.Sc. from Peking Union Medical College of the Chinese Academy of Medical Sciences. With a China Scholarship Council Scholarship. Now research staff at the 3rd Hospital of Peking University Medical School.
2011-2012 Ph.D. Trainee (Physiology) **Wei** came with China Scholarship Council Scholarship. Was Assistant Professor then associate professor, Xian University, PRC
2014 M.Sc. (McGill Program on Biotechnology) **Chen Guo**, continued to PhD heee.
2015 M.Sc (McGill Program on Biotechnology) **Shou Ma**
2015 M.Sc (McGill Program on Biotechnology) **Christoher Lee**
2015- 2018 Ph.D. (Experimental Medicine) **Chen Guo**. PhD in 2018 now research staff in a Chinese company
2017 M.Sc (McGill Program on Biotechnology) **Amir Shahein**
2018 M.Sc (McGill Program on Biotechnology) **Petko Komsalov**
2019. M.Sc. (McGill Program on Biotechnology) **J. Zhang**
2020 M.Sc. (McGill Program on Biotechnology) **Hoq**

2021- Ph.D. (Experimental Medicine) **Hoq**
2021- MSc (Experimental Medicine) **Zhao**
2022- Ph.D. (Experimental Medicine) **Zhao**

OTHER TEACHING AT McGILL:

Physiology 518a: Course coordinator: 25 hours (1972 - Ongoing) Physiology

518a 6 hours of lectures and 6 hours seminar(1972-Ongoing)

Biomedical Engineering 399-501A 2.5 hours of lectures (onging)

Biomedical Engineering (Prof Prakash's new course) 2 hours of lectures (ongoing)

Med 1 Physiology 5 hours of lectures (1972 to 2008)

Biotechnology 202-505B 3 hours of lectures

518a "Artificial Cells and Biotechnology" For many years, Professor Chang has organized this course and gives about half the lectures for this course. This is a difficult and highly demanding interdisciplinary advance course. This is included in the suggested courses for Physiology, Biomedical Engineering, Biotechnology Diploma, Biotechnology minor and others students came from Experimental Medicine; and anatomy and molecular biology and occasionally from the faculty of engineering.

PUBLICATIONS AND INVITED LECTURESHIPS:

Summary: More than 560 papers and chapters (abstracts not included) and 29 books and symposium volumes. Invited to more than 400 international invited lectureships including opening plenary lectures, special lectureships, keynote lectures, plenary lectures. He has also assigned 30 patents and patent applications to McGill University

PUBLICATIONS: (full papers and chapters)

1. CHANG TMS (1957) "Hemoglobin Corpuscles" Report of a research project for Honours Physiology, Medical Library, McGill University. Also reprinted as part of "30 anniversary in Artificial Red Blood Cells Research" J. Biomaterials, Artificial Cells &Artificial Organs 16:1-9, 1988." and also in Chang's 2007 Monograph on 'Artificial Cells' http://www.medicine.mcgill.ca/artcell/514.pdf
2. CHANG TMS (1964) Semipermeable microcapsules. **Science** 146(3643):524-525.
3. CHANG TMS (1965) Semipermeable aqueous microcapsules. Ph.D.Thesis,McGill University, Montreal.
4. CHANG TMS, FC MACINTOSH, SG MASON (1966) Semipermeable aqueous microcapsules: I. Preparation and properties. Can J Physiol Pharmacol 44:115-128.
5. CHANG TMS (1966) Semipermeable aqueous microcapsules ("artificial cells"): with emphasis on experiments in an extracorporeal shunt system. Trans Am Soc Artif Intern Organs 12:13-19.
6. CHANG TMS, LJ JOHNSON, OJ RANSOME (1967) Semipermeable aqueous microcapsules: IV. Nonthrombogenic microcapsules with heparin-complexed membranes. Can J Physiol Pharmacol 45:705-715.
7. CHANG TMS (1967) Microcapsules as artificial cells. Science J 3:62-67.
8. CHANG TMS, POZNANSKY MJ (1968) Semipermeable microcapsules containing catalase for enzyme replacement in acatalsaemic mice. **Nature** 218(5138):242-45.
9. CHANG TMS, A PONT, LJ JOHNSON, N MALAVE (1968) Response to intermittent extracorporeal perfusion through shunts containing semipermeable microcapsules. Trans Am Soc Artif Intern Organs 14:163-168.
10. CHANG TMS, POZNANSKY MJ (1968) Semipermeable aqueous microcapsules (artificial cells): V. Permeability characteristics. Biomed Mater Res 2:187-199.
11. CHANG TMS (1969) Clinical potential of enzyme technology. (1st Incentive Lecture) Science Tools 16(3):33-39.

12. CHANG TMS (1969) Removal of endogenous and exogenous toxins by a microencapsulated absorbent. **Can J Physiol Pharmacol** 47(12):1043-5.
13. CHANG TMS (1969) Artificial cells made to order. New Scientist 4:18-19.
14. CHANG TMS, N MALAVE (1970) The development and first clinical use of semipermeable microcapsules (artificial cells) as a compact artificial kidney. Trans Am Soc Artif Intern Organs 16:141-148.
15. CHANG TMS (1971) A new concept in artificial kidneys using semipermeable microcapsules. "Chemeca '70", Butterworths of Australia (Publisher), pp 48-54.
16. CHANG TMS, A GONDA, JH DIRKS, N MALAVE (1971) Clinical evaluation of chronic, intermittent, and short term hemoperfusions in patients with chronic renal failure using semipermeable microcapsules (artificial cells) formed from membrane-coated activated charcoal. Trans Am Soc Artif Intern Organs 17:246-252.
17. CHANG TMS (1971) The in vivo effects of semipermeable microcapsules containing L-asparaginase on 6C3HED lymphosarcoma. **Nature** 229(528):117-118.
18. CHANG TMS (1971) Stabilisation of enzymes by microencapsulation with a concentrated protein solution or by microencapsulation followed by cross-linking with glutaraldehyde. **Biochem Biophys Res Common** 44(6):1531-1536.
19. CHANG TMS (1972) In vitro and in vivo kinetics of enzymes immobilized by microencapsulation. **Biotechnol & Bioeng** 14:520-525 (Symp.Vol 3:395-399).

20. CHANG TMS, A GONDA, JH DIRKS, JF COFFEY, T LEE-BURNS (1972) ACAC microcapsule artificial kidney for the long term and short-term management of eleven patients with chronic renal failure. Trans Am Soc Artif Intern Organs 18:465-472.
21. SUNDARUM PV, EK PYE, TMS CHANG, VH EDWARDS, AE HUMPHREY, NO KAPLAN, E KATCHALSKI, Y LEVIN, MD LILLY, G MANECKE, K MOSBACH, A PATCHORNIK, J PORATH, HH WEETALL, LB WINGARD, Jr. (1972) Recommendations for standardization of nomenclature in enzyme technology. **Biotechnology & Bioengineering** 14:15-18 (Symp. Vol 3:15-18).
22. CHANG TMS (1972) A new approach to separation using semipermeable microcapsules (artificial cells): combined dialysis, catalysis, and absorption. **"Recent Developments in Separation Science"** (N LI, ed.) Chemical Rubber Co. Press, Cleveland, OH, USA pp 203-216.
23. CHANG TMS (1972) Haemoperfusions over microencapsulated adsorbent in a patient with hepatic coma**. Lancet** ii:1371-1372.
24. CHANG TMS (1972) Microcapsule artificial kidney and medium molecular weight clearance. **Proc Eur Dial Transplant Assoc** 9:568-574.
25. CHANG TMS (1972) Effects of local applications of microencapsulated catalase on the response of oral lesions to hydrogen peroxide in acatalasemia. J Dental Res 51(2):319-321.
26. CHANG TMS, JF COFFEY, P BARRE, A GONDA, JH DIRKS, M LEVY, C LISTER (1973) Microcapsule artificial kidney: treatment of patients with acute drug intoxication. **Can Med Assoc J** 108:429-433.
27. CHANG TMS (1973) Immobilization of enzymes, adsorbents, or both within semipermeable microcapsules (artificial cells) for clinical and experimental treatment of metabolite-related disorders**. "Enzyme Therapy for Congenital Diseases"** D BERGSMA, ed. Birth Defects: Original Article Series, Vol IX, No 2),Williams & Wilkins Co., Baltimore, MD, pp 66-76.
28. CHANG TMS (1973) Recent trends in biocompatible materials and microcapsular absorbents for kidney function replacement**. "Perspectives in Biomedical Engineering"** (RM KENEDI, ed.) University Park Press (MacMillan), Baltimore, MD, pp 39-44.
29. CHANG TMS, JF COFFEY, C LISTER, E TAROY, A STARK (1973) Methaqualone, methyprylon, and glutethimide clearance by the ACAC microcapsule artificial kidney: in vitro and in patients with acute intoxication. Trans Am Soc Artif Intern Organs 19:87-91.
30. CHANG TMS, M MIGCHELSEN (1973) Characterization of possible "toxic" metabolites in uremia and hepatic coma based on the clearance spectrum for larger molecules by the ACAC microcapsule artificial kidney. Trans Am Soc Artif Intern Organs 19:314-319.
31. CHANG TMS (1973) L-Asparaginase immobilized within semipermeable microcapsules: in vitro and in vivo stability. **Enzyme** 14(2):95-104.

32. CHANG TMS (1973) Biomedical applications of artificial cells. **Biomedical Engineerin**g 8(8):334-339.
33. CHANG TMS (1973) The use of semipermeable microcapsules (artificial cells)as Microsystems for separation. **Am Chem Soc** 33:581-583.
34. CHAWLA, AS, CHANG TMS (1973) Nonthrombogenic polymeric membraneprepared by gamma-radiation grafting of heparin. **Am Chem Soc** 33:379-385.
35. SIU-CHONG, CHANG TMS (1974) In vivo effects of intraperitoneally injected L-asparaginase solution and L-asparaginase immobilized within semipermeable nylon microcapsules with emphasis on blood L-asparaginase, 'body' L-asparaginase, and plasma L-asparagine levels. **Enzyme** 18:218-239.
36. CHANG TMS (1974) Enzymes immobilized by microencapsulation: preparation and biomedical applications. **"Insolubilized Enzymes"** (M SALMONA, C SARONIO, S GARATTINI, eds.) Raven Press, New York, pp 15-27.
37. POZNANSKY MJ, CHANG TMS (1974) Comparison of the enzyme kinetics and immunological properties of catalase immobilized by microencapsulation and catalase in free solution for enzyme replacement. **Biochim Biophys Acta** 334:103-115.
38. CHANG TMS (1974) Effects of different routes of in vivo administrationof microencapsulated enzymes. **Enzyme Engineering** 2:419-424.
39. CHANG TMS (1974) Platelet-surface interaction: effect of albumin coating orheparin complexing on thrombogenic surfaces. **Can J Physiol Pharmacol** 52(2):275-285.
40. CHANG TMS (1974) A spherical ultrathin polymeric membrane systemcontaining enzymes. Polymer Preprints, American Chemical Society 15:381-382.
41. CHANG TMS (1974) Performance characteristics of the microcapsule artificial kidney. in **"Renal Dialysis"** (D WHELPTON, ed.) Sector Publisher, London, pp 135-147.
42. CHANG TMS (1974) Future prospective: pediatric hemodialysis based on artificial cells. Clin Proc Children's Hospital National Medical Center, Washington, DC,30(10):304-311.
43. CHANG TMS, M MIGCHELSEN, JF COFFEY, A STARK (1974) Serum middle molecule levels in uremia during long term intermittent hemoperfusions with the ACAC (coated charcoal) microcapsule artificial kidney. Trans Am Soc Artif Intern Organs 20:364-371.
44. CHANG TMS (1974) Artificial cells and microcapsules: Comparison of structuraland functional differences. **"Microencapsulation: Processes and Applications"** (JEVANDAGAER, ed.) Plenum Press, New York, pp 95- 102.
45. CHANG TMS (1974) A comparison of semipermeable microcapsules andstandard dialysers for use in separation. **J Separation & Purification Methods** 3(2):245-262.
46. CHAWLA AS, CHANG TMS (1974) Nonthrombogenic surface by radiation graftingof heparin: preparation, in-vitro and in-vivo studies. **Int J Biomaterial Medical Devices & Artif Organs** 2(2):157-169.
47. CHANG TMS (1975) Rationale for the use of the ACAC microcapsule artificialkidney for the treatment of patients with chronic renal failure. L'Ateneo Parmense**, Acta Bio-Medica** 46:35368.
48. CHANG TMS (1975) Artificial cells. **Chem Tech** 5:80-85.
49. CHANG TMS (1975) Artificial kidney and artificial liver**. Lancet** iv:1451-1452.
50. CHANG TMS (1975) Microencapsulated adsorbent hemoperfusion foruremia, intoxication and hepatic failure. **Kidney Int** 7:S387-S392.
51. CHAWLA AS, CHANG TMS (1975) A new method for the preparation of nonthrombogenic surface by radiation grafting of heparin: Preparation and in-vitro studies. in **"Biomedical Applications of Polymers"** (HP GREGOR, ed.) Plenum Press, New York, pp 147-157.
52. CHANG TMS (1975) Biocompatible microencapsulated (coated) charcoal for haemoperfusions in patients. **"Artificial Support Systems for Acute Hepatic Failure"** (R WILLIAMS, ed.) Whitefriars Press, Ltd., London, UK, pp 94-103.
53. CHANG TMS (1975) Experience with the treatment of acute liver failure patientsby haemoperfusion over biocompatible microencapsulated (coated) charcoal. in "Artificial Support Systems for Acute Hepatic Failure" (R WILLIAMS, ed.) Whitefriars Press, Ltd., London, UK, pp 229-233.
54. CHANG TMS (1975) Immobilized enzymes and their biomedical applications. in **"Immobilized Enzymes, Antigens, Antibodies, and Peptides"** (HH WEETALL, ed.)

Marcel Dekker, Inc., New York, pp 245-292.
55. CHAWLA AS, CHANG TMS (1975) Use of solubility parameters for the preparation of hemodialysis membranes**. J Applied Polymer Sci** 19:1723-1730.
56. CHANG TMS (1975) Biomedical research for the treatment of drug abuse and related problems. "Biomedical Research in Narcotic Abuse Problems" (MO MAYKUT, ed.) Health and Welfare Canada, pp 69-78.
57. CHANG TMS (1975) The one-shot vaccine. in "Socio-Economic and Ethical Implications of Enzyme Engineering" (C-G HEDEN, ed.) International Federation of Institutes for Advanced Studies, Stockholm, Sweden, pp 17-18.
58. CAMPBELL J, CHANG TMS (1975) Enzymatic recycling of coenzymes by a multienzyme system immobilized within semipermeable collodion microcapsules. **Biochim Biophys Acta** 397:101-109.
59. CHANG TMS, CHIRITO E, P BARRE, C COLE, M HEWISH (1975) Clinical performance characteristics of a new combined system for simultaneous hemoperfusionhemodialysis-ultrafiltration in series. Trans Am Soc Artif Intern Organs 21:502-508.
60. CHANG TMS (1975) Artificial cells as carriers for biologically active materials in therapy. in "Clinical Pharmacology" (MJ MATTILA, ed.) Proc 6th International Congress of Pharmacology, Finland, Vol 5, pp 81-90.
61. CHANG TMS (1975). A microcapsule artificial kidney: a step toward miniaturization J **Dial Transplant** 4:23-25.
62. WATSON WJ, CHANG TMS (1975) Platelet-surface interaction: effects of dextran 70 on platelet retention in extracorporeal surfaces. Int J Biomaterial, Medical Devices & Artificial Organs 3(4):489-502.
63. CHANG TMS (1976) Semipermeable microcapsules as artificial cells: clinical applications and perspectives. **"Microencapsulation"** (J NIXON, ed.) Marcel Dekker, Inc., New York, pp 57-65.
64. CAMPBELL J, CHANG TMS (1976) The recycling of NAD+ (free and immobilized) within semipermeable aqueous microcapsules containing a multi-enzyme system. **Biochem Biophys Res Commun** 69(2):562-569.
65. CHANG TMS (1976) Microcapsule artificial kidney: including updated preparative procedures and properties. **Kidney Int** 10:S218-S224.
66. CHANG TMS (1976) Hemoperfusion alone and in series with ultrafiltration or dialysis for uremia, poisoning and liver failure. **Kidney Int** 10:S305-S311.
67. CHANG TMS (1976) Enzymes immobilized by microencapsulation within spherical ultra-thin polymeric membranes. **J Macromol Sci Chem** A10(1_):245-258.
68. CHANG TMS (1976) Methods for the therapeutic applications of immobilized enzymes. **Methods in Enzymology** XLIV: 676-698.
69. CHANG TMS (1976) Microencapsulation of enzymes and biologicals**. Methods in Enzymology** XLIV: 201-217.
70. CHANG TMS (1976) Biodegradable semipermeable microcapsules containing enzymes, hormones, vaccines, and other biologicals. **J Bioengineering** 1:25-32. www.artcell.mcgill.ca/1976ChangBiodegr.pdf
71. CHANG TMS (1977) Enzyme immobilized within spherical ultrathin polymeric membranes. "Polymer Grafts in Biochemistry-Bioactive Material".Preprint, American-Japanese Chemical Societies Joint Meeting, Hawaii.
72. CHANG TMS, CHIRITO E, P BARRE, C COLE, C LISTER, E RESURRECCION (1977) Clinical evaluation of the clearance profiles of a portable, compact, dialysate-free system incorporating microencapsulated charcoal hemoperfusion for blood purification with ultrafiltration for fluid removal. **J Dialysis** 1(3):239-259.
73. PRICHARD S, CHIRITO E, CHANG TMS, AD SNIDERMAN (1977) ell.mcgMicroencapsulated charcoal hemoperfusion: A possible therapeutic adjunct in digoxin toxicity**. J Dialysis** 1(4):367-377.
74. CHANG TMS (1977) Introduction. Introductory Chapter in "Biomedical Applications of Immobilized Enzymes and Proteins" Vol 1 (CHANG TMS, ed.) Plenum Press, New York, pp 1-4.
75. CHANG TMS (1977) Encapsulation of enzymes, cell contents, cells, vaccines, antigens, antiserum, cofactors, hormones, and proteins. in "Biomedical Applications Immobilized Enzymes and Proteins" Vol 1 (CHANG TMS, ed.) Plenum Press, New York, pp 69-90.
76. CHANG TMS (1977) Rationale and strategies for the therapeutic applications of

immobilized enzymes. in "Biomedical Applications of Immobilized Enzymes and Proteins" Vol 1 (CHANG TMS, ed.) Plenum Press, New York, pp 93-104.
77. SIU-CHONG ED, CHANG TMS (1977) L-Asparaginase as a model for enzyme therapy of substrate- dependent tumors. in "Biomedical Applications of Immobilized Enzymes and Proteins" Vol 1 (TMS CHANG, ed.) Plenum Press, New York, pp 105-120.
78. CHANG TMS (1977) Experimental therapy using semipermeable microcapsules containing enzymes and other biologically active material. in "Biomedical Applications of Immobilized Enzymes and Proteins" Vol 1 (CHANG TMS, ed.) Plenum Press, New York, pp 147-162.
79. CHANG TMS (1977) Artificial kidney, artificial liver, and detoxifiers based on artificial cells, immobilized proteins, and immobilized enzymes in "Biomedical Applications of Immobilized Enzymes and Proteins" Vol 1 (CHANG TMS, ed.) Plenum Press, New York, pp 281-295.
80. CAMPBELL J, CHANG TMS (1977) Immobilized multienzyme systems and coenzyme requirements: Perspectives in biomedical applications. in "Biomedical Applications of Immobilized Enzymes and Proteins" Vol 2 (CHANG TMS, ed.) Plenum Press, New York, pp 281-302.
81. CHANG TMS (1977) Criteria, evaluation, and perspectives of various microencapsulated charcoal hemoperfusion systems**. J Dial Transplant** 6:50-53.
82. CHIRITO E, B REITER, C LISTER, CHANG TMS (1977) Artificial liver: The effect of ACAC microencapsulated charcoal hemoperfusion on fulminant hepatic failure. **Artif Organs** 1(1):76-83.
83. CAMPBELL J, CHAWLA AS, CHANG TMS (1977) The use of immobilized enzyme-membrane sandwich reactors in automated analysis. **Analytical Biochem** 83:330-335.
84. CHANG TMS (1977) Protective effects of microencapsulation (coating) on platelet depletion and particulate embolism in the clinical applications of charcoal haemoperfusion. "**Artificial Organs**" (RM KENEDI, JM COURTNEY, JDS GAYLOR, T GILCHRIST, eds.) MacMillan Press Ltd., London, UK, pp 164-177.
85. GRUNWALD & CHANG (1977) Formation of amino acid from urea and ammonia by sequential enzyme reaction using a microencapsulated multi-enzyme system. **Biochem Biophys Res Commun** 79(1):24-3l.
86. CHANG TMS (1977) Novel approaches in artificial kidney, artificial liver, and detoxification. **J Dialysis & Transplant** 8:20-26.
87. CHANG TMS (1978) Artificial cells in 1977. **Int J Artif Organs** 1(1):35-43.
88. CHANG TMS (1978) Biomedical applications of microencapsulation. in "Microencapsulation" (T KONDO, ed.) Tokyo, Japan, pp 369-376.
89. CHANG TMS (1978) Biomedical application of microencapsulated enzyme. Hind Antibiot Bull 2-:5-9.
90. CHANG TMS (1978) Artificial cells and charcoal hemoperfusion**. Int J Artif Organs** 1:111-112.
91. CHANG TMS (1978) Introductory chapter. in Artificial Kidney, Artificial Liver and Artificial Cells" (CHANG TMS, ed.) Plenum Press, New York, pp 3- 8.
92. CHANG TMS (1978) Artificial cells for artificial kidney, artificial liver and detoxification. "Artificial Kidney, Artificial Liver and Artificial Cells" (CHANG TMS, ed.) Plenum Press, New York, pp 57-77.
93. COUSINEAU J CHANG TMS (1978) Conversion of urea and ammonium to an amino acid using sequential enzymatic reaction with microencapsulated multienzyme system. "Artificial Kidney, Artificial Liver and Artificial Cells" (CHANG TMS, ed.) Plenum Press, New York, pp 249-254.
94. PRICHARD S, CHIRITO E, AD SNIDERMAN, CHANG TMS (1978) Use of albumin cellulose nitrate microencapsulated charcoal hemoperfusion: In acute digoxin toxicity in dogs. "Artificial Kidney, Artificial Liver and Artificial Cells" (CHANG TMS, ed.) Plenum Press, New York, pp 245-247.
95. CHIRITO E, B REITER, C LISTER, CHANG TMS (1978) Assessment of two rat models of acute hepatic failure for testing artificial liver devices. "Artificial Kidney, Artificial Liver and Artificial Cells" (CHANG TMS, ed.) Plenum Press, New York, pp 239-243.
96. NASIELSKI P, CHANG TMS (1978) Microencapsulated charcoal hemoperfusion for galactosemia. "Artificial Kidney, Artificial Liver and Artificial Cells" (CHANG TMS,

ed.) Plenum Press, New York, pp 255-257.
97. CHANG TMS (1978) Adsorbent hemoperfusion - general discussion. "Artificial Kidney, Artificial Liver and Artificial Cells" (CHANG TMS, ed.) Plenum Press, New York, pp 301-304.
98. GRUNWALD J, CHANG TMS (1978) Nylon polyethyleneimine microcapsules for immobilizing multienzymes with soluble dextran-NAD+ for the continuous recycling of the microencapsulated dextran-NAD+. **Biochem Biophys Res Commun** 81(2):565-570.
99. CAMPBELL J, CHANG TMS (1978) Microencapsulated multi-enzyme systems as vehicles for the cyclic regeneration of free and immobilized coenzymes. **Enzymes Engineering** 3: 371-377.
100. CHANG TMS (1978) Microcapsule artificial kidney. Proc Canadian Clinical Engineering Conference, National Research Council, Ottawa, Canada, pp 134-137.
101. NASIELSKI P, CHANG TMS (1978) Coated charcoal hemoperfusion for the removal of galactose in rats. **Int J Artif Organs** 1(3):143-147.
102. CHANG TMS, C MALOUF (1978) Artificial cells microencapsulated multienzyme system for converting urea and ammonia to amino acid using alpha-ketoglutarate and glucose as substrate. Trans Am Soc Artif Intern Organs 24:18-20.
103. CHANG TMS, C LISTER, CHIRITO E, P O'KEEFE, E RESURRECCION (1978) Effects of hemoperfusion rate and time of initiation of ACAC charcoal hemoperfusion on the survival of fulminant hepatic failure rats. Trans Am Soc Artif Intern Organs 24:243-245.
104. CHANG TMS, N KUNTARIAN (1978) Galactose conversion using a microcapsule immobilized multienzyme cofactor recycling system. **Enzyme Engineering**, 4: 193-197.
105. CHANG TMS (1978) Future of haemoperfusion. "Dialysis '77" (A DAVIDSON, ed.) Pitman Medical Publisher, London, UK, pp 269-277.
106. CHANG TMS (1978) A 1978 perspective of hemoperfusion. Artif Organs 2(4):359-362.
107. CHANG TMS (1978) Hemoperfusion in chronic schizophrenia. **Int J Artif Organs** 1(6):253-255.
108. CHANG TMS (1978) Microcapsule artificial kidney in replacement of renal function: with emphasis on adsorbent hemoperfusion. in "**Replacement of Renal Function by Dialysis**" (W DRUKKER, FM PARSONS, JF MAHER, eds.) Martinus Nijhoff Publishers bv, The Hague, pp 217-231.
109. CHANG TMS (1979) Assessments of clinical trials of charcoal hemoperfusion in uremic patients. **Clin Nephrol** 11(2):111-119.
110. CHIRITO E, C LISTER, CHANG TMS (1979) Biochemical, hematological and histological changes in a fulminant hepatic failure rat model for artificial liver assessment. **Artif Organs** 3(1):42-46.
111. CHANG TMS, C MALOUF (1979) Effects of glucose dehydrogenase in converting urea and ammonia into amino acid using artificial cells. **Artif Organs** 3(1):38-41.
112. PISKIN E, CHANG TMS (1979) Urea and ammonium removal based on alkalinization and removal of free ammonia. **Int J Artif Organs** 2(4):211-214.
113. GRUNWALD J, CHANG TMS (1979) Continuous recycling of NAD+ using an immobilized system of collodion microcapsules containing dextran-NAD+, alcohol dehydrogenase, and malic dehydrogenase. **J Applied Biochem** 1:104-114.
114. CHANG TMS, CHIRITO E, P BARRE, C COLE, C LISTER, E RESURRECCION (1979) Long-term clinical assessment of combined ACAC hemoperfusion- ultrafiltration in uremia. **Artif Organs** 3(2):127-131.
115. KAZIUKA EN, CHANG TMS (1979) In-vitro assessment of the removal of phenols by ACAC hemoperfusion. **Int J Artif Organs** 2(4):215-221.
116. CHANG TMS (1979) Review on "Immobilized enzymes: research and development" **Quarterly Review of Biology** 54:32l.
117. CHANG TMS (1979) Review on "Uses of enzymes and immobilized enzymes". **Quarterly Review of Biology** 54:32l.
118. CHANG TMS (1979) Artificial cells as drug carriers in biology and medicine. in "**Drug Carriers in Biology and Medicine**" (G GREGORIADIS, ed.) Academic Press, Inc., New York, pp 271-285.
119. ESPINOSA-MELENDEZ E, S LAL, NPV NAIR, CHANG TMS (1979) Plasma betaendorphin levels in chronic schizophrenic patients and normal controls. **Artif Organs** 3(4):375-376.

120. SIDEMAN S, CHANG TMS (1979) Hemoperfusion: kidney and liver supports and detoxification. **Artif Organs** 3(4):393-402.
121. CHANG TMS (1979) Hemoperfusion: clearance, blood compatibility and safety. Int J **Artif Organs** 2(6):276-277.
122. BETTER OS &, G BRUNNER, TMS CHANG, JM COURTNEY, PC FARRELL, MC GELFAND, A GIMSON, HJ GURLAND, E HOFFER, K MAEDA, R MAINI, JL ROSENBAUM, S SIDEMAN, U TAITLEMAN, JF WINCHESTER (1979) Controlled trials of hemoperfusion for intoxication. **Ann Int Med** 91(6):925.
123. CHANG TMS (1979) A visitor's impression of uremia therapy in China. **Artif Organs** 3(supp):34-35.
124. CHANG TMS, C MALOUF, E RESURRECCION (1979) Artificial cells containing multienzyme systems for the sequential conversion of urea into ammonia, glutamate, then alanine. **Artif Organs** 3(supp):284-287.
125. PISKIN E, CHANG TMS (1980) Effects of pH and urea concentration on urea removal from dialysate by enzymatic conversion and gas absorption using a capillary hemodialyzer. **Int J Artif Organs** 3(1):36-40.
126. CHANG TMS (1980) Use of immobilized enzymes in medical practice. "Enzymes: The Interface Between Technology and Economics" (JP DANEHY, B WOLNAK, eds.) Marcel Dekker Inc., New York, pp 123- 130.
127. CHANG TMS, E ESPINOSA-MELENDEZ, TE FRANCOEUR, NR EADE (1980) Albumin-collodion activated coated charcoal hemoperfusion in the treatment of severe theophylline intoxication in a 3-year-old patient. **Pediatrics** 65(4):811-814.
128. CHANG TMS, C LISTER (1980) Analysis of possible toxins in hepatic coma including the removal of mercaptan by albumin-collodion charcoal. **Int J Artif Organs** 3(2):108- 112.
129. SIDEMAN S, CHANG TMS (1980) Hemoperfusion: State of the art and future requirements. **Artif Organs** 4:70-75.
130. ROSENTAL AM, CHANG TMS (1980) The incorporation of lipid and Na+-K+-ATPase into the membranes of semipermeable microcapsules. **J Membrane Sciences** 6(3):329-338.
131. CHANG TMS (1980) Artificial red blood cells. Trans Am Soc Artif Intern Organs 26:354-357.
132. CHANG TMS, J WINCHESTER, J ROSENBAUM, A SAITO, S STEFONI, CD SHU, HL GURLAND (1980) Adsorbent hemoperfusion for blood purification. Trans Am Soc **Artif Intern Organs** 26:593-597.
133. CHANG TMS (1980) Microencapsulation of specific sorbents for medical applications\"Sorbents and Their Clinical Applications" (C GIORDANO, ed.) Academic Press, Inc.,
134. GRUNWALD J, CHANG TMS (1980) Microencapsulated multienzyme system and the recycling of NAD+ bound to soluble dextran. "Hemoperfusion: Artificial Kidney and Liver Support and Detoxification" (SIDEMAN S, CHANG TMS, eds.) Hemisphere Publishing Corp.,Washington, D.C., pp 389-395.
135. CHANG TMS (1980) Animal model studies: Enzyme entrapment, neural delivery, and transplantation - "**Enzyme Therapy in Genetic Diseases: 2. Birth Defects: Original Article Series**" Vol 15, No 1 (RJ DESNICK, ed.) Alan R. Liss Inc., New York, pp 231- 235.
136. CHANG TMS (1980) Present status and future prospectives of artificial cells in hemoperfusion. "Hemoperfusion: Artificial Kidney and Liver Support and Detoxification" (SIDEMAN S, CHANG TMS, eds.) Hemisphere Publishing Corp.,Washington, D.C., pp 93-104.
137. CHANG TMS (1980) Hemoperfusion: Closing remarks. "Hemoperfusion: Artificial Kidney and Liver Support and Detoxification" (SIDEMAN S, CHANG TMS, eds.) Hemisphere Publishing Corp., Washington, D.C., pp 403-405.
138. MOHSINI K, C LISTER, CHANG TMS (1980) The effects of homologous cross-circulation and in situ liver perfusion on fulminant hepatic failure rats. **Artif Organs** 4:171-175.
139. PISKIN E, CHANG TMS (1980) Effects of air and fluid flow rates on removing different concentrations of urea and ammonia from fluid by gas absorption in a capillary hemodialyzer. **J Dialysis** 4(1):31-42.
140. CHANG TMS (1980) Biomedical applications of artificial cells."Biomedical Polymers" (EP GOLDBERG, A NAKAJIMA, eds.) Academic Press, New York, pp 171-187.
141. ESPINOSA-MELENDEZ E, CHANG TMS (1980) ACAC (albumin-collodion coated

activated charcoal) hemoperfusion: in-vitro removal and clearance of theophylline. **J Dialysis** 4(1):21-29.
142. CHANG TMS (1980) Clinical experience with ACAC coated charcoal hemoperfusion in acute intoxication. **Clinical Toxicology** 17:529-542.
143. TABATA Y, CHANG TMS (1980) Comparisons of six artificial liver support regimes in fulminant hepatic coma rats. Trans Am Soc Artif Intern Organs 26:394-399.
144. CHANG TMS (1980) Blood compatible coating of synthetic immunoadsorbents. Trans Am Soc Artif Intern Organs 26:546-549.
145. YU YT, CHANG TMS (1980) The effects of polymer-solvent compositions on the formation of collodion membrane artificial cells. Int J of Biomaterial, Medical Devices & Artif Organs 8:273-281.
146. CHANG TMS (1980) New approaches using immobilized enzymes for the removal of urea and ammonia. **Enzyme Engineering** 5:225:229.
147. PISKIN K, CHANG TMS (1980) A new combined enzyme-charcoal system formed by enzyme adsorption on charcoal followed by polymer coating. Int J Artif Organs 3(6):344-347.
148. CHANG TMS (1980) Guest editor of Symposium Volume on "Hybrid Artificial Organs". Artif Organs 4(4):264-301.
149. CHANG TMS (1980) Guest Editorial: Hybrid Artificial Organs. Artif Organs 4(4):258.
150. CHANG TMS (1980) Artificial cells: The use of hybrid systems. Artif Organs 4(4):264-271.
151. PISKIN E, CHANG TMS (1980) A new process for removal of urea. Proc Europ Soc Artif Organs 7:127-131.
152. SHU CD, CHANG TMS (1980) Tyrosinase immobilized within artificial cells for detoxification in liver failure. I. Preparation and in vitro studies. Int J Artif Organs 3(5):287-291.
153. PISKIN E, CHANG TMS (1981) Effects of temperature on the removal of urea as ammonia by enzymatic conversion and gas absorption using an oxygenator. Int J Artif Organs 4(1):45-48.
154. SHU CD, CHANG TMS (1981) Tyrosinase immobilized within artificial cells for detoxification in liver failure: II. In vivo studies in fulminant hepatic failure rats. Int J Artif Organs 4:82-84.
155. GRUNWALD J, CHANG TMS (1981) Immobilization of alcohol dehydrogenase, malic dehydrogenase and dextran-NAD+ within nylon-polyethyleneimine microcapsules: preparation and cofactor recycling. **J Molecular Catalysis** 11:83-90.
156. YU YT, CHANG TMS (1981) Ultrathin lipid-polymer membrane microcapsules containing multienzymes, cofactors and substrates for multistep enzyme reactions. **FEBS Letters** (Fed of Euro Biochem Societies) 125(1):94-96.
157. CHANG TMS, C LISTER (1981) Middle molecules in hepatic coma and uremia. **Artif Organs** 4(supp):169-172.
158. YU YT, CHANG TMS (1981) Lipid-polymer membrane artificial cells containing multienzyme systems, cofactors and substrates for the removal of ammonia and urea. Trans Am Soc Artif Intern Organs 27:535-538.
159. CHANG TMS (1981) Current status of sorbent microencapsulation. "**Advances in Basic and Clinical Nephrology**" Proc 8th Int Congress of Nephrology, S Karger Publisher, Basel, Switzerland, pp 400- 406.
160. CHANG TMS (1981) Hemoperfusion, exchange transfusion, cross circulation, liver perfusion, hormones and immobilized enzymes. "**Artificial Liver Support**" (G BRUNNER, FW SCHMIDT, eds.) Springer-Verlag, Berlin, pp 126-133.
161. PISKIN E, CHANG TMS (1981) Urea and ammonia removal from dialysate in an oxygenator: Effects of dialysate and air flow rates. **J Membrane Science** 9:343-350.
162. CHANG TMS, SHU CD (1981) Artificial cells for hemoperfusion. Chinese J Organs Transplant, Zhonghua Qiguan Yizhi Zazhi 2:50- 55.
163. CHANG TMS (1981) Artificial cells. Proc World Congress of Chemical Engineering.
164. CHANG TMS (1981) Biocompatibility and experimental therapy of immobilized enzymes and proteins. "**Systemic Aspects of Biocompatibility**" (DF WILLIAMS, ed.) Vol II, pp 181-188.
165. DIXIT V, CHANG TMS (1981) Soluble liver extracts as supplement to detoxification by hemoperfusion. Int J Artif Organs 4:291-294.

166. PISKIN E, V EVREN, AR OZDURAL, CHANG TMS (1981) Design of a packed-bed gas desorption column for the removal of urea as ammonia. Artif Organs 5(supp):624-627.
167. CHANG TMS (1981) Controversies and issues in hemoperfusion. Artif Organs 5(supp):10-15.
168. CHANG TMS, Y LACAILLE, X PICART, E RESURRECCION, A LOBELL, D MESSIER, NK MAN (1981) Composite artificial kidney: a single unit combining hemodialysis and hemoperfusion. Artif Organs 5(supp):200-203.
169. CHANG TMS (1982) Blood compatible adsorbent hemoperfusion for extracorporeal blood treatment. "Theoretical Aspects, Industrial and Biomedical Applications of Affinity Chromatography and Related Techniques" (TCJ CRIBAN, J VISSAR, RJF NIVARD, eds.) Elsevier Scientific Publishing Co., Amsterdam, Netherlands, pp 357-364.
170. CHANG TMS (1982) Artificial cells encapsulated enzymes and adsorbents in congenital metabolic disorders. "**Inborn Errors of Metabolism in Humans**" (F COCKBURN, R GITZELMAN, eds.) Alan R. Liss Inc., New York, pp 131-138.
171. CHANG TMS (1982) Hemoperfusion in 1981. **Contr Nephrol** 29:11-22.
172. CHANG TMS (1982) Hemoperfusion and artificial cells. **Contr Nephrol** 29:3-6.
173. DIXIT V, CHANG TMS (1982) Effects of prostaglandine on the survival time of fulminant hepatic failure rats. Int J Artif Organs 5:388.
174. CHANG TMS, SHU CD, YU YT, J GRUNWALD (1982) Artificial cells immobilized enzymes for metabolis disorders. "**Advances in the Treatment of Inborn Errors of Metabolism**" (M CRAWFORD, D GIBBS, RWE WATTS, eds.) John Wiley & Son Ltd. Publisher, UK, pp 175-184.
175. YU YT, CHANG TMS (1982) Multienzymes and cofactors immobilized within lipid polyamide membrane microcapsules for sequential substrate conversion**. Enzyme Engineering** 6:163-164.
176. YU YT, CHANG TMS (1982) Immobilization of multienzymes and cofactors within lipid-polyamide membrane microcapsules for the multistep conversion of lipophilic and lipophobic substrates. **Enzyme Microb Technol** 4:327-331.
177. TABATA Y, CHANG TMS (1982) Effects of hemoperfusion on liver regeneration based on DNA synthesis. J Japanese Soc Artif Organs
178. TABATA Y, CHANG TMS (1982) Microencapsulation of liver enzymes. J Japanese Soc Artif Organs.
179. CHANG TMS, YU YT, J GRUNWALD (1982) Artificial cells immobilized multienzyme systems and cofactors. **Enzyme Engineering** 6:451-561.
180. CHANG TMS (1982) Microcapsules as artificial cells. "Microcapsules and Microcarriers in Biotechnology" (LANGER, ed.) Massachusetts Institute of Technology, Mass.,USA.
181. CHANG TMS, P BARRE, S KURUVILLA, D MESSIER, N MAN, E RESURREC- CION (1982) Phase one clinical trial of a new composite artificial kidney: a single unit combining dialysis with hemoperfusion. Trans Am Soc Artif Internal Organs 28:43-48.
182. SHI ZQ, CHANG TMS (1982) The effects of hemoperfusion using coated charcoal or tyrosinase artificial cells on middle molecules and tyrosine in brain and serum of hepatic coma rats. Trans Am Soc Artif Internal Organs 28:205-209.
183. CHANG TMS (1982) Plasma perfused over immobilized protein A for breast cancer. **New Engl J Med** 306:936.
184. TABATA Y, CHANG TMS (1982) Intermittent vascular access for extracorporeal circulation in conscious rats: A new technique. Artif Organs 6:213-214.
185. CHANG TMS, P BARRE, S KURUVILLA, NK MAN, Y LACAILLE, D MESSIER,M MESSIER, E RESURRECCION (1982) Hemoperfusion-hemodialysis in a single unit: composite artificial kidney. J Artificial Support Systems 1:63-67.
186. ESPINOSA-MELENDEZ E, M ZELMAN, P BARRE, C LISTER, CHANG TMS (1982) Oxystarch modified by boiling: Effects of oral administration in stable hemodialysis patients. Proceedings, International Symposium on "Hemoperfusion and Artificial Organs",83-85.
187. PISKIN E, V EVREN, K PISKIN, AR OZDURAL, CHANG TMS (1982) Kinetics of ammonia removal by gas desorption. Proceedings, International Symposium on "Hemoperfusion and Artificial Organs", 89-91.
188. KEIPERT P, J MINKOWITZ, CHANG TMS (1982) Cross-linked stroma-free polyhemoglobin as a potential blood substitute. Int J Artif Organs 5(6):383-385.
189. SHU CD, CHANG TMS (1982) Artificial cells immobilized tyrosinase for

detoxifications in liver failure. Chongqing Medical College Bulletin 1:1-4(1981-82).
190. SHU CD, CHANG TMS (1982) Effects of hemoperfusion on plasma cortisone levels in galactosamine induced fulminant hepatic failure rats. Proc Symposium on Artificial Liver.
191. CHANG TMS (1982) Earlier hemoperfusion in fulminant failure. **Lancet** 2(8306):1039.
192. SHU CD, CHANG TMS (1983) Galactosamine induced fulminant hepatic failure rats: changes in middle molecules. Chinese J of Gastroenterology 3:102-104.
193. CHANG TMS, E ESPINOSA-MELENDEZ, S LAL, NP NAIR, C LISTER (1983) BEndorphin and other middle molecules in chronic schizophrenia and removal by adsorbent hemoperfusion. "Detoxifications in Psychiatric Disorders" (K ERNST, K SEIDEL, eds.) Veb Verlag Volk und Gesundheit,Berlin, pp 69-77.
194. TMS CHANG, P BARRE, S KURUVILLA, NK MAN, Y LACAILLE, D MESSIER, M MESSIER, E RESURRECCION (1983) Laboratory and clinical assessments of hemoperfusion and hemodialysis in a single unit: composite artificial kidney. "Past, Present and Future of Artificial Organs" (PISKIN E, CHANG TMS, eds.) Meteksan Publr. Co., Ankara, pp 196-200.
195. CHANG TMS (1983) Past, present and future of artificial cells. "Past, Present and Future of Artificial Organs" (PISKIN E, CHANG TMS, eds.) Meteksan Publr. Co., Ankara, pp 10-24.
196. CHANG TMS (1983) Past, present and future of hemoperfusion. "Past, Present and Future of Artificial Organs" (PISKIN E, CHANG TMS, eds.) Meteksan Publr. Co., Ankara, pp 109-127.
197. TABATA Y, M ODAKA, H HIRASAWA, H SATOH, CHANG TMS (1983) The effect of charcoal hemoperfusion on DNA in the liver of hepatic failure rats. "Past, Present and Future of Artificial Organs" (PISKIN E, CHANG TMS, eds.) Meteksan Publr. Co., Ankara, pp 255-259.
198. SHU CD, CHANG TMS (1983) Middle molecules in the serum, brain, liver and urine of galactosamine-induced fulminant hepatic failure rats. Int J Artif Organs 6:273-277.
199. CHANG TMS (1983) A multifaceted approach to artificial liver support. "Liver support/transplants and artificial organs", Panel Conference (TE STARZL,CHANG TMS, R WILLIAMS, Y NOSE) Trans Am Soc Artif Intern Organs 29:795-799.
200. SHI ZQ, CHANG TMS (1983) In vitro adsorption spectrum of plasma amino acids by coated charcoal hemoperfusion. Int J Artif Organs 6(5):267-270.
201. CHANG TMS (1983) Artificial cells. Proceedings, Symposium on "Plastics in Artificial Organs", American Chemical Society, Seattle, USA.
202. KEIPERT P, CHANG TMS (1983) In vivo assessment of pyridoxalated cross-linked polyhemoglobin as an artificial red cell substitute in rats. Trans Am Soc Artif Internal Organs 29:329-333.
203. CHANG TMS (1983) Artificial liver support: requirements and approaches. Int J Artif Organs 6(4):178-182.
204. ESPINOSA-MELENDEZ E, CHANG TMS (1983) State-of-the-art in hemoperfusion. Nephrologica Mexicana 4:51-55.
205. CHANG TMS (1983) Membrane biotechnology in artificial cells. Proceedings, Membrane Technology Conference, Oregon, USA.
206. CHANG TMS, P BARRE (1983) Effect of desferrioxamine on removal of aluminium and iron by coated charcoal haemoperfusion and haemodialysis. The **Lancet** Nov:1051-1053.
207. CHANG TMS, WH ZHENG (1983) Hemoperfusion with collodion coated Chinese petroleum based spherical charcoal. Chinese J of Biomedical Engineering 2:170-177.
208. ERGAN F, D THOMAS, CHANG TMS (1984) Selection and microencapsulation of an "NADH-oxidizing" bacterium and its use for NAD regeneration. **Applied Biochemistry and Biotechnology** 10:61-71.
209. CHANG TMS (1984) Artificial cells in medicine and biotechnology. **Applied Biochemistry and Biotechnology** 10:5-24.
210. ORTMANIS A, RJ NEUFELD, CHANG TMS (1984) Study of microencapsulated urease in a continuous feed, stirred tank reactor. **Enzyme Microb Technol** 6:135-139.
211. BOURGET L, CHANG TMS (1984) Artificial cell-microencapsulated phenylalanine ammonia-lyase. **Applied Biochemistry and Biotechnology** 10:57-59.
212. CHANG TMS (1984) Artificial cells in hemoperfusion and other applications. **Nephron** 36:161-168 (special festschrift issue for Professor Kolff).

213. CHANG TMS (1984) Artificial cells. "Biomedical Applications ofMicroencapsulation (F LIM, ed.) CRC Press, Boca Raton, Florida, USA. pp 85-103.
214. NEUFELD R, M ARBELOA, CHANG TMS (1984) Design of a fluidized bed reactorfor microencapsulated urease. **Applied Biochemistry and Biotechnology** 10:109-119.
215. CHANG TMS (1984) Microencapsulation: An introduction**. Applied Biochemistry and Biotechnology** 10:3-4.
216. KEIPERT P, CHANG TMS (1984) Preparation and in-vitro characteristics of a blood substitute based on pyridoxylated polyhemoglobin**. Applied Biochemistry and Biotechnology** 10:133-141.
217. CHANG TMS (1984) Liver support systems. in "Life Support Systems in IntensiveCare" (BARTLETT, ed.) Year Book Publisher, pp.461- 485.
218. CHANG TMS (1984) Artificial cells. in "Polymeric Materials and ArtificialOrgans" (CG GEBELEIN, ed.) American Chemical Society, Washington, DC,pp.171-180.
219. CHANG TMS (1984) Coated charcoal hemoperfusion. Life Support Systems 2:99-106.
220. BARRE P, CHANG TMS (1984) Application of coated charcoal hemoperfusionto clinical practice. The Renal Family Journal 6:20-25.
221. SHI ZQ, CHANG TMS (1984) Amino acid disturbances in experimental hepaticcoma rats. Int J Artif Organs 7:197-202.
222. SHI ZQ, CHANG TMS (1984) Effect of charcoal hemoperfusion on aminoacid disturbance in experimental hepatic coma. Int J Artif Organs 7:203-208.
223. CHANG TMS (1984) Artificial cells. "Biomaterial in Artificial Organs" (JP PAUL,JDS GAYLOR, JM COURTNEY, T GILCHRIST, eds.) McMillan Press, London. pp.103-111.
224. CHANG TMS, C LISTER, R VARMA (1984) Kinetics of coated charcoal hemoperfusion in the removalof Desferal for the elimination of aluminum. "Progress in Artificial Organs" (K ATSUMI, M MAEKAWA, K OTA, ed.) ISAO Press, Cleveland. pp. 602-605.
225. DIXIT V, CHANG TMS (1984) In vitro and clinical studies of the removal of cortisol, thyroxine, insulin and thyroid-stimulating hormone by coated charcoalhemoperfusion.
226. CHANG TMS, M ODAKA, GE SCHREINER, V BONOMINI, O OTUBSA, R IKSAWA (1984) Adsorbents in hemoperfusion. "Progress in Artificial Organs" (K. ATSUMI, M MAEKAWA, K. OTA, eds.) ISAO Press, Cleveland. pp. 624-627.
227. TABATA Y, M ODAKA, H HIRASAWA, H KOBAYASHI, M OHKAWA, H SATO, T SHIMADA, Y IRIE, CHANG TMS (1984) The effects of charcoal hemoperfusion onthe liver metabolism of fulminant hepatic failure rats. "Progress in Artificial Organs" (K. ATSUMI, M MAEKAWA, K. OTA, eds.) ISAO Press, Cleveland. pp. 747-749.
228. SHI ZQ, CHANG TMS (1985) Amino acid disturbance in experimental hepaticcoma: the effects of charcoal hemoperfusion. "Hemoperfusion and Artificial Organs" (TMS CHANG & BL HO, eds.) China Academic Publisher, pp. 301-310.
229. TABATA T, M ODAKA, H HIRASAWA, H KOBAYASHI, M OHKAWA, K SOEDA, H SATO, T SHIMADA, Y IRIE, CHANG TMS (1985) The effect of charcoal hemoperfusion on the adenine nucleotide of the liver in fulminant hepatic failure rats. "Hemoperfusion and Artificial Organs" (CHANG TMS & BL HO, eds.) China Academic Publisher, pp. 296-300.
230. CHANG TMS (1985) Biomedical applications of artificial cells immobilized enzymes, cells and other biologically active materials. "Enzymes and Immobilized Cells in Biotechnology" (AI LASKIN, ed.) Addison-Wesley Publishing Co., Reading, Mass., USA, pp.263-281.
231. BOURGET L, CHANG TMS (1985) Phenylalanine ammonia-lyase immobilized in semipermeable microcapsules for enzyme replacement in phenylketonuria. Federationof European Biochemical Societies (FEBS Letters) 180:5-8.
232. CHANG TMS (1985) Biotechnology of artificialcells including its application in artificial organs. "The principles, applications and regulations of biotechnology in Industry, Agriculture and Medicine" (CL COONEY, A HUMPHREY, eds.) in "Comprehensive Biotechnology", Pergamon Press, New York. pp. 53-72.
233. CHANG TMS (1985) Artificial cell research at the Artificial Cells and Organs Research Centre. "Hemoperfusion and Artificial Organs" (CHANG TMS & BL HO, eds.) China Academic Publisher, pp. 12-20.
234. KEIPERT PE, CHANG TMS (1985) Pyridoxylated polyhemoglobin as a blood

substitute for resuscitation of lethal hemorrhagic shock in conscious rats. Biomat Med Dev Artif Organs 13:1-15.
235. DIXIT V, CHANG TMS (1985) Preliminary report on effects of prostaglandine on brain edema in fulminant hepatic failure rats. Int J Artificial Organs 8(1):55-56.
236. CHANG TMS (1985) Artificial cells with regenerating multienzyme systems**. Methods in Enzymology** 112:195-203.
237. CHANG TMS, BARRE P, S KURUVILLA (1985) Long-term reduced time hemoperfusion-hemodialysis compared to standard dialysis: A preliminary crossover analysis. Trans Am Soc Artif Intern Organs 31:572-576.
238. CHANG TMS (1985) The future potentials of blood substitutes in transfusion. Transplantation Today Sept:40-45.
239. CHANG TMS (1986) Experimental evaluation of artificial liver support. "Liver Failure" (R WILLIAMS, ed.) Clinics in Critical Medicine Series, Churchill Livingstone Inc., UK pp. 191-206.
240. YUAN ZY, CHANG TMS (1986) Rat microsomes and cytosol immobilized by microencapsulation in artificial cells. Int J Artif Organs 9(1):63-68, 1986.
241. CHANG TMS (1986) Application of artificial cells in hemoperfusion, blood substitutes, immunosorption, artificial pancreas, and enzyme replacement. Progress in Artificial Organs (Y. Nose C. Kjellstrand and P. Ivanovich, eds.) ISAO Press, Cleveland, USA pp. 232-238.
242. HERTZMAN CM, PE KEIPERT, CHANG TMS (1986) Serum antibody titers in rats receiving repeated small subcutaneous injections of hemoglobin or polyhemoglobin: a preliminary report. Int J Artif Organs 9:179-182.
243. CHANG TMS (1986) Experimental artificial liver support with emphasis on fulminant hepatic failure: concepts and reviews. "Seminars in Liver Diseases Series" on "Fulminant Hepatic Failure" 6:148-159.
244. CHANG TMS (1986) Immobilization of bioactive material by microencapsulation in artificial cells for medicine and biotechnology. Proceedings 13th International Symposium on Controlled Release Bioactive Materials, pp. 21-22.
245. CHAWLA AS, CHANG TMS (1985-86) In-vivo degradation of poly-(lactic acid) of different molecular weights. Biomat, Med Dev, Art Org 13(3_):153-162.
246. BARRE P, A GONDA, CHANG TMS (1986) Routine clinical applications of hemoperfusion-hemodialysis in uremia. Int J Artif Organs 9:305-308.
247. CHANG TMS (1986) Book review on "Bioactive Polymeric Systems" Quarterly Review of Biology 61:255.
248. CHANG TMS (1986) Hemoperfusion in poisoning, fulminant hepatic failure, aluminium and iron removal, uremia and immunosorption. Progress in Artificial Organs (Y. Nose, C. Kjellstrand and P. Ivanovich, eds.) ISAO Press, Cleveland, USA pp. 595-600.
249. DUECK CL, RJ NEUFELD, CHANG TMS (1986) Hydrodynamics of a fluidized bed reactor for urea hydrolysis by microencapsulated urease. Can J Chemical Engineering 64:540-546.
250. SIPEHIA R, CHAWLA AS, CHANG TMS (1986) Enhanced albumin binding to polypropylene beads via anhydrous ammonia gaseous phase. **Biomaterials** 1, 471-473, 1986.
251. SIPEHIA R, RAB BANNARD, CHANG TMS (1986) Adsorption of large lipophilic molecules with exclusion of small hydrophilic molecules by microencapsulated activated charcoal formed by coating with polyethylene membrane. **Journal of Membrane Science** 29:277-286, 1986
252. ESPINOSA-MELENDEZ E, PA BOURGOUIN, CHANG TMS (1986) Combined hemoperfusion/hemodialysis in the treatment of uremic patients with vascular access problems: Int J Artif Organs 9:309-312.
253. WONG H, CHANG TMS (1986) Bioartificial liver: implanted artificial cells microencapsulated living hepatocytes increases survival of liver failure rats. Int J Artif Organs 9:335-336.
254. BOURGET L, CHANG TMS (1986) Phenylalanine ammonia-lyase immobilized in microcapsules for the depleture of phenylalanine in plasma in phenylketonuric rat model. **Biochim. Biophys. Acta**. 883:432-438.
255. ILAN E, CHANG TMS (1986) Modification of lipid-polyamide microcapsules for immobilization of free cofactors and multienzyme system for the conversion of ammonia to glutamate. **Applied Biochemistry and Biotechnology** 13:221-230, 1986.
256. ARBELOA M, RJ NEUFELD, CHANG TMS (1986) Analysis of microencapsulated

urease, fluidized bed reactor under steady and transient state operating conditions**.** **Journal of Membrane Science** 29:321-331.
257. WAHL HP, CHANG TMS (1986) Recycling of NAD+ cross-linked to albumin or hemoglobin immobilized with multienzyme systems in artificial cells**. J of Molecular Catalysis** 39:147-154, 1986.
258. LANGER R, PJ BLACKSHEAR, CHANG TMS, MD KLEIN, JS SCHULTZ (1986) Enzyme and drug delivery systems. Trans Am Soc Artif Internal Organs 32:639-645.
259. CHANG TMS (1987) Modified Hemoglobin as Red Blood Cell Substitutes. J Biomat. Art. Cells Art. Org. 15:323-328.
260. ILAN E, CHANG TMS (1987) Conversion of ammonia to glutamate by L-glutamate dehydrogenase, alcohol dehydrogenase and NAD+ immobilized within lipid-polyamide polyethyleneimine microcapsules. **Advances in Experimental Medicine and Biology** 223, 189-192.
261. CHANG TMS, R VARMA (1987) Pyridoxalated Heterogenous and Homologous Polyhemoglobin and Hemoglobin: Systemic effects of replacement transfusion in rats previously receiving immunizing doses. J. Biomat. Art. Cells Art. Org. 15:443-452.
262. CHANG TMS (1987) Biomaterials, Artificial Cells and Artificial Organs: an editorial. J. Biomat. Art. Cells Art. Org. 15:vii-viii.
263. WOLFE EA, CHANG TMS (1987) Orally ingested microencapsulated urease and an adsorbent, zirconium phosphate, to remove urea in kidney failure. Int. J. Artif. Organs 10:269-275.
264. CHANG TMS (1987) Applications of Artificial Cells in Medicine and Biotechnology. Int. J. Biomaterials, Artificial Cells and Artificial Organs 15:1-20.
265. GU KF, CHANG TMS (1987) Conversion of ammonia or urea to L-leucine, L-valine and L- isoleucine by Artificial Cells, immobilized multienzyme system. Int. J. Biomaterials, Artificial Cells and Artificial Organs 15:297-304.
266. CHANG V, A. BATTISTIN, R. RODRIGUE CHANG TMS (1987) Flow Analysis for Optimal Configuration of Hemoperfusion Device. Int. J. Artificial Organs 10:115-120.
267. ERGAN F, D THOMAS, CHANG TMS (1987) Immobilization of the "NADH-oxidase" function of the bacterium Leuconostoc Mesenteroides in matrix supported microcapsules for continuous cofactor regeneration. Ann. New York Acad. Sci 501:372-376.
268. KEIPERT PE, CHANG TMS (1987) In-vivo effects of total and partial isovolemic exchange transfusion in fully conscious rats using pyridoxylated polyhemoglobin solution as a colloidal oxygen-delivery blood substitute. **Vox Sanguinis** 53:7-14.
269. CHANG TMS (1987) Artificial Cells in Medicine and Biotechnology. Cas Lek Ces 126:6-10.
270. CHANG TMS (1987) Recycling of NAD(P) by Multienzyme Systems Immobilised by microencapsulation in Artificial cells. **Methods in Enzymology** 136:67-82
271. HANG TMS, M FARMER, RP GEYER, G MOSS (1987) Blood substitutes based on modified hemoglobin and fluorochemicals. TASAIO - Official Journal of Am. Soc. Artif. Int. Organs. 33.
272. DIXIT V, CHANG TMS (1987) Effects of prostaglandin on brain edema and liver histopathology in a galactosamine- induced fulminant hepatic failure rat model. J. Biomat. Art. Cells Art. Org. 15:559-574.
273. ZHOU MX, CHANG TMS (1987) Effects of Polylactic Acid Microcapsules Containing Prostaglandin E2 on the Survival Rates of Grade II Coma Galactosamine-induced Fulminant Hepatic Failure Rats. J. Biomat. Art. Cells Art. Org. 15:549-558.
274. MORLEY D, CHANG TMS (1987) Effect of Membrane Thickness of Collodion Coated Activated Charcoal on Adsorption of Small and Middle Molecules. J. Biomat. Art. Cells Art. Org. 15:617-632.
275. GU KF, CHANG TMS (1988) Multienzyme system and Dextran-NAD immobilized by microencapsulation within artificial cells in a reactor for conversion of urea into L-glutamic acid in "Bioreactor Immobilized Enzymes and Cells" (M Moo-Young, ed.) Elsevier Press, New York, pp. 59-62.
276. CHANG TMS (1988) Methods in the medical applications of immobilized proteins, enzymes and cells. **Methods in Enzymology** 137:444-457.
277. GU KF, CHANG TMS (1988) Conversion of ammonia or urea into L-leucine, L-valine and L- isoleucine using artificial cell immobilising multienzyme system and dextran-NADH+. I. Glucose dehydrogenase for cofactor recycling. ASAIO - Official Journal Am.

Soc. Artif. Int. Organs. 11:24-28.
278. ZHOU MX, CHANG TMS (1988) Control release of prostaglandin E2 from polylactic acid microcapsules, microparticles and modified microparticles. J. Microencapsulation. 5:27-36.
279. SIPEHIA R, CHAWLA AS, JN DAKA, CHANG TMS (1988) "Immobilization of enzymes on polypropylene beads surfaces by anhydrous ammonia gaseous plasma technique". Journal of Biomedical Material Research 22(5):417-422.
280. CHANG TMS (1988) 30th Anniversary of Artificial Red Blood Cell Research. J. Biomat. Art. Cells Art. Org. 16:1-9.
281. CHANG TMS (1988) Red blood cells substitutes: Microencapsulated hemoglobin and cross- linked hemoglobin including pyridoxylated polyhemoglobin and conjugated hemoglobin. J. Biomat. Art. Cells Art. Org. 16:11-29.
282. NING J, CHANG TMS (1988) Effects of stroma-free Hb and polyhemoglobin on complement activation blood cell counts and coagulation factors in rats. J. Biomat. Art. Cells Art. Org. 16:651-652.
283. CHANG TMS, R VARMA (1988) Immunological and systemic effects of transfusions in rats using pyridoxylated hemoglobin and polyhemoglobin from homologous and heterogenous sources. J. Biomat. Art. Cells Art. Org. 16:205-215.
284. KEIPERT PE, CHANG TMS (1988) Pyridoxylated-polyhemoglobin solution: A low viscosity oxygen- delivering blood replacement fluid with normal oncotic pressure and long-term storage feasibility. J. Biomat. Art. Cells Art. Org. 16:185-196.
285. deVARENNES B, CHANG TMS, DJF SYMES, A GUERRATY (1988) Isolated heart preservation for 24 hours: is O2 important? J. Biomat. Art. Cells Art. Org. 16:357-358.
286. WALTER S, CHANG TMS (1988) Chronotropic effects of stroma-free hemoglobin and polyhemoglobin on cultured myocardiocytes derived from newborn rats. J. Biomat. Art. Cells Art. Org. 16:701-703.
287. GU KF, CHANG TMS (1988) Conversion of -ketoglutarate into L-glutamic acid with urea as ammonium source using multienzyme system and dextran-NAD+ immobilised by microencapsulation with artificial cells in a bioreactor. **J. Bioeng. Biotech**. 32: 363-368.
288. DAKA JN, KG LAIDLER, SIPEHIA R, CHANG TMS (1988) "Immobilized and kinetics of lactate dehydrogenase at a rotating nylon disk: **Biotechnology and Bioengineering**, 32: 213-219.
289. CHANG TMS (1988) Artificial Cells as Bioreactive Biomaterials. J. Biomaterials Applications, 3, 116-125.
290. CHANG TMS, R LANGER, R SPARKS, G REACH (1988) Drug Delivery System in Biotechnology. J. Artificial Organs 12: 248-251.
291. WONG H, CHANG TMS (1988) The viability and regeneration of artificial cell microencapsulated rat hepatocyte xenograft transplants in mice. J. Biomaterials, Artificial Cells and Artificial Organs. 16, 731-740.
292. CHANG TMS (1988) Medical application of artificial cells in transfusion, phenylketonuria, essential amino acid production and liver failure. Ann. New York Acad. Sci. 542: 507-514.
293. CHANG TMS (1988) Blood substitutes prepared from modified hemoglobin "Blood Substitutes: Preparation, Physiology and Medical Application" K.C. Lowe (ed.) 87-93.
294. KASHANI SA, CHANG TMS (1988) Release of hepatic stimulatory substance from cultures of free and microencapsulated hepatocytes: preliminary report. J. Biomaterials, Artificial Cells and Artificial Organs. 16, 741-746.
295. CHANG TMS (1988) The role of Biotechnology in Bioartificial or Hybrid Artificial Cells and Organs: editorial. J. Biomaterials, Artificial Cells and Artificial Organs. 16: 704-705.
296. CHANG TMS (1988) Artificial Cells in Blood Substitutes and Artificial Organs. Cirugia Y Cirujano
297. CHANG TMS (1988) Artificial cells with ultrathin lipid-polymer or lipid-protein membranes "New Technological Applications of Phospholipid Bilayers, Thin Films and Vesicles", B.P. Gaber, J.M. Schnur, D. Chapman, eds., Plenum Press, 215-223.
298. NISHIYA T, Y. OKUMURA, CHANG TMS (1988) Synthesis and Properties of circular dichroism active phospholipids. Chem. Phys. Lipids 49(1-2): 69-79.
299. NISHIYA T, M. DASGUPTA, Y. OKUMURA, CHANG TMS (1988) Circular Dichroism Study of Membrane Dynamics Focused on Effect of Monosialoganglioside**. J.**

Biochemistry 104(1):62-65.
300. CHANG TMS, CW LISTER (1988/1989) Plasma/Intestinal concentration patterns suggestive of entero- portal recirculation of amino acids: Effects of oral administration of asparaginase, glutaminase and tyrosinase immobilized by microencapsulation in Artificial Cells. J. Biomaterials, Artificial Cells and Artificial Organs 16:915- 926.
301. CHANG TMS (1989) The use of modified hemoglobin as an oxygen carrying blood substitute. **Transfusion Medicine Review** 3:213-218.
302. CHANG TMS (1989) Hybrid artificial cells encapsulation and immobilisation of cell culture, organelles and multienzyme system "Hybrid Artificial Organs", ed. C. Baquey and B. Dupuy. Colloque INSERM 177:239-246.
303. CHANG TMS, P. BARRE, C. LISTER, S. KURUVILLA (1989) Artificial cells in medical applications with emphasis on hemoperfusion for aluminium removal and crossover control clinical trial on hemoperfusion-hemodialysis **Contributions to Nephrology** 70:237-249.
304. BOURGET L, CHANG TMS (1989) Effects of oral administration of artificial cells immobilized phenylalanine ammonia-lyase on intestinal amino acids of phenylketonuric rats. J. Biomat., Art. Cells and Art. Organs, 17:161-182.
305. GAROFALO F, CHANG TMS (1989) Immobilization of P. pictorum in open pore agar, alginate polylysine-alginate microcapsules for serum cholesterol depletion. J. Biomat., Art. Cells and Art. Organs, 17: 271-290.
306. LALLA FR, NING J AND CHANG TMS (1989) Effects of pyridoxalated polyhemoglobin and stroma-free hemoglobin on ADP-induced platelet aggregation. J. Biomat., Art. Cells and Art. Organs, 17:363-369.
307. DAKA NJ, SIPEHIA R, CHANG TMS (1989) Enhanced oxidation of bilirubin by an immobilized tri-enzyme system of glucose oxidase, bilirubin oxidase and horseradish peroxidase. **Biochim. Biophys. Acta**. 991:487-489.
308. SIPEHIA R, J.N. DAKA, A.S. CHAWLA, CHANG TMS (1989) Immobilisation of protein and enzymes onto functionalised polypropylene surfaces by a gaseous plasma modification technique "Biocatalysis and Biomimetics", J.D. Burrington and D.S. Clark, eds., Washington,D.C., Chapter 12, 1989.
309. BRUNI S, CHANG TMS (1989) Hepatocytes immobilized by microencapsulation in artificial cells: Effects on hyperbilirubinemia in Gunn Rats. J. Biomat. Artif. Cells and Artif. Org. 17:403-412.
310. PALMOUR RM, P. GOODYER, T. READE, CHANG TMS (1989) Microencapsulated xanthine oxidase as experimental therapy in Lesch-Nyhan Disease. **Lancet** 2(8664):687-688.
311. DAKA JN, CHANG TMS (1989) Bilirubin removal by the pseudoperoxidase activity of free and immobilized hemoglobin and hemoglobin co-immobilized with glucose oxidase. Biomat. Artif. Cells and Artif. Org. 17:553-562.
312. CHANG TMS (1989) Preparation and characterization of xanthine oxidase immobilized by microencapsulation in artificial cells for the removal of hypoxanthine. Biomat. Artif. Cells and Artif. Org. 17:611-616.
313. SIPEHIA R, RAB BANNARD, CHANG TMS (1989) "Poly(vinylidene fluoride) or poly(vinylidene chloride/vinyl chloride) - coated activated charcoal for the adsorption of large lipophilic molecules with exclusion of small hydrophilic molecules**". J. Membrane Science** 47:293-301.
314. CHANG TMS (1989) Artificial Cells for hemoperfusion and other applications. Nefrologia Mexicana. 10(1):21-26.
315. NISHIYA T, CHANG TMS (1989) Effects of cholesterol and melittin on spontaneous lipid transfer between liposomes. Chem. Phys. Lipids. 51:83-90.
316. DIXIT V, CHANG TMS (1990) Brain edema and blood brain barrier in galactosamine induced fulminant hepatic failure rats: animal models for evaluation of liver support systems Journal of American Soc. Artif. Int. Organs 36:21-27.
317. CHANG TMS (1990) Modified hemoglobin: Endotoxin and safety studies. J. Biomaterials, Artificial Cells and Artificial Organs 18:vii- viii.
318. WALTER SV, CHANG TMS (1990) Chronotropic effects of in-vivo perfusion with albumin, stroma- free hemoglobin and polyhemoglobin solutions J. Biomaterials, Artificial Cells and Artificial Organs 18:283- 299.
319. NING J, CHANG TMS (1990) Measurement of complement activation by CH50 in rats. J. Biomaterials, Artificial Cells and Artificial Organs 18:203-218.

320. NING J, CHANG TMS (1990) Effects of homologous an heterologous stroma-free hemoglobin and polyhemoglobin on complement activation, leukocytes and platelets. J. Biomaterials, Artificial Cells and Artificial Organs 18:219- 233.
321. GU KF, CHANG TMS (1990) Conversion of ammonia or urea into essential amino acids, L- leucine, L-valine and L-isoleucine using artificial cells containing an immobilized multienzyme system and dextran-NAD+. 2. Yeast Alcohol Dehydrogenase for coenzyme recycling. **J. Biotechnology and Applied Biochemistry** 12:227-236.
322. GU KF, CHANG TMS (1990) Production of essential L-branched-chained amino acids, in bioreactors containing artificial cells immobilized multienzyme systems and dextran-NAD+. **Applied Biochemistry and Biotechnology** 26:263-269.
323. KHANNA R, CHANG TMS (1990) Characterization of L-histidine ammonia-lyase immobilized by microencapsulation in artificial cells: Preparation kinetics, stability, and in vitro depletion of histidine. Int. J. Art. Org. 13:189-195.
324. NING J AND CHANG TMS (1990) In-vivo effects of stroma-free hemoglobin and polyhemoglobin on coagulation factors in rats. Int. J. Artificial Organs 13(8):509-516
325. CHANG TMS (1990) Biotechnological and medical application of immobilization of hepatocytes, microorganisms and enzyme system by microencapsulation in artificial cells. **Enzyme Engineering** 10(613):109-115.
326. GU KF, CHANG TMS (1990) Conversion of ammonia or urea into essential amino acids. L- leucine, L- valine and L-isoleucine using artificial cells containing an immobilized multienzyme system and dextran-NAD+. IV. Malate dehydrogenase for co-enzyme recycling. **J. of Catalysis** 62:331-339.
327. SIPEHIA R, A. GARFINKLE, W.B. JACKSON, AND CHANG TMS (1990) Towards an artificial cornea: Surface modification of optically clear, oxygen permeable soft contact lens materials by ammonia plasma modification technique for the enhanced attachment and growth of corneal epithelial cells. Int. J. Biomaterials, Artificial Cells and Artificial Organs 18(5):643-656.
328. CHANG TMS, AND C. LISTER (1990) A screening test of modified hemoglobin blood substitute before clinical use in patients - based on complement activation of human plasma. J. Biomaterials, Artificial Cells and Artificial Organs 18(5):693-702.
329. CHANG TMS (1991) Therapeutic application of immobilized protein and cells "Immobilized Proteins" of Bioprocess Technology Series (RF Taylor, ed.) Marcel Dekker, Inc., New York, 305-318.
330. GAROFALO FA, CHANG TMS (1991) Effects of mass transfer and reaction kinetics on serum cholesterol depletion rates of free and immobilized Pseudomonas-pictorum **Applied Biochemistry and Biotechnology** 27:75-91.
331. CHANG TMS (1991) Artificial Cells "Encyclopedia of Human Biology" (editor-inchief: Renalo Dulbecco). Volume 1, 377-383, Academic Press, Inc., San Diego, CA.
332. CHANG TMS (1991) Biomaterials, Artificial Cells and Immobilization Biotechnology, an editorial. Biomaterials, Artificial Cells and Immobilization Biotechnology, an International Journal 19:i-iii, 1991.
333. BRUNI S, CHANG TMS (1991) Encapsulated hepatocytes for controlling hyperbilirubinemia in Gunn Rats Int. J. Artificial Organs 14:239-241, 1991.
334. CATTANEO M and CHANG TMS (1991) The potential of microencapsulated ureasezeolite oral sorbent for the removal of urea in uraemia. Official Journal of the American Society of Artificial Internal Organs 37:80-87, 1991.
335. GU KF, CHANG TMS (1991) Conversion of urea into essential amino acids, L-leucine, L- valine and L- isoleucine using artificial cells containing an immobilized multienzyme system and dextran-NAD+. III. L-lactic dehydrogenase for co-enzyme recycling. **J. Applied Biochemistry and Biotechnology** 27:75-91
336. KASHANI S, CHANG TMS (1991) Physical chemical characteristics of hepatic stimulatory factor prepared from cell free supernatant of hepatocyte cultures. Biomaterials, Artificial Cells and Immobilization Biotechnology 19: 565-578.
337. KASHAN SI, CHANG TMS (1991) Effects of hepatic stimulatory factor released from free or microencapsulated hepatocytes on galactosamine induced fulminant hepatic failure animal model. Biomaterials, Artificial Cells and Immobilization Biotechnology 19:579-598.
338. WONG H, CHANG TMS (1991) Microencapsulation of cells within alginate poly-Llysine microcapsules prepared with standard single step drop technique: histologically identified membrane imperfections and the associated graft rejection. Biomaterials,

Artificial Cells and Immobilization Biotechnology 19:675-686.
339. WONG H, CHANG TMS (1991) A novel two-step procedure for immobilizing living cells in microcapsule for improving xenograft survival. Biomaterials, Artificial Cells and Immobilization Biotechnology 19:687- 698, 1991.
340. MOBED M, CHANG TMS (1991) Preparation and surface characterization of carboxymethylchitus incorporated submicron bilayer lipid membrane artificial cells (liposomes) encapsulating hemoglobin. Biomaterials, Artificial Cells and Immobilization Biotechnology 19:731- 744, 1991.
341. CHANG TMS (1992) Recent advances in artificial cells with emphasis on biotechnological approaches based on microencapsulation “Microcapsules and Nanoparticles in Medicine and Pharmacy" (editor: M. Donbrow), CRC Press Inc., Boca Raton, USA, 323-339.
342. CHANG TMS (1992) Blood substitutes based on modified hemoglobin prepared by encapsulation or crosslinking. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:154- 174, 1992.
343. CHANG TMS, C.W. LISTER (1992) An in-vitro screening test for modified hemoglobin to bridge the gap between animal safety studies and clinical use in patients. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:481-487, 1992.
344. CHANG TMS, C. LISTER, T. NISHIYA, R. VARMA (1992) Immunological effects of hemoglobin, microencapsulated hemoglobin, polyhemoglobin and conjugated hemoglobin using different immunizing schedules. Biomaterials, Artificial Cells and ImmobilizationBiotechnology 20:519- 526, 1992.
345. CHANG TMS, MOBED M, T. Nishiya (1992) Purification and characterization of liposomes encapsulating hemoglobin as potential blood substitutes. Biomaterial, Artificial Cells and Immobilization Biotechnology 20:53-70, 1992.
346. CHANG TMS (1992) Artificial Cells - 35 years. J. Artificial Organs 16:8-12, 1992.
347. CHANG TMS (1992) Artificial liver support based on artificial cells with emphasis on encapsulated hepatocytes. J. Artificial Organs 16:71-74, 1992.
348. MOBED M, CHANG TMS (1992) Purification and quantitative determination of carboxymethylchitin- incorporated into submicron bilayer-lipid membrane artificial cells (liposomes) encapsulating hemoglobin. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:329- 336, 1992.
349. TANI T, CHANG TMS, M. KODAMA, M. TSUCHIYA (1992) Endotoxin removed from hemoglobin solution using polymyxin-B immobilized fibre (PMX-F) followed by a new turbidometric endotoxin assay. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:394- 399, 1992.
350. ILAN E, P. MORTON, CHANG TMS (1992) Bovine hemoglobin anaerobically reacted with divinyl sulfone: A potential source for hypothermic oxygen carriers. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:246- 255, 1992.
351. MOBED M, T. NISHIYA, CHANG TMS (1992) Preparation of carboxymethylchitin incorporated submicron bilayer-lipid membrane artificial cells (liposomes) encapsulating hemoglobin. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:325-328, 1992.
352. CHANG TMS, R. VARMA (1992) Effect of a single replacement of Ringer lactate, hypertonic saline/dextran, 7g% albumin, stroma-free hemoglobin, o-Raffinose polyhemoglobin, or whole blood, on the long-term survival of unanesthetized rats with lethal hemorrhagic shock after 67% acute blood loss. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:433- 440, 1992.
353. ITO Y, CHANG TMS (1992) In-vitro study of multicellular hepatocytes spheroid formed in microcapsules. J. Artificial Organs 16:422-426.
354. CHANG TMS (1992) Artificial cells in immobilization biotechnology. Biomaterials, Artificial Cells and Immobilization Biotechnology 20:1121-1143.
355. CHANG TMS (1992) Living cells and microorganism immobilized by microencapsulation inside artificial cells "Fundamentals of animal cell encapsulation and immobilization" (editor: M. Goosen), CRC Press, pp. 183-196.
356. CHANG TMS (1992) Artificial cells for artificial liver support "Artificial Liver Support" (editor: G.Brunner), Springer-Verlag Berlin, pp. 261-270.
357. CHANG TMS (1992) Hybrid artificial cells microencapsulation of living cells Official Journal of the American Society for Artificial Internal Organs 38:128-130.
358. CHANG TMS (1993) Safety studies of modified hemoglobin as oxygen carrying blood

substitute. **J. Hematologic Pathology**, 7:47-52.
359. CHANG TMS (1993) Adequacy of hemoperfusion in uremia "Adequacy of Dialysis", edited by V. BONOMINI and S. STEFONI.
360. ILAN E, P. MORTON, CHANG TMS (1993) The anaerobic reaction of bovine hemoglobin with divinyl sulfone: Structural changes and functional consequences. **Biochimica and Biophysica Acta** 1163:257-265.
361. GROWE GH, CHANG TMS, S.J. SLICHTER, P. TARTLER, M.C. POON (1993) New concepts in blood product usage. Annuals, Royal College of Physicians and Surgeons of Canada 26:106-108.
362. CHANG TMS (1993) Bioencapsulation in biotechnology. Biomaterials, Artificial Cells and Immobilization Biotechnology (Guest Editors D. Oncelet & M.Lievremont) 21:291-298,1993
363. COROMILI V, CHANG TMS (1993) Polydisperse dextran as a diffusing test solute to study the membrane permeability of alginate polylysine microcapsules. Biomaterials, Artificial Cells and Immobilization Biotechnology (Guest Editors D. Oncelet & M. Lievremont) 21: 427-444, 1993.
364. KOO J, CHANG TMS (1993) Secretion of erythropoietin from microencapsulated rat kidney cells: Preliminary results. International Journal of Artificial Organs 16:557-560,1993.
365. LLOYD-GEORGE I, CHANG TMS (1993) Free and microencapsulated Erwinia Herbicola for the production of tyrosine. Biomaterials, Artificial Cells and Immobilization Biotechnology (Guest Editors D. Oncelet & M.Lievremont) 21: 323-334, 1993.
366. D'Agnillo F & CHANG TMS (1993) Cross-linked hemoglobin-superoxide dismutase-catalase scavenges oxygen-derived free radicals and prevents methemoglobin Formation and iron release. Biomaterials, Artificial Cells and Immobilization Biotechnology 21:609-622, 1993
367. CHANG, TMS & CW LISTER (1993) Use of finger-prick human blood samples as a more convenient way for in vitro screening of modified hemoglobin blood substitutes for complement activation: a preliminary report. Biomaterials, Artificial Cells and Immobilization Biotechnology 21:685-690,1993.
368. PRAKASH S and CHANG TMS (1993) Genetically engineered E. coli cells containing K. aerogenes gene, microencapsulated in artificial cells for urea and ammonia removal. Biomaterials, Artificial Cells and Immobilization Biotechnology 21:629-636, 1993
369. CHANG TMS, C. LISTER (1994) Assessment of blood substitutes: II. In-vitro complement activation of human plasma and blood for safety studies in research, development, industrial production and preclinical analysis. J. Artificial Cells, Blood Substitutes and Immobilization Biotechnology (Guest editors: CHANG TMS, R.Winslow and J.Reiss) 22:171-180, 1994
370. CHANG TMS, R. VARMA (1994) Assessment of blood substitute: 1. Efficacy studies in anesthetized and conscious rats with loss of 1/3, 1/2 and 2/3 total blood volume J. of Artificial Cells, Blood Substitutes and Immobilization Biotechnology (Guest editors: CHANG TMS, R.Winslow and J.Reiss) 22:159-169, 1994.
371. YU WP, CHANG TMS (1994) Submicron biodegradable polymer membrane hemoglobin nanocapsules as potential blood substitutes: A preliminary report. J. of Artificial Cells, Blood Substitutes and Immobilization Biotechnology (Guest editor: R.Winslow) 22: 889-894,1994.
372. ILAN E, CHANG TMS (1994) Human hemoglobin anaerobically reacted with divinyl sulfone: A source for oxygen carriers. J. of Artificial Cells, Blood Substitutes and Immobilization Biotechnology (Guest editor: R.Winslow) 22: 687-694, 1994.
373. NISHIYA T, CHANG TMS (1994) Toxicity of liposomes containing low mol% of dienoyl phosphocholine to blood: Use of carboxymethyl chitin to reduce toxicity. J. of Artificial Cells, Blood Substitutes and Immobilization Biotechnology (Guest editor: R.Winslow) 22: 883-888, 1994.
374. CHANG TMS (1994) Efficacy of rbc substitutes J. of Artificial Cells, Blood Substitutes and Immobilization Biotechnology 22: ii-iii,1994
375. CHANG TMS (1994) Artificial Cell including blood substitutes and biomicroencapsulation: from ideas to applications. J. Artificial Cells, Blood Substitutes and Immbolization Biotechnology, 22: vii-xiv,1994
376. PRAKASH, S, CHANG. TMS (1995) Kinetic studies of microencapsulated genetically

engineered E. coli cells containing K. aerogenes gene for urea and ammonia removal. **Biotechnology & Bioengineering** 46: 621-626, 1995.
377. CHANG TMS (1995) Artificial cells with emphasis on bioencapsulation in biotechnology **Biotechnology Annual Review** - 1: 267-296,1995
378. CHANG TMS, BOURGET L & Lister C (1995) A new theory of enterorecirculation of amino acids and its use for depleting unwanted amino acids using oral enzyme-artificial cells, as in removing phenylalanine in phenylketonuria. Artificial Cells, Blood Substitutes & Immobilization Biotechnology,25: 1-23.
379. BRUNI S and CHANG TMS (1995) Effects of donor strains and age of the recipient in the use of microencapsulated hepatocytes to control hyperbilirubinemia in the Gunn rat. **International Journal of Artificial Organs** 18: 332-339, 1995.
380. BRUNI, S & CHANG TMS (1995) Kinetics of UDP-glucuronosyltransferase in bilirubin conjugation by encapsulated hepatocytes for transplantation into Gunn rats **J. Artificial Organs** 19:449-457, 1995.
381. CHANG TMS (1995) Present Status and future perspectives of modified hemoglobin as red blood cell substitutes pp 21-34 in **book on "Red Blood Cells Substitutes"** edited by E.Tsuchida. John Wiley & Sons, New York
382. CHANG TMS (1995) "Modified hemogolobin as red blood cell substitutes" Chapter 11 **in "Liposome in Biomedical Application"** ed P.N.Shek, Harwood Academic Publisher GmbH USA. pp 209-216.
383. SAFOS S & CHANG TMS (1995) Enzyme replacement therapy in ENU2 phenylketonuric mice using oral microencapsulated phenylalanine ammonia-lyase: a preliminary report. Artificial Cells, Blood Substitutes & Immobilization Biotechnology,23: 681-692.
384. QUEBEC EA & CHANG TMS (1995) Superoxide dismutase and catalase crosslinked to polyhemoglobin reduces methemoglobin formation in-vitro. Artificial Cells, Blood Substitutes & Immobilization Biotechnology,23: 693-706, 1995.
385. LYOLD-GEORGE, I and CHANG TMS (1995) Characterization of free and alginate polylysine-alginate microencapsulated Erwinia herbicola for the conversion of ammonia, pyruvate and phenol into L-tyrosine and L-DOPA **J. Bioengineering and Biotechnology** 48:706-714,1995.
386. CHANG TMS (1995) Crosslinked hemoglobin being well into clinical trials, increasing research efforts are now on a second-generation red blood cell substitute based on encapsulated hemoglobin. Artificial Cells, Blood Substitutes & Immobilization Biotechnology,23:257-263.
387. CHANG TMS (1995) Kunstliche Zellen und kunstlicher Blutersatz (Artificial Cells & Blood Substitutes) invited chapter **in "Kunstliche Organe"** (Artificial Organs) pp32- 40 (ed E.S.Bucherl) Wissenschaftliche Buchgesellschaft, Darmstadt. Germany.
388. MOBED, M and CHANG, TMS (1996) The importance of standardization of carboxymethylchitin cocnetration by the dye- binding capacity of alcian blue before adsorption on liposomes Artificial Cells, Blood Substitutes & Immobilization Biotechnology,24:107-120
389. CHANG TMS and PRAKASH, S (1996) Artificial cells for bioencapsulation of cells and genetically engineered e. Coli: for cell therapy, gene therapy and removal of urea and ammonia. Chapter 75 in book on "Expression and Detection of Recombinant Genes" **in Methods in Molecular Biology**
390. MOBED, M and CHANG, TMS (1996) Use of Chitinase for surface characterization of carbozymethy and carboxtmethyl/clycolchitin coated liposomes for potential medical applications. **Chitin Enzymology** 2:313-315.
391. PRAKASH, S and CHANG TMS (1996) Microencapsulated genetically engineered E.coli DH5 cells for plasma urea and ammonia removal based on: 1. column bioreactor and 2. oral administration in uremic rats. Artificial Cells, Blood Substitutes & Immobilization Biotechnology, an international journal. 24:201-218.
393. Yu WP & TMS CHANG (1996) Submicron polymer membrane hemoglobin nanocapsules as potential blood substitutes: preparation and characterization. Artificial Cells, Blood Substitutes & Immobilization Biotechnology,an international journal 24:169-184.
394. PRAKASH, S. and CHANG, T.M.S (1996) Microencapsulated genetically engineered live E coli DH5 cells administered orally to maintain normal plasma urea level in uremic

rats" **Nature Medicine**. 2: 883-887, August 1996.
395. TMS CHANG (1996) Editorial: Past, Present and Future Perspectives on the 40thAnniversary of Hemoglobin Based Red Blood Cell Substitutes. Artificial Cells,Blood Substitutes & Immobilization Biotechnology,an international journal 24: ixxxvi.
396. F. D'AGNILLO & TMS CHANG (1997) Production of hydroxyl radical generation in a rat hindlimb model of ischemia-reperfusion injury using crosslinked hemoglobin-superoxide dismutase-catalase. Artificial Cells, Blood Substitutes & Immobilization Biotechnology, an internationaljournal 25:163-180.
397. S. RAZACK, F. D'AGNILLO & TMS CHANG (1997) Crosslinked hemoglobin-superoxide dismutase-catalase scavenges free radicals in a rat model of intestinal ischemia-reperfusion injury. Artificial Cells, Blood Substitutes & Immobilization Biotechnology, an international journal 25: 181-192.
398. TMS CHANG (1997) Recent and Future Developments in Modified Hemoglobin and Microencapsulated Hemoglobin as Red Blood Cell Substitutes. Artificial Cells, Blood Substitutes & Immobilization Biotechnology, an international journal 25: 1-24
399. CHANG TMS (1997) Live E. coli cells to treatment uremia: replies to letters to the editor, **Nature Medicine**. 3:2-3, 1997.
400. CHANG TMS (1997) Red Blood Cell Substitutes based on Modified Hemoglobin **Chapter in "Principles of Tissue Engineering"** eds. RP Lanza, R Langer & WL Chick Academic Press/Landes Co. Austin, pp517-526 399.
401. CHANG TMS (1997). An Urgent need to include blood substitute as a priority area in any national policies on blood supply. Artificial Cells, Blood Substitutes & Immobilization Biotechnology, an international journal 25: 4th issue,i-ii, 1997.
402. CHANG TMS (1997) "Artificial Cells" in **"Encyclopedia of Human Biology" 2nd Edition (Editor in chief: Renalo Dulbecco)**.Academic Press, Inc., San Diego, CA. 457-463
403. CHANG TMS (1997) Artificial Cells & Bioencapsulation in Bioartificial Organs. **New York Academy of Science.** 831:249-259.
404. CHANG TMS (1997) "Introduction" Chapter I in Book on "Blood substitutes: principles, methods, products & clinical trials" , Karger, Basel, Switzerland pp1-2.
405. CHANG TMS (1997) "Why do we need blood substitutes?" Chapter II in Book on "Blood substitutes: principles, methods, products & clinical trials", Karger, Basel, Switzerland pp 3-8.
406. CHANG TMS (1997) "What are modified hemoglobin blood substitutes?" Chapter III in Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel, Switzerland pp 9-31.
407. CHANG TMS (1997) "What are the functional and efficacy properties of modified hemoglobin?" Chapter VI in Book on "Blood substitutes: principles, methods, products & clinical trials" , Karger, Basel, Switzerland pp 32-47.
408. CHANG TMS (1997) "How safe are modified hemoglobin blood substitutes?" Chapter V in Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel, Switzerland pp 49-68.
409. CHANG TMS (1997) "What are the present modified hemoglobin blood substitutes being tested in clinical trial?" Chapter VI in Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel, pp 73-81.
410. CHANG TMS (1997) "Blood substitutes based on perflurocochemicals" Chapter VII in Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel, Switzerland pp 82-86.
411. CHANG TMS (1997) "Future perspectives of blood substitutes" Chapter VIII in Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel, Switzerland pp 88-105.
412. CHANG TMS (1997) "Should there be a priority on blood substitutes for national blood supply policy?" Chapter IX in Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel, pp 111-114.
413. CHANG TMS (1997) Future Perspectives of Red Blood Cell Substitutes in "Fundamental Principles and Clinical Application of Red Blood Cell Substitutes" (ed Rudolph,A, Feuerstein G & Rabinovici R)Marcel Dekker Publisher, N.Y. pp 465-474.
414. CHANG TMS (1998) Pharmaceutical and Therapeutic Applications of Artificial Cells including microencapsulation. Opening article, theme edition on "microspheres & microcapsules" **European Journal of Pharmaceutics and Biopharmaceutics** 45:3-8.

414. CHANG TMS (1998) "Introduction" in Volume II, Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel,Switzerland xv-vvii.
415. CHANG TMS , F D'AGNILLO & S. RAZACK (1998) "Crosslinked hemoglobin-superoxide dismutase-catalase: a second generation hemoglobin based blood substitute with antioxidant activities. in Volume II, Book on "Blood substitutes: principles, methods, products & clinical trials" Karger,Basel,Switzerland pp178-196
416. CHANG TMS & WP YU (1998) Nanoencapsulation of hemoglobin and red blood cell enzymes based on nanotechnology and biodegradable polymer. in Volume II, Book on "Blood substitutes: principles, methods, products & clinical trials" Karger, Basel,Switzerland. pp 216-231
417. PRAKASH S & TMS CHANG (1998) Growth and survival of renal failure rats that received oral microencapsulated genetically engineered E. coli DH5 cells for urea removal. Artificial Cells, Blood Substitutes & Immobilization Biotechnology.26: 35-51
418. CHANG TMS & PRAHASH, S. (1998) Microencapsulated genetically engineered cells: comparison with other strategies and recent progress. **Molecular Medicine Today**. 4:221-227
419. D'AGNILLO, F & TMS CHANG (1998) Absence of hemoprotein-associated free radical events following oxidant challenge of crosslinked hemoglobin-superoxide dismutase-catalase **Free Radical Biology & Medicine** 24(6):906-912
420. D'AGNILLO, F & TMS CHANG (1998) Polyhemoglobin-superoxide dismutase-catalase as a blood substitute with antioxidant properties. **Nature Biotechnology** 16 (7): 667-671
421. YU WP, J. WONG & TMS CHANG (1998) Preparation and characterization of polylactic acid microcapsules containing ciprofloxacin for controlled release **J. Microencapsulation**. 15:515-523
422. CHANG, TMS (1998) Modified hemoglobin-based blood substitutes: crosslinked, recombinant and encapsulated hemoglobin. **Vox Sanguinis** 74(suppl. 2):233-241
423. CHANG, TMS (1998) Editorial: New Concepts and Theories. Artif. Cells Blood Subst. Immobil. Biotech. 26: vii-viii.
424. CHANG, TMS (1998) Modified hemoglobin blood substitutes: present status and future perspectives. **Biotechnology Annual Review** 4:75-112
425. MOBED, M & TMS CHANG (1998) Adsorption of chitin derivatives onto liposomes:optimization of adsorption conditions. **J. Microencapsulation**. 15: 595-607
426. MOBED, M, CHANG, TMS (1998) Comparison of polymerically stabilized PEEGgrafted liposomes and physically adsorbed carboxymethylchitin and carboxytmethyl/clygochitin liposomes for biological applications. **Biomaterials** 19: 1167-1177
427. CHANG, TMS (1998). Editorial: Is there a role for first generation blood substitutes in the resuscitation of hemorrhagic shock? Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal. 26(5-6);i-iii,1998
428. MOBED, M, CHANG, TMS (1998) Colloidal stability of sterically stabilized grafted stealth liposomes and physically adsorbed carboxymethylchitin/ carboxymethylglycolchitin liposomes for biological applications. **J. Microencapsulation**
429. CHANG, TMS (1998) Artificial Cells with emphasis on cell encapsulation of genetically engineered cells. Artificial Organs. 22:958-965

430. CHANG, TMS (1998) Red blood cell substitutes in “Blood Preservation, Artificial Blood & Perioperative Fluid Management” **Seminars in Anesthesia, Perioperative Medicine and Pain**. Issue 67, vol 17, No 3, 208-215
431. CHANG. TMS (1998) Method for Microencapsulation of Enzymes, Cells and Genetically Engineered Microorganisms in "Tissue Engineering Methods and Protocols" (ed. JR Morgan and ML. Yarmush) in **Methods in Molecular Medicine** 18: 315-330
432. CHANG, TMS (1999) Artificial Blood: a prospective. **Trends in Biotechnology**. 17: 61-67.
433. SARKISSIAN, CN, SHAO, Z, Blain,F, PEEVERS,R, SU,H, HEFT,R, CHANG,TMS, SCRIVER, CR. (1999) A different approach to treatment of phenylketonuria: phenylalanine degradation with recombinant phenylalanine ammonia lyase**. Proceedings National Academy of Sciences.** 96: 2339-2344
434. WP YU, JP WONG AND TMS CHANG (1999) Biodegradable polylactic acid nanocapsules containing ciprofloxacin: preparation and characterization. Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 27 (3) 263-278

435. S. PRAKASH, AND T.M.S. CHANG (1999) Growth kinetics of genetically engineered *E. coli dh 5* cells in artificial cell apa membrane microcapsules: preliminary report Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 27 (3) 291-301
436. CHANG TMS & WP Yu (1999) Polymeric biodegradable hemoglobin nanocapsule as a new red blood cell substitute. Chapter 13 In "Present and furture perspectives of blood substitutes" ed. E. Tsuchida pp 161-169
437. CHANG, TMS (1999) Artificial Cells, Encapsulation and Immobilization. **Annual, N.Y. Acad. Sci**. 875:71-84
438. SILVIA BRUNI. & T.M.S. CHANG (1999) Comparision of bilirubin conjugation in encapsulated hepatocytes, hepatocyte homogenate and intact hepatocytes Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 27(4) 343-356
439. SILVIA BRUNI. & T.M.S. CHANG (1999) Kinetic studies of hepatocyte udpglucuronosyltransferase:evidence of an allosteric enzyme Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 27 (4) 357-366
440. CHANG TMS (1999) "Foreword" for book on **"Handbook of Cell Encapsulation**" (eds WM Kuhtreiber RP Lanza & WL Chick), Birkhauser & Springer-Verlag. xi-xiii
441. CHANG TMS & S PRAKASH (1999) Chapter on "Removal of urea in uremia and ammonia in liver failure with emphasis on the use of artificial cells containing genetically engineered cells" for book on **"Handbook of Cell Encapsulation"** (eds WM Kuhtreiber,RP Lanza & WL Chick), Birkhauser & Springer-Verlag. 379-416
442. PRAKASH, S. and T.M.S. CHANG (1999) Artificial cell microcapsules containing genetically engineered *e.coli dh5* cells for in-vitro lowering of plasma potassium, phosphate, magnesium, sodium, chloride, uric acid, cholesterol, and creatinine: a preliminary report Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 28 (5-6) 475-482
443. CHANG TMS (2000) Editorial: Is there a need for blood substitutes in the new millennium and what can we expect in the way of safety and efficacy**?** Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 28 (1) i-vii
444. Chang,TMS, F.D'Agnillo, W.P. Yu and S Razack (2000). New generations of blood subsitutes based on polyhemoglobin-SOD-CAT and nanoencapsulation. **Advanced Drug Delivery Review.**40:213-218
445. CHANG TMS, N MALAVE (2000) The development and first clinical use of semipermeable microcapsules (artificial cells) as a compact artificial kidney (special milliniium republication of previous key papers). **Therapeutic Apheresis** 4:108-116
446. YU, WP, J.P. WONG and T.M.S. CHANG (2000) Sustained drug release characteristics of biodegradable composite poly(d,l)lactic acid poly(l)lactic acid microcapsules containing ciprofloxacin Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 28 (1) 39-56
447. CHANG TMS (2000) Artificially boosting the blood supply. **Chemistry & Industry** 17 April, 281-284
448. CHANG TMS (2000) Artificial Cell Biotechnology in Medical Applications. **Journal of Blood Purification**. 18:91-96
449. Z LIU & TMS CHANG (2000) Effects of bone marrow cells on hepatocytes: when cocultured or co-encapsulated together Artif Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 28 (4) (365-374).
450. S. PRAKASH, T.M.S. CHANG (2000) Lowering of uric acid in-vitro and in-vivo by artificial cell microcapsulated genetically engineered *E. coli DH 5* cells. **Int J Artificial Organs** 23:429-435
451. Prakash, S and Chang TMS (2000) Artificial Cells microencapsulated genetically engineered E. coli DH5 cells for the lowering of plasma creatinine in-vitro and in-vivo. Artificiall Cells, Blood Substitutes & Immob. Biotechnology, an international journal, 28 (5) 397-408
452. CHANG TMS (2000) " Red Blood Cell Substitutes" **Best Practice & Research: Clinical Haematology** 13 (4) 651-668
453. CHANG, TMS (2001) "Bioencapsulated hepatocytes for experimental liver support" **Journal of Hepatology** 34:148-149
454. CHANG TMS & PRAKASH, S (2001) Procedure for microencapsulationof enzymes, cells and genetically engineered microorganisms. **Molecular Biotechnology** 17:249-260
455. POWANDA D & CHANG TMS (2002) Cross-linked polyhemoglobin-superoxide

dismutase-catalase supplies oxygen without causing blood brain barrier disruption or brain edema in a rat model of transient global brain ischemia-reperfusion. Artificial Cells, Blood Substitutes & Immob. Biotechnology, an international journal 30:25-42,2002
456. CHANG TMS (2002) "Red Blood Cell Substitutes" in A. Atala & R. Lanza (ed) **"Methods of Tissue Engineering"** Academic Press pp 965-975.
457. CHANG TMS (2002) Present status of modified hemoglobin as blood substitutes & oral therapy for end stage renal failure using artificial cells containing genetically engineered cells**.** Annals of the **New York Academy of Sciences** 944: 362-372, 2002
458. LIU ZC & CHANG TMS (2002) Increased viability of transplantation Hepatocytes when coencapsulated with Bone Marrow Stem Cells using a novel method. Artificiall Cells, Blood Substitutes & Immobilization Biotechnology, an international journal 30: 99-112, 2002
459. CHANG TMS (2002) Red Blood Cell Substitutes based on Modified Hemoglobin Chapter in **"Principles of Tissue Engineering"** eds. RP Lanza, R Langer & WL Chick Academic Press pp 601-610
460. CHANG TMS (2002) Oxygen Carriers. **Current Opinion in Investigational Drugs**, 3(8): 1187-1190
461. YU BL, CHANG TMS (2002) In-vitro kinetics of encapsulated tyrosinase. Artificial Cells, Blood Substitutes & Immob. Biotechnology, an international journal 30: 533-546
462. ORIVE G, HERNANDEZ RM, GASCON AR, CALAFIORE R, CHANG TMS et al (2003) Cell encapsulation: promise and progress. **Nature Medicine** 9:104-107
463. CHANG TMS (2003) New Generations of Red Blood Cell Substitutes. **Journal Internal Medicine** 253:527-535
464. CHOW KM, LIU ZC & CHANG TMS (2003) Animal Remnant Kidney Model of Chronic Renal Failure **HK J. Nephrology** 5: 57-64
465. CHANG TMS (2003) Artificial cells for replacement of metabolic organ functions. Artif Cells, Blood Substitutes & Biotechnology, an international journal, 31 (2):151-162.
466. CHANG TMS, POWANDA D & YU, WP (2003) Analysis of polyethyleneglycol-polylactide nano-dimension artificial red blood cells in maintaining systemic hemoglobin levels and prevention of methemoglobin formation. Artif Cells, Blood Substitutes & Biotechnology, an international journal, 31 (3) 231-248
467. LUI ZC, CHANG TMS (2003) Coencapsulation of Stem Cells and Hepatocytes: In-Vitro Conversion of Ammonia and In-vivo Studies on the Lowering of Bilirubin in Gunn Rats after transplantation. **Interantional Journal of Artificial Organs** 26 (6): 491-497,
468. LIU ZC, CHOW, KM and CHANG TMS (2003) Evaluation of Two Protocols of Uremic Rat Model: Partial Nephrectomy and Infarction. **Renal Failure** 25(6); 935-943, 2003.
469. CHOW, KM, LIU ZC, PRAKASH S and CHANG TMS (2003) Free and microencapsulated Lactobacillus and effects of metabolic induction on Urea Removal Artificial Cells, Blood Substitutes & Biotechnology. 4: 425-434
470. ORIVE G, HERNÁNDEZ, R.M, GASCÓN, A.R, CALAFIORE, R., CHANG, T.M.S. et al (2004) History, challenge and perspectives of cell microencapsulation. **Trends in Biotechnology**: 22:87-92
471. CHANG TMS (2004) Artificial Cells bioencapsulation in macro, micro, nano and molecular dimensions. Artificial Cells, Blood Substitutes & Biotechnology, international journal 32:1- 23
472. YU BL, CHANG TMS (2004) Effects of Long-Term Oral Administration of Microencapsulated Tyrosinase on Maintaining Decreased Systemic Tyrosine Levels in Rats. **J. Pharmaceutical Sciences** 93:831-837
473. YU BL, CHANG TMS (2004) Effects of Combined Oral Administration and Intravenous Injection on Maintaining Decreased Systemic Tyrosine Levels in Rats. Artificial Cells, Blood Substitutes & Biotechnology, international journal 32: 129 – 148
474. CHANG TMS (2004) A New Red Blood Cell Substitute **Critical Care Medicine** 32:612-613
475. YU BL, CHANG TMS (2004) Polyhemoglobin-tyrosinase, an oxygen carrier with Murine B16F10 Melanoma Suppression Properties: a preliminary report. Artificial Cells, Blood Substitutes & Biotechnology, international journal 32: 293-302
477. YU BL, CHANG TMS (2004) In Vitro and In Vivo Enzyme Studies of Polyhemoglobin-tyrosinase. **J. Biotechnology & Bioengineering** 86:835-841
478 YU BL, CHANG TMS (2004) In Vitro and In Vivo Effects of Polyhemoglobin-tyrosinase on Murine B16F10 Melanoma. **Melanoma Research Journal** 14:197-202

479. CHANG TMS (2004) Artificial Cells for Cell and Organs Replacement. **Artificial Organs Journal**. 28: 265-270
480: CHANG TMS (2004) Hemoglobin based red blood cell substitutes. **Artificial Organs Journal:** 28:289-294
481. CHANG TMS & E TSUCHIDA (2004) guest editorial on Blood Substitutes: present and future. **Artificial Organs Journal.** 28:287-288.
482. CHANG TMS (2005) Red Blood Cell Substitutes: Past, Present and Future pp 22-33. In "**Artificial Oxygen Carriers**" ed. K.Kobayashi, E. Tsuchida, H. Horinouchi Spring-Verlag Publisher
483 CHANG TMS (2005) Methods for microencapsulation of enzymes and cells in **Methods in Biotechnology:** 17:289-306
484. CHANG TMS (2005). Therapeutic applications of polymeric artificial cells. **Nature Review:Drug Discovery** 4: 221-235
485. CHANG TMS (2005). The role of artificial cells in cell and organ transplantation in regenerative medicine **Panminerva Medica**, **journal on clinical and experimental medicine** 47: 1-9
486. MAN-YAN WANG, YAO-TING YU, T.M.S. CHANG (2005) New method for preparing more stable microcapsules for the entrapment of genetically engineered cells. Artificial Cells, Blood Substitutes & Biotechnology, international journal 33: 257-269
487. LIU ZC & T.M.S. CHANG (2005) Transplantation of bioencapsulated bone marrow stem cells improve hepatic regeneration and survival of 90% hepatectomized rats: a preliminary report. Artificial Cells, Blod Substitutes & Biotechnology, international journal, 33: (4) 405-410
488 CHANG TMS. Hemoglobin-based red blood cell substitutes, Chapter31 in "Scaffolding in Tissue Engineering" edited by PX Ma and J Elisseeff, Taylor & Francis, New York pp 473-480
489 CHANG TMS (2005) "Artificial cells for blood substitutes, enzyme therapy, cell therapy and drug delivery" in "**Cell Immobilization Biotechnology**" eds V. Nedovic & R. Willaert. Springer, Netherland, pp 249-255
490. DAULL P, A BLOUIN, J CAYER, M BEAUDOIN, K BELLEVILLE, P SIROIS, F NANTEL, TMS CHANG & B BATTISTINI (2005) Profiling biochemical and hemodynamic markers using chronically instrumented, conscious and unrestrained rats undergoing severe, acute controlled hemorrhagic hypovolemic shock as an integrated in-vivo model system to assess new blood substitutes. **Vascular Pharmacology** 43: 289-301
491. CHANG TMS (2005) Artificial Red Blood Cell Substitutes" Chapter in Ratner, BD, Hoffman AS, Lemmons, JE and Schoen FI. **"Biomaterials Science: An Introduction to Materials in Medicine.",** Academic Press, San Diego, CA
492. LIU, ZC, TMS CHANG (2006) Transdifferentiation of bioencapsulated bone marrow cells into hepatocyte-like cells in the 90% hepatectomized rat model. **Journal of Liver Transplantation** 12: 566-572, 2006.
493. CHANG TMS (2006) Polyhemoglobin-enzyme complexes. Chapter in **book on "Blood Substitutes"** editor: R. Winslow 451-459
494 CHANG TMS (2006) PEG-PLA biodegradable hemoglobin nanocapsules as rbc substitutes. Chapter in **book on "Blood Substitutes**" editor R. Winslow 523-531
495 YU BL, ZC LIU & TMS CHANG (2006). Polyhemoglobin with different percentage of tetrameric hemoglobin and effects on vasoactivity and electrocardiogram. Artificial Cells, Blood Substitutes & Biotechnology, international journal 34: 159-175
494. CHANG TMS (2006) Nanobiotechnology based Blood Substitutes **Trends in Biotechnology**. 24: 72-377
495. LIU ZC & TMS CHANG. (2006) Polymeric artificial cells for coencapsulation of hepatocytes and bone marrow stem cells: in vitro and vivo analysis. **Annual Review of Biotechnology** 12: 137-152, 2006
496. CHANG TMS (2006) Evolution of Artificial Cells Using Nanogbiotechnology of Hemoglobin Based RBC Blood Substitute as an Example. Artificial Cells, Blood Substitutes & Biotechnology 34:551-566
497. WONG, N & TMS CHANG (2007) Polyhemoglobin-fibrinogen: a novel blood substitutes with platelet-like activity for extreme hemodilution. Artificial Cells, Blood Substitutes and Biotechnology 35:481-489
498. CHANG TMS (2007) "Red Blood Cell Substitutes based on Modified Hemoglobin" Chapter in 3rd edition **"Principles of Tissue Engineering"** eds. RP Lanza, R Langer & WL Chick
499. CHANG TMS (2007) Artificial Cells in Medicine with emphasis on Blood Substitutes in **Book on Artificial Cells and Cell therapy** (ed.S.Prakash) 321-332

500. YU BL and TMS CHANG (2007) Enzyme artificial cells: with emphasis on Polyhemoglobin-tyrosinase in **Book on Artificial Cells & Cell Therapy** (ed. S.Prakash) 424-432
501. CHANG, TMS (2007) "50th Anniversary of Artificial Cells". in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:1-11 http://www.medicine.mcgill.ca/artcell/503.pdf
502. CHANG, TMS (2007). "Basic Principles in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:12-30 http://www.medicine.mcgill.ca/artcell/504.pdf
503. CHANG, TMS (2007) "Oxygen Carriers based on Nanobiotechnology"in "ArtificialCells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:31-61 http://www.medicine.mcgill.ca/artcell/505.pdf
504. CHANG, TMS (2007). "A Nanobiotechnologic Therapeutic that Transport Oxygen and Remove Oxygen Radicals: For Stroke, Hemorrhagic Shock and Related Conditions." in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:62-92 http://www.medicine.mcgill.ca/artcell/506.pdf
505. CHANG, TMS (2007). "Nanotechnology based Artificial Red Blood Cells " in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:93-128 http://www.medicine.mcgill.ca/artcell/507.pdf
506. CHANG, TMS (2007). "Use of enzyme artificial cells for genetic enzyme defects that increase systemic substrates to toxic levels" in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:130-159 http://www.medicine.mcgill.ca/artcell/508.pdf
507. CHANG, TMS (2007). "Enzyme artificial cells in substrate-dependent tumours and activation of prodrug" in. "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:. 160-194 http://www.medicine.mcgill.ca/artcell/509.pdf
508. CHANG, TMS (2007). "Artificial cells for cell encapsulation".in "**Artificial Cells" Regenerative Medicine, Artificial Cells & Nanomedicine** 1: 195-224 http://www.medicine.mcgill.ca/artcell/510.pdf
509. CHANG, TMS (2007)."Artificial cells containing hepatocytes and/or stem cellsin regenerative medicine" in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:225-251 http://www.medicine.mcgill.ca/artcell/511.pdf
510. CHANG, TMS (2007). "Hemoperfusion in poisoning, kidney failure, liver failure and immunology" in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:252-299 http://www.medicine.mcgill.ca/artcell/512.pdf
511. CHANG, TMS (2007). "Perspectives on the future of artificial cells as suggested by past research" in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:299-334 http://www.medicine.mcgill.ca/artcell/513.pdf
512. CHANG, TMS (2007). "Appendix I: 1957 report on Methods for preparing artificial hemoglobin corpuscles. in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:335-354 http://www.medicine.mcgill.ca/artcell/514.pdf
513. CHANG, TMS (2007) "Appendix II: Methods not described in detail" in "Artificial Cells" **Regenerative Medicine, Artificial Cells & Nanomedicine** 1:355-376 http://www.medicine.mcgill.ca/artcell/515.pdf
514. CHANG, TMS (2008) "50th Anniversary of Artificial Cells" Artificial Cells, Blood Substitutes & Biotechnolog: 35:545-554 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2512
515. LIU ZC & TMS CHANG (2008) Effects of PEG-PLA-nano artificial cells containing hemoglobin on kidney function and renal histology in rats Artificial Cells, Blood Substitutes & Biotechnology 36, 421-430 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2511
516. CHANG, TMS (2008) Safety of red blood cell substitutes compared to donor red blood cells. Artificial Cells, Blood Substitutes & Biotechnology 36: 1-2 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2514
517. CHANG, TMS (2008) Nanobiotechnological modification of hemoglobin and enzymes from this laboratory. **Biochimica et Biophysica Acta: proteins & Proteomics** 1784:1435-144 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2513
518. LIU ZC & TMS CHANG (2008) Long term effects on the histology and function of livers and spleens in rats after 33% toploading of PEG-PLA-nano artificial red blood cells. Artificial Cells, Blood Substitutes & Biotechnology 36, 513-524 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2515
519. LIU ZC & TMS CHANG (2009) Preliminary study on Intrasplenic Implantation of Artificial Cell Bioencapsulated Stem Cells to Increase the Survival of 90% Hepatectomized Rats. Artificial Cells,

Blood Substitutes & Biotechnology 37: 53-55
http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2517
520. GU, G & TMS CHANG (2009) Extraction of erythrocyte enzymes for the preparation of Polyhemoglobin-catalase-superoxide dismutase Artificial Cells, Blood Substitutes &Biotechnology 37:69-77 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2513
521. CHANG TMS (2009) Nanobiotechnology for hemoglobin based blood substitutes. **Critical Care Clinics** 25 :373–382 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2516
522. STEFANESCU,A & TMS CHANG (2009) Use of tangential flow ultrafiltration for the removal of tetrameric hemoglobin from polyhemoglobin, hemolysate purification and polyhemoglobin concentration Artificial Cells, Blood Substitutes & Biotechnology 37: 61-68
http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2519
523. CHANG TMS (2009) Memorials for Editorial Board Members: Debakey, Kolff andWinslow. Artificial Cells, Blood Substitutes & Biotechnology 37: 105.
524. LIU ZC & TMS CHANG (2010) Artificial Cell microencapsulated stem cells in regenerative medicine, tissue engineering and cell therapy **Advances in Experimental Medicine and Biology. 670:**68-79. http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2521
525. Zhu, HG, Du QQ, Chen,C and TMS Chang (2010) The immunological properties of polyhemoglobin containing catalase and superoxide dismutase activities prepared by polymerized bovine stroma-free hemoglobin. Artificial Cells, Blood Substitutes & Biotechnology 38: 57-64
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3518482/
526. CHANG TMS (2010) Blood replacement with engineered hemoglobin and hemoglobin nanocapsules. **Wiley Interdisciplinary Reviews Nanomedicine and Nanobiotechnology** 2:418-430 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2523
527. CHANG, TMS (2010). Artificial Cells containing Stem Cells for Liver Failure. Feature article in Special Issue on Stem Cells, Asia Pacific Biotechnology (APBN) 14: (3), 17-19.
528. CHANG, TMS (2011) Progress in the field of blood substitutes Chapter in **Cardiothoracic Surgery Review** pp1441-1443
529. BIAN, Y, RONG, Z and CHANG TMS (2011) Polyhemoglobin-superoxide Dismutase-catalase-carbonic anhydrase: A Novel Biotechnology-based Blood Substitute that Transports Both Oxygen and Carbon Dioxide and Also Acts as an Antioxidant Artificial Cells, Blood Substitutes & Biotechnology 39: 127-136 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2634
530. CHANG TMS (2011) Editorial on “What is in a name?”. Artificial Cells, Blood Substitutes & Biotechnology 39: 118
531. Zhu,H, Yan,K, Dang,X, Huang,H, Chen,E, Chen,B,Luo Chao,Chang,TMS,Dai,P and Chen,Chao (2011) Immune Safety Evaluation of Polymerized Porcine Hemoglobin (pPolyHb) - a Potential Red Blood Cell Substitutes. Artificial Cells, Blood Substitutes & Biotechnology, an international journal 39: 398-405 http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2635
532. CHANG, TMS (2011) Nanobiotechnology-based Blood Substitutes and the Cardiovascular Systems in Transfusion Medicine Chapter in **Nanomedicine and Cardiovascular System** pp77-98
533. Zhu,H, Dang,X, Yan, K, Dai, P Luo, C, Ma, J , Li, Y, Chang, T.M.S, Chen, C (2011) Pharmacodynamic Study of Polymerized Porcine Hemoglobin (pPolyHb) in a Rat Model of Exchange Transfusion. Artificial Cells, Blood Substitutes & Biotechnology, an international journal 39: 119-126. http://capmc.ca/CAPMC/pmc/articlerender.cgi?artid=2637
534. CHANG, TMS (2012) Opening lecture at XIII Int Sym Blood Substitutes at Mass General, Harvard, Boston “From Artificial Red Blood Cells, Oxygen Carriers, Oxygen Therapeutics to Artificial Cells and Nanomedicine and beyond”. Artificial Cells, Blood Substitutes & Biotechnology, an international journal, 40(3) 197-199 http://www.medicine.mcgill.ca/artcell/536.pdf
http://pubmedcentralcanada.ca/articlerender.cgi?accid=PMC3566225
535. CHANG, TMS (2012) Forward for the book on “**Theory, Techniques and Applications of Nanotechnology in Gene Silencing**” eds. Surendra Nimesh,S and Chandra, R pp v-vi
536. Fustier C and Chang TMS (2012 online) PEG-PLA nanocapsules containing a nanobiotechnological complex of polyhemoglobin-tyrosinase for the depletion of tyrosine in melanoma: preparation and in vitro characterisation **Journal Nanomedicine and Biotherapeutics Discovery** 2012, 2:1 http://www.medicine.mcgill.ca/artcell/538.pdf
537. CHANG TMS (2012): “The history, development and promise of artificial cells: microdialyser and nanodialysers with bioreactive properties: Chapter in “**DIALYSIS: History, Development and Promise”** Editors: Todd S. Ing, Mohamed A. Rahman, and Carl M. Kjellstrand. World Scientific Publisher/Imperial College Press, Singapore/London pages 873-888

538. CHANG, TMS (2012) “Artificial Cells” Chapter in **“Biomaterial Science: An Introduction to materials in Medicine”** 3rd edition. Eds Buddy Ratner**,** Allan Hoffman,Fred Schoen and Jack Lemons

539. Liu, ZC and TMS Chang (2012) Intrasplenic transplantation of bioencapsulated mesenchymal stem cells enhances the regeneration of remnant livers and improves the recovery rates of 90% partial hepatectomized rats” Stem Cells International Volume 2012 (2012), Article ID 697094, 6 pagesdoi:10.1155/2012/697094 PMC3515999 http://www.hindawi.com/journals/sci/2012/697094/

540. Wang, Yun and TMS Chang (2012) Nanobiotechnological nanocapsules containing polyhemoglobin-tyrosinase: effects on murine B16F10 melanoma cell proliferation and attachment. Special issue on ‘melanoma’ Journal of Skin Cancer PMC3503398 http://www.hindawi.com/journals/jsc/2012/673291/

541. Yuzhu Bian, Gao Wei and Thomas M.S. Chang (2013) Lowering of elevated tissue PCO_2 in a hemorrhagic shock rat model after reinfusion of a novel nanobiotechnological polyhemoglobin-superoxide dismutase-catalase-carbonic anhydrase that is an oxygen and carbon dioxide carrier with enhanced antioxidant properties. Artificial Cells, Nanomedicine and Biotechnology, an international journal 41: 60-68 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3618434

542. Wei, Gao, Yuzhu Bian and TMS Chang (2013) PLA-PEG nanoencapsulated Nano artificial red blood cells that act as O_2 and CO_2 carrier with enhanced antioxidant activity: Polyhemoglobin-superoxide dismutase-catalase-carbonic anhydrase. Journal Artificial Cells, Nanomedicine and Biotechnology 41, 4: 232–239. www.medicine.mcgill.ca/artcell/2013 Wei Bian Chang.pdf

543. CHANG TMS (2013) “Red Blood Cell Substitutes based on Modified Hemoglobin” Chapter in 4th edition **"Principles of Tissue Engineering"** eds. RP Lanza, R Langer & WL Chick, Academic Press

544. CHANG TMS (2013) Opening chapter on “Artificial Cells that started Nanomedicine” in book on “Selected Topics in Nanomedgicine) (ed.TMS Chang) World Science Publisher/Imperial College Press. p 12-30 http://www.worldscientific.com/doi/suppl/10.1142/8776/suppl_file/8776_chap01.pdf

545. CHANG TMS (2014) Opening chapter on ” From hemoglobin based oxygen carrier to oxygen therapeutics, blood substitutes, nanomedicine and artificial cells. in Book on “Hemoglobin-Based Oxygen-Carriers as Red Cell Substitutes and Oxygen Therapeutics” (eds: Kim &Greenburg). Springer Heidelber New York Dordrecht London pp 3-26 (740page book)

546. Y. Bian and TMS Chang (2015) A novel nanobiotherapeutical Poly-[hemoglobin-superoxide dismutase-catalase-carbonic anhydrase] with no cardiac toxicity for the resuscitation of a 90 minutes sustained severe hemorrhagic shock rat model with 2/3 blood volume loss Artificial Cells, Nanomedicine and Biotechnology 43, 1: 1-9 , www.medicine.mcgill.ca/artcell/2015Bian&Chang.pdf

547. C. Guo, M.Gynn and TMS Chang (2015) Extraction of Superoxide Dismutase, Catalase and Carbonic Anhydrase from stroma-free red blood cell hemolysate for the preparation of the nanobiotechnological complex of PolyHemoglobin-Superoxide Dismutase-Catalase-Carbonic Anhydrase, Journal Artificial Cells, Nanomedicine and Biotechnology 43, 3, 157-162 www.medicine.mcgill.ca/artcell/2015 Guo et al.pdf

548. TMS Chang (2015) Red Blood Cell replacement or nanobiotherapeutics with enhanced red blood cell functions? Journal Artificial Cells, Nanomedicine and Biotechnology 43:3,145-147 www.medicine.mcgill.ca/artcell/online.pdf

549. YZ Bian, C Guo & TMS Chang (2016) Temperature stability of Poly-[hemoglobin-superoxide dismutase–catalase- carbonic anhydrase] in the form of a solution or in the lyophilized form during storage at -80 ^{o}C, 4 ^{o}C, 25 ^{o}C and 37 ^{o}C or pasteurization at 70 ^{o}C. Journal Artificial Cells, Nanomedicine and Biotechnology 44:41-47 www.medicine.mcgill.ca/artcell/2016 Bian_Guo_Chang.pdf

550. Wenhua Jiang[1], Yuzhu Bian, Zhenghui Wang, and Thomas Ming Swi Chang (2016 June online))

Hepatoprotective Effects of Poly-[hemoglobin-superoxide Dismutase-catalase-carbonic anhydrase] on alcohol damaged primary rat hepatocyte culture in vitro Journal Artificial Cells, Nanomedicine and Biotechnology 44 www.medicine.mcgill.ca/artcell/2016 Jiang et al.pdf

551 Wang Y & TMS Chang (2016) Biodegradable Nanocapsules Containing A Nanobiotechnological Complex for the In-vitro Suppression of A Melanoma Cell Line B16F10 Journal of Nanosciences: Current Research 1:1-6 www.medicine.mcgill.ca/artcell/2016 Wang & Chang.pdf

552 Chang TMS (2017) Opening Chapter: First design and clinical use in patients of surface modified sorbent hemoperfusion based on artificial cells for poisoning, kidney failure, liver failure

and immunology. In Book on "Hemoperfusion and Plasma-perfusion and other Clinical Uses of General ,Biospecific, immune and leucocyte Adsorbents" (editors: Chang, Endo, Nicolaev, Tani and Zheng) World Scientific Publisher/Imperial College Press 3-78 www.medicine.mcgill.ca/artcell/HPBk_ch1.pdf

553 Chang TMS (2017) Translational feasibility of soluble nanobiotherapeutics with enhanced red blood cell functions. Artificial Cells, Nanomedicine and Biotechnology 45 :671-676 http://www.tandfonline.com/doi/full/10.1080/21691401.2017.1293676

554. Chang TMS (2017) Editorial: A novel approach to restore function of stroke or trauma related paralyzed limbs, Artificial Cells, Nanomedicine and Biotechnology 45

555. Chang TMS (in Press) PREFACE of book on "Advances in Nanomedicine for the Delivery of Therapeutic Nucleic Acids" Nimesh,S, Gupta, N and Chandra, R (editors).Elsevier .(in press)

556. Chang, TMS (2017) Preface pp 13-14 for a large 57 chapters 994 pages book on the present status and future perspectives of Transfusion Medicine in China (edited by Yang et al.) Published in the Fall of 2017.

557 Chen Guo & Thomas Ming Swi Chang (2018) Long term safety and immunological effects of a nanobiotherapeutic, bovine poly-[hemoglobin-catalase-superoxide dismutase-carbonic anhydrase], after four weekly 5% blood volume top-loading followed by a challenge of 30% exchange transfusion, Artificial Cells, Nanomedicine, and Biotechnology, 46:7, 1349-1363. www.artcell.mcgill.ca/safety_immune.pdf (DOI: 10.1080/21691401.2018.1476375 https://doi.org/10.1080/21691401.2018.1476375Safety & immunology)

558. Chan Gang and Chang TMS (2018) Dual effects include antioxidant and pro-oxidation of ascorbic acid on the redox properties of bovine hemoglobin, Artificial Cells, Nanomedicine, and Biotechnology, DOI: 10.1080/21691401.2018.1476374

559. Chang TMS (2019) **ARTIFICIAL CELL evolves into nanomedcine, biotherapeutics, blood substitutes, drug delivery, enzyme/gene therapy, cancer therapy, cell/stem cell therapy, nanoparticles, liposomes, bioencapsulation, replicating synthetic cells, cell encapsulation/scaffold, biosorbent/immunosorbent hemoperfusion/plasmapheresis, regenerative medicine, encapsulated microbe, nanobiotechnology, nanotechnology**. *Artificial Cells, Nanomedicine, & Biotechnology 47* 997–1013 https://doi.org/10.1080/21691401.2019.1577885

560. Does conventional early life academic excellence predict later life scientific Discovery? An assessment of the lives of Great Medical Innovators

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561. Chang **History and Potential of nanobiotechnology based blood substitutes, artificial cells and nanobiotherapeutics** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Press" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

562. TMS Chang **Biotechnology based-Oxygen Carriers** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

563. TMS Chang. **A NANOBIOTECHNOLOGIC THERAPEUTIC THAT TRANSPORT OXYGEN AND REMOVE OXYGEN RADICALS** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

564. Powanda D & Chang TMS**. Cross-linked polyhemoglobin-superoxide dismutase-catalase supplies oxygen without causing blood brain barrier disruption or brain edema in a rat**

model of hemorrhagic shock with transient global brain ischemia. Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

565. Chen Gang & TMS Chang **Dual effects include antioxidant and pro-oxidation of ascorbic acid on the redox properties of bovine hemoglobin** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021). https://doi.org/10.1142/12054

566. Chang TMS **Soluble nanobiotherapeutics with enhancements of all 3 major red blood cell functions** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

567. Bian, YZ and TMS Chang. **A novel nanobiotherapeutical Poly-[hemoglobin-superoxide dismutase-catalase-carbonic anhydrase] with no cardiac toxicity for the resuscitation of a 90 minutes sustained severe hemorrhagic shock rat model with 2/3 blood volume loss** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

568. Chen Guo and Thomas Ming Swi Chang **Long term safety and immunological effects of a nanobiotherapeutic , bovine poly-[hemoglobin-catalase-superoxide dismutase-carbonic anhydrase], after four weekly 5% blood volume top-loading followed by a challenge of 30% exchange transfusion** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

569. C. Guo, M.Gynn and TMS Chang **Extraction of Superoxide Dismutase, Catalase and Carbonic Anhydrase from stroma-free red blood cell hemolysate for the preparation of the nanobiotechnological complex of PolyHemoglobin-Superoxide Dismutase-Catalase-Carbonic Anhydrase** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

570. YZ Bian, C Guo & TMS Chang **Temperature stability of Poly-[hemoglobin-superoxide dismutase–catalase- carbonic anhydrase] in the form of a solution or in the lyophilized form during storage at -80 ºC, 4 ºC, 25 ºC and 37 ºC or pasteurization at 70 ºC.** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

571. Chang TMS **Nanoencapsulated nano-artificial red blood cells.** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

572. Chang TMS, Powanda D & Yu WP **Analysis of polyethyleneglycol-polylactide nano-dimension artificial red blood cells in maintaining systemic hemoglobin. levels and prevention of methemoglobin formation**. Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

573. Liu ZC & TMS Chang **Effects of PEG-PLA-nano artificial cells containing hemoglobin on kidney function and renal histology in rats** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

574. LIU ZC & TMS Chang **Long term effects on the histology and function of livers and spleens in rats after 33% toploading of PEG-PLA-nano artificial red blood cells**. Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

575. Wei G, Bian YZ & Chang TMS. **Polylactide-Polyethylene membrane nanoencapsulated Polyhemoglobin-superoxide dismutase-catalase-carbonic anhydrase**. **nano artificial red blood cells that act as O_2 and CO_2 carrier with enhanced antioxidant activity:** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

576. TMS Chang, Jiang WH, D'Agnillo F, Razack S. **NANOBIOTHERAPEUTICS AS PRESERVATION FLUIDS FOR ORGANS AND CELLS** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

577. Wong, N & TMS Chang **Polyhemoglobin-fibrinogen: a novel blood substitutes with platelet-like activity for extreme hemodilution** Chapter in Multiauthor book edited by Chang, Jahr, & Sakai "Nanobiotheraeutic basis for blood substitutes and oxygen therapeutics World Scientific Publisher/Imperial College Pres" Regenerative Medicine, Artificial Cells & Nanomedicine volume 5:(2021) https://doi.org/10.1142/12054

578. Wang,Yun, Thomas Ming Swi Chang(2021) A nanobiotherapeutic approach for melanoma based on polylactide artificial cell nanoencapsulated polyhemoglobin-tyrosinase: in vitro 3D culture and in vivo suppression of B16F10 murine melanoma in C57BL6 mice. Artificial Cells, Nanomedlicine & Biotechnology). 49: 461-470 https://www.tandfonline.com/doi/full/10.1080/21691401.2021.1918134

579. Thomas Ming Swi Chang (2022) **"The role of artificial cells in the fight against COVID-19: deliver vaccine, hemoperfusion removes toxic cytokines, nanobiotherapeutics lower free radicals and pCO2 and replenish blood supply"** Artificial Cells, Nanomedlicine & Biotechnology). 50:1, 240-251, DOI: 10.1080/21691401.2022.2126491

580. XL Xie, XL. Zhou,TD Liu,ZQ Zhong,QI Zhou,WQ Iqbal,QD Xie,CJ Wei, X Zhang,TMS Chang and PG Sun (2022) **Direct Differentiation of Human Embryonic Stem Cells to 3D Functional Hepatocyte-like Cells in Alginate Microencapsulation Sphere**. **Cells** 2022, 11(19), 3134; https://doi.org/10.3390/cells11193134

581. TMS Chang (for 2023) **A BRIEF HISTORY OF THE DEVELOPMENT OF NANOBIOTECHNOLOGY BASED BLOOD SUBSTITUTES**. Chapter in book on. Blood Substitutes and Oxygen Biotherapeutics. Edited by Henry Liu, Alan Kaye, Jonathan S.Jahr Springer Nature

582. TMSChang (for 2023) **SOLUBLE NANOBIOTHERAPEUTICS WITH ENHANCEMENTS OF ALL 3 MAJOR RED BLOOD CELL FUNCTIONS** Chapter in book on. Blood Substitutes and Oxygen Biotherapeutics. Edited by Henry Liu, Alan Kaye, Jonathan S.Jahr Springer Nature

583. M Hoq and T.M.S. Chang*(2023)

Preliminary feasibility study on Polyhemoglobin and stable synthetic catalase, superoxide dismutase and carbonic anhydrase: a novel approach for the regeneration of warm ischemic cells/ tissues. Frontier Bioengineering Biotechnology: https://www.frontiersin.org/articles/10.3389/fbioe.2023.1231384

BOOKS AND SPECIAL ISSUES:

1. CHANG TMS (1972) **"Artificial Cells", monograph** 212 pages, 77 illustrations, 5 tables, Charles C. Thomas, Publisher, Springfield, Illinois,USA. **(Out of print but available for free online viewing at** http://www.medicine.mcgill.ca/artcell/1972bookCovercr.pdf Book Reviewed by:

Nature, 242:211, 1973
ScientificAmerican,Vol227,November1972;
ChemicalEngineeringJournal,May14,1973.
BiomedicalEngineeringJournal,April1973...

Book Translated into:

1) Japanese (1976) by Prof. T KONDO, Japan.
2) Russian (1979) by Prof. V NICOLAEV, USSR.

2. CHANG TMS (ed) (1977), **Biomedical applications of immobilized enzymes & proteins**: I 415 pages, 129 illustrations, 55 tables, Plenum Publishing Corporation, New York,

3. CHANG TMS (ed) (1977**), Biomedical applications of immobilized enzymes & proteins:II** 355 pages, 127 illustrations, 34 tables, Plenum Publishing Corporation, New York,

4. CHANG TMS (ed) (1978), "**Artificial kidney, artificial liver, and artificial cells**" 315 pages, Plenum Publishing Corporation, New York.

5. SIDEMAN S and CHANG TMS (eds) (1980), "**Hemoperfusion: I. Artificial kidney and liver support and Detoxification**" 473 pages, Hemisphere Publishing Corp., Washington, D.C., USA.

6. SIDEMAN S and CHANG TMS (ed) (1981), "**Hemoperfusion: II. Devices and clinical applications**" 167 pages, Samuel Newman Institute for Advanced Studies in Science and Technology, Technion, Haifa, Israel.

7. "**Lecture series on artificial cells" Monograph in Chinese** of a 12 hour lecture series by CHANG TMS at the Chinese Academy of Sciences, Beijing, China (monograph prepared and translated into Chinese by HZ WANG, WH ZHENG, EH MIAO, CX HUANG, WC PENG, DH ZHAO) Chinese Medical Association, Hopei, Shijiazhuang (1981).

8. V BONOMINI and CHANG TMS (eds) (1982), **"Hemoperfusion**" 149 pages, Contributions to Nephrology Series, S. Karger AG, Basel, Switzerland.

9. PISKIN E and CHANG TMS (eds) (1982),"**Hemoperfusion and artificial organs**" 187 pages, Artificial Organs Society.

10. PISKIN E and CHANG TMS (eds) (1983), **Past, present and future of artificial organs** 262 pages, Meteksan Publisher Co., Ankara, Turkey.

11. CHANG TMS (ed) (1984), **"Microencapsulation and artificial cells**" 312 pages, Humana Press, Clifton, New Jersey, USA.

12. CHANG TMS and BL HO (eds) (1985)"**Hemoperfusion and artificial organs**", 464 pages, China Academic Publishers, Beijing, China.

13. "Hemoperfusion" CHANG TMS and A TREVINO BECERRA (eds) (1986) Special issue Int. J. Artificial Organs, Volume 9:279-368.

14. CHANG TMS and N NICOLAEV (eds) (1987) "Hemoperfusion, sorbent and immobilized bioreactants" Special Issue, Int. J. Biomaterials, Artificial Cells and Artificial Organs 15:1 321,

15. CHANG TMS and R GEYER (eds) (1989) "**Blood substitutes**" Marcel Dekker Publisher, U.S.A., 714 pages

16. WINSLOW R and CHANG TMS (eds) (1990) "Red blood cell substitutes" Special issue, Int. J. Biomaterials, Artificial Cells and Artificial Organs 18:133-342,1990.

17. H KLINKMANN, D FALKENHAGEN, and CHANG TMS (eds) (1990) "Hemoperfusion, sorbentand immobilized bioreactants". Special issue, Int. J. Biomaterials, Artificial Cells and Artificial Organs 18:455-568.

18. CHANG TMS and M ODAKA (eds) 1991. "Hemoperfusion, sorbent and immobilized bioreactants" Special issue, Biomaterials, Artificial Cells and Immobilization Biotechnology, an international journal 19: 1-298, 1991.

19. GURLAND H and CHANG TMS (eds) 1992. "Artificial organs" Special Festschrift issue for W. Kolff's 80th Birthday, J. Artificial Organs, Official Journal of the International Society for Artificial Organs (1992).

20. CHANG TMS (ed) (1992). **Blood substitutes and oxygen carriers**. Marcel Dekker Publisher, USA, 784 pages. Book Reviews: " excellent very useful and easy to read "" recommended an important addition to medical and basic-science libraries."`Canadian Medical Association Journal. "The authors of the papers represent a list of "who's who" in the field." Hematologic Pathology

21. CASCIANI C, G. SPLENDIANI AND CHANG TMS (eds) (1993)."Hemoperfusion, sorbent and immobilized bioreactants" Special issue, Biomaterials, Artificial Cells and Immobilization Biotechnology, An International Journal

22. CHANG TMS, J REISS and R WINSLOW(eds) (1994). Blood substitutes: general. Special issue, Artificial Cells, Blood Substitutes and Immbolization Biotechnology, An International Jounral, 22:123-360, 1994

23. CHANG TMS and S. WEINSTOCK (eds) (1995). Blood substitutes Special issue, Artificial Cells, Blood Substitutes and Immbolization Biotechnology, An International Jounral, 23: 257-459.

24. CHANG TMS, G. GREENBERG and E TSUCHIDA (eds) (1997)Blood substitutes. Special issue, Artificial Cells, Blood Substitutes and Immbolization Biotechnology, An International Journal, 25:1-241.

25. CHANG TMS (1998) (editor: multiauthors) **Red blood cell substitutes: Principles, Methods, Products and Clinical Trials** Vol II Karger/Landes Systems, Basel, Switzerland

26. CHANG TMS (2004) Guest Editor. Special issue on Blood Substitutes:present and future. Artificial Organs Journal.

27. **CHANG TMS (May 2007) Monograph on "ARTIFICIAL CELLS**: biotechnology, nanotechnology, blood substitutes, regenerative medicine, bioencapsulation, cell/stem cell therapy" World Scientific Publisher/Imperial College Press 435 pages.(**Since April 2010 has obtained copyright to place this book for noncommercial free**

online viewing or download on:
http://www.medicine.mcgill.ca/artcell/2007%20ebook%20artcell%20web.pdf *Book reviewed by A Gerson Greenburg, MD, PhD, Professor Emeritus of Surgery, Brown University, U.S.A. "This volume is the most comprehensive review of the field of artificial cells and associated fields published to date. It refreshes the knowledge of the experts while informing the naive of the history and promise of the future. Written in a conversational style and very well illustrated for fact and emphasis, it is an easy and informative read. Presented in easily accessible form are the underlying theories and concepts of artificial cells, blood substitutes, nanomedicine, regenerative medicine and stem cell therapy in the context of specific clinical situations ranging from general to very specific diseases. Basic science observations support the tested or proposed clinical applications in an exact manner. This volume contains a near encyclopedia quantity of information, carefully and logically assembled and presented. Future developments in the field will depend on the essential information presented here. An essential read for anyone interested in this field, the vision and foresight of this senior scientist and leading statesman of the field makes the topic accessible and understandable."*

28. CHANG, TMS (2013) editor, Book on **"Selected Topics in Nanomedicine**" World Scientific Publisher/Imperial College Press pp590 http://www.medicine.mcgill.ca/artcell/NanoBk_Ch1.pdf

29. Chang, Endo, Nicolaev, Tani and Zheng (editors) (2017) editors, Book on "**Hemoperfusion and Plasma-perfusion and other Clinical Uses of General ,Biospecific, immune and leucocyte Adsorbents"** World Scientific Publisher/Imperial College Press 1004 pages www.medicine.mcgill.ca/artcell/HPBk_Ch1.pdf

30. Editor in Chief Chang , coeditors:Bulow, Jahr,Sakai & Yang (for 2021) A multiauthor book on "**Nanobiotheraeutic basis for blood substitutes**, World Scientific Publisher/Imperial College >1000 pages (2021) https://www.worldscientific.com/worldscibooks/10.1142/12054#t=toc

30. CHANG TMS (for 2023) 3rd edition of Monograph on "ARTIFICIAL CELLS: biotechnology, nanotechnology, blood substitutes, synthetic cells, regenerative medicine, bioencapsulation, cell/stem cell therapy" World Scientific Publisher/Imperial College Press

INVITED LECTURES:

1963 Invited speaker, Red Cell Club, NIH, Bethesda, Maryland, USA.
1963 Invited lecturer, Dept. of Physiology, University of Pennsylvania, Philadelphia, USA.

1964 Invited lecturer, Gordon Research Conference on Medicinal Chemistry, New Hampshire, USA.
1964 Invited lecturer, Merck, Sharpe and Dohe, New Jersey, USA.
1964 Invited lecturer, Eli Lilly, Indianapolis, Indiana, USA.

1965 Invited lecturer, University of Montreal, Montreal, Quebec, Canada.
1965 Invited lecturer, New York Blood Center, New York, USA.
1965 Invited lecturer, Battelle Memorial Institute, Columbus, Ohio, USA.

1966 Invited lecturer, NCR, Dayton, Ohio, USA.

1967 Invited lecturer, Dept. of Artificial Organs, Cleveland Clinic, Cleveland, Ohio, USA.

1968 Invited lecturer, Microencapsulation Symposium, New Jersey, USA.
1968 Guest speaker, Association of Professional Engineers, Ottawa, Ontario, Canada.
1968 Guest speaker, Stamford Section, American Chemical Society, Stamford,Connecticut .
1968 Invited lecturer, New York Blood Center, New York, USA.

1969 **First Incentive Lecturer, Sweden**.The Annual Incentive Lectures were instituted in Sweden in 1969 to invite once a year a foreign scientist to give an Incentive Lecture in Stockholm
and other Swedish universities. The first Incentive Lecturer was "invited to inaugurate these annual lectures". The lecture on "The Clinical Potential of Enzyme Technology" was given at:
) (1) Karolinska Institute, Stockholm, Sweden.
) (2) Chemical Centre, University of Lund, Lund, Sweden.
(3) University of Gothenberg Hospital, Gothenberg, Sweden.

1969 Invited lecturer, Dept. of Physiology, University of Toronto,Toronto, Ontario, Canada.
1969 Invited lecturer, Dept. of Pathology, Rhode Island Hospital, Rhode Island, USA.
1969 **MRC Visiting Professor**, Dept. of Biophysics, University of Western Ontario, London, Ontario, Canada.
1969 Invited lecturer, Dept. of Artificial Organs, University of Utah,Salt Lake City,Utah,
1969 Invited lecturer, Alza Co., Pala Alto, California, USA.

1970 Invited lecturer, Cardiovascular Research Institute, San Francisco, California, USA.
1970 Invited lecturer, Renal Unit, Sydney Hospital, Sydney, Australia.
1970 Invited lecturer, Dept. of Physiology, University of Sydney, Sydney, Australia.
1970 Invited lecturer, Renal Unit, Prince Henry Hospital, Sydney, Australia.
1970 Invited lecturer, Biomedical Symposium, Australian Academy of Science and Society of Engineers, Sydney, Australia.
1970 Invited lecturer, Microencapsulation Symposium, New Jersey, USA.

1971 Invited lecturer, Dept. of Chemical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania, USA.
1971 Invited lecturer, Gordon Research Conference on Biomaterials, New Hampshire, USA.
1971 Enzyme Engineering Conference, New Hampshire, USA.
1) Invited lecturer.
2) Invited panel discussant on "Future of Enzyme Engineering".

1971 Invited lecturer, Life Science Seminar, Battelle Memorial Institute, Columbus, Ohio,
1972 Invited lecturer, National Foundation Symposium on Enzyme Replacement, Sarasota, Florida, USA.
1972 Invited lecturer, Chemical Engineering Dept., Princeton University, New Jersey, USA.
1972 Invited lecturer, Biomedical Engineering Symposium, MRC Bioengineering Unit, University of Strathclyde, Glasgow, Scotland.
1972 Invited lecturer, Renal Unit, Edinburgh Royal Infirmary, Edinburgh Medical School, Scotland.
1972 Invited guest speaker, Canadian Kidney Foundation Annual Meeting.
1972 Invited lecturer, NIH, General Medical Sciences, Bethesda, Maryland, USA.
1972 Invited lecturer, Microencapsulation Symposium, New Jersey, USA.

1973 Invited lecturer, First International Microencapsulation Symposium,Athens, Georgia.
1973 Chairman, session on "Biomedical Applications" and invited lecturer, International Conference on Insolubilized Enzymes, Milan, Italy.
1973 Invited lecturer, Gordon Research Conference on "Separation in Engineering", New Hampshire, USA.
1973 Co-chairman, session on "Future Applications of Enzyme Engineering", Enzyme Engineering Conference.
1973 Invited lecturer, Enzyme Engineering Conference, Engineering Foundation.
1973 Invited lecturer, International Nephrological course, Parma, Italy.
1973 Invited lecturer, Microencapsulation Symposium American Chemical Society Annual Meeting, Chicago
1973 Invited lecturer, Canadian High Polymer Forum of Membranes, St. John,Quebec.
1973 Annual guest speaker, Japanese Society for Artificial Organs, Sandai, Japan.
1973 Guest speaker, Japanese Society for Promotion of Renal Transplantation,Tokyo, Japan.
1973 Invited lecturer, Tokyo Science University, Tokyo, Japan.
1973 Guest discussant, Panel on "Microcapsule Hemoperfusion for Chronic and Renal Failure", Tokyo College of Medicine and Dentistry, Tokyo, Japan.

1974 **Visiting professor**, Medical Engineering Session, Faculty of Medicine, University of Minnesota, Minneapolis, Minnesota, USA.
1974 Invited lecturer, Dept. of Anatomy, University of Minnesota, Minneapolis, Minnesota.
1974 Invited lecturer, American Chemical Society Symposium on "Polymer Graft in Biochemistry", California, .
1974 Invited panelist on "Sorbent for Uremia", American Society for Artificial Internal Organs Annual Meeting, Chicago, Illinois, USA.
1974 Invited lecturer, Microencapsulation Workshop, New Jersey, USA.
1974 Invited participant and session chairman, Workshop on "Implications of Enzyme Engineering". Organized by **International Federation of Institutes for Advanced Studies, Stockholm, Sweden.**
1974 Invited lecturer, "Immobilization of Enzymes by Microencapsulation", Gordon Research Conference on "Lysozyme", New Hampshire, USA.
1974 Invited lecturer and session chairman, 2nd International Microencapsulation Symposium, London, UK.
1974 Invited lecturer, International Symposium on "Artificial Support Systems for Acute Hepatic Failure", King's College Hospital Medical School, London, UK.
1974 Invited lecturer, International Society of Nephrology sponsored symposium on "Uremic Toxins and New Devices for their Removal", Naples, Italy.
1974 Invited discussant, Biomedical Research in Narcotic Abuse Problems, organized by the Non Medical Use of Drugs Directorate, Health & Welfare Canada.

1975 Conference on "Sorbents in Uremia and Hepatic Failure", Sponsored by the **International Society of Nephrology, NIH Chronic Uremia Program and the Clinical Dialysis** and

Invited introductory lecturer on "Microencapsulation and Coating for Adsorbent".
Invited lecturer on "Microencapsulated Adsorbent for Acute Intoxication, Liver Failure and Uremia".

1975 Invited speaker, Symposium of the International Pharmacological Congress, Helsinki, Finland.
1975 Invited speaker, New York Nephrology Society, New York, USA.
1975 Invited speaker, Downstate University of New York, School of Medicine, New York,
1975 Invited lecturer, "Microencapsulation Workshop", New Jersey, USA.
1975 Invited lecturer, NIH group on "Liver Failure Support", Clinical Center, NIH, Bethesda, Maryland, USA.
1975 Invited lecturer, Nephrology Dept., Children's Hospital, National Medical Center, Washington, D.C., USA.
1975 Invited speaker, symposium on "Immobilized Enzyme Applications", Chemical Institute of Canada, Toronto, Ontario, Canada.
1975 Invited lecturer, Gordon Conference on "Transport Phenomena in Synthetic and Biological Membranes", New Hampshire, USA.
1975 Poona International Workshop and Symposium on Enzyme Engineering, Poona, India.
Main speaker on "Microencapsulated Enzymes".
Main speaker on "Medical Applications of Immobilized Enzymes". Panel discussant on "Technique and Novel Approaches".
Chairman of session on "Applications of Immobilized enzymes".
1975 Invited speaker, University of Poona, Poona, India.
1975 Invited participant, Second International Federation of Institutes of Advanced Studies Workshop, Poona, India.

1976 Chairman, session on "Biomedical Applications of Microencapsulation" and Invited speaker, 3rd International Symposium on Microencapsulation, Tokyo, Japan.
1976 Chairman, "Panel on Adsorbent Hemoperfusion for Uremia, Acute Intoxication and Liver Failure", Annual Meeting, American Society for Artificial Internal Organs, San Francisco, California, USA.
1976 Invited lecturer, symposium on "New Technologies of Blood Purification in Uremia", sponsored by NIH, International Society of Nephrology, Weisban, Germany.

1976 Chairman and invited lecturer, Session on "Adsorbents in Therapeutic Medicine", Strathclyde Bioengineering Seminar series on "Artificial Organs", Glasgow, Scotland.
1976 Consultant and participant, "Drug Delivery Systems Workshop", NIH, Bethesda, Maryland, USA.
1976 Invited lecturer, Gordon Research Conference on "Immobilized Enzymes", New Hampshire, USA.
1976 Invited speaker, "Lecture Series on Possibilities of Synthetic Biology", Dept. of Life Sciences (James F. Danielli) Worcester Polytechnic Institute, Worcester, Massachusetts, USA.
1976 Co-chairman, Session 3 on "Artificial Organs", llth International Conference on Medical and Biological Engineering, Ottawa, Ontario, Canada.

1977 International Enzyme Engineering Conference, Germany. Chairman, session on "New Medical Applications in Immobilized Enzymes". Invited speaker, "New Approaches of Biodegradable Polymer Membranes, Microcapsules and Microencapsulation of Multistep Enzyme Systems."
1977 **Organizer and program chairman**, McGill Artificial Organs Research Unit International Symposium on "Some Novel Approaches in Artificial Kidney, Artificial Liver and Detoxification", McGill University, Montreal, Quebec, Canada.
1977 NIH International Conference on "Fulminant Hepatic Failure", Bethesda, Maryland.
Chairman, session on "Hemoperfusion Through Sorbents".
Invited speaker on "Albumin Cellulose Nitrate Coated Charcoal Hemoperfusion in FHF".
Invited speaker on "Microencapsulation of Multienzyme Systems and Recycling of Cofactors".
1977 Guest speaker, "Biomedical Applications of Artificial Cells", Montreal Physiological Society, Montreal, Quebec, Canada.
1977 Chairman, panel workshop on "Some Problems Related to Adsorbent Therapy", Annual Meeting, American Society for Artificial Internal Organs, Montreal, Quebec, Canada.
1977 Invited speaker, "Biomedical Applications of Enzymes" Symposium on Enzymes, American Chemical Society, Amherst, Massachusetts, USA.
1977 Invited speaker on "The Future of Hemodialysis", Dialysis '77 Symposium, Leeds, UK.
1977 First International Society of Artificial Organs Meeting, Tokyo, Japan.
1977 Invited speaker, "Artificial Cells", Dow Cordis Artificial Kidney Division, Concord, California, USA.
1977 Invited speaker on "Hemoperfusion", Canadian Conference on Clinical Engineering, Notre Dame Hospital, Montreal, Quebec, Canada.

1978 **Visiting Professor by invitation of the Chinese Academy of Sciences**, lectured at:
i. Biophysics Institute, Chinese Academy of Sciences, Peking (12 hrs lectures, plus seminars and demonstrations).
ii. Capital Hospital (previously Union Medical School), Peking.
iii. National Symposium, Lang Fang (12 hours of lectures, plus seminars & demonstrations).
iv. Suchiachung Medical School, Suchiachung.
v. Hongchow Medical School, Hongchow.
vi. Shanghai Medical Association, Shanghai.
vii. Canton Medical and Scientific group, Canton.
1978 International Symposium on "Hemoperfusion, Dialysate and Diafiltrate Purification", Tutzing, Munich, Germany.
Chairman, session on "Hemoperfusion".
Invited introductory lecturer on "Hemoperfusion".
Invited lecturer on "Hemoperfusion in Fulminant Hepatic Failure".
Invited lecturer on "Conversion of Urea and Ammonia into Amino Acid".
1978 Invited speaker in symposium on "Nondialytic Management of Uremia", sponsored by NIH, Downstate Medical Center and New York Society of Nephrology, New York, USA.
1978 Invited speaker on "Biodegradable Drug Carriers", Gordon Research Conference, Plymouth, New Hampshire, USA.
1978 Invited speaker on "Immobilized Enzymes in Therapy", Conference on "Enzyme Economy", Chicago, Illinois, USA.

1978 **Keynote speaker**, Annual meeting of the Biomaterials Society, University of Toronto, Toronto, Ontario, Canada.
1978 Chairman, session on "Hemodialysis", International Congress of the International Society of Nephrology, Montreal, Quebec, Canada.

1979 International Symposium on Hemoperfusion: Kidney Support, Liver Support and Detoxification", Israel Institute of Technology, Technion, Israel.
Co-chairman of Symposium.
Invited speaker on "Present Status and Prospective of Artificial Cells in Hemoperfusion".
Chairman, session on "Hemoperfusion".
1979 Invited speaker on "Progress in Polymer Encapsulation of Enzymes, Biospecific Adsorbents and Drugs", American Japanese Chemical Societies joint symposium, Honolulu, Hawaii, USA.
1979 International Enzyme Engineering Conference, Enzyme Foundation, New Hampshire, USA.
Invited speaker on "Novel Urea Removal Systems".
Co-chairman of Workshop on "Biomedical and Analytical Application".
1979 Reporteur, Enzyme Therapy in Congenital Diseases Symposium, Hilton Head, North Carolina, USA.
1979 Symposium co-chairman and invited speaker, International Workshop on "Hemoperfusion", Haifa, Israel.
1979 Invited speaker on "Artificial Liver Support", International Workshop on "Artificial Organs", Sorrento, Italy.
1979 Invited speaker, Faculty of Medicine, University of Edmonton, Alberta, Canada.

1980 Co-chairman of Gordon Research Conference, "Drug Carriers in Biology and Medicine", New Hampshire, USA. Invited speaker on Artificial Cells
1980 International Symposium on "Artificial Liver Support", Hannover, Germany.
Invited speaker on "Effects of Artificial Liver Support for Galactosamine Fulminant Hepatic Failure Rats".
Co-chairman, session on "Hemoperfusion".
1980 Invited speaker on "Encapsulated Enzymes and Adsorbent" in replacement therapy.
International Symposium on "Therapy in Congenital Diseases", Swiss Academy of Medical Sciences, Interlaken, Switzerland.
1980 Annual Meeting, American Society for Artificial Internal Organs, New Orleans, Louisiana, USA.
Invited plenary speaker on "Artificial Blood Cells" in plenary symposium.
Chairman, panel conference on "Adsorbent Hemoperfusion in Blood Purification".
Co-chairman, sessions on "Artificial Liver".
1980 **Recipient "Clemson Award" for "Basic Research in the Development of the Microcapsule Artificial Kidney",** World Congress of International Society for Biomaterials, Vienna, Austria.
1980 Guest speaker, Mexico Society of Nephrology, Mexico on: Artificial Cells. Hemoperfusion in Chronic Renal Failure. Hemoperfusion in Acute Intoxication and Liver Failure.

1981 International Symposium on "Hemoperfusion", Bologna, Italy. Invited speaker on hemoperfusion in
1981
1981 International Symposium on Detoxification Approaches in Chronic Schizophrenia, Berlin, East Germany.
Invited speaker on "Endorphin and Middle Molecule Removal in Schizophrenia".
Co-chairman on "Detoxification Session".
1981 Invited speaker, "Artificial Cells", Science Association, National Research Council of Canada, Ottawa, Ontario, Canada.
1981 "**Distinguished Honoured Guest",** Preview Ceremony, International Center for Artificial Organs and Transplantation, Cleveland, Ohio, USA.
1981 Annual Meeting, American Society for Artificial Internal Organs, Anaheim, California.
Co-chairman, session on "Plasma Manipulation and Enzyme".
Program Committee.

1981 Invited plenary lecturer on "Blood Compatible Adsorbent Hemoperfusion in Extracorporeal Blood Treatment", 4th International Symposium on Affinity Chromatography and Related Techniques, Katholieke Universiteit, Nijmegen, The Netherlands. (Unable to attend just before meeting, paper presented as publication in book)

1981 Invited speaker on "Present Status of Microencapsulated Adsorbent", Symposium on "Adsorbent in Uremia", Congress of the International Society of Nephrology, Athens, Greece. (Paper read in absence by Dr. E. Espinosa)

1981 International Congress of the International Society for Artificial Organs, Paris.
Invited speaker on "Hemoperfusion" in **opening plenary symposium** on "Controversies and Issues in Artificial Organs".
Chairman, session on "Hemoperfusion".
Keyman of Hemoperfusion, program committee of International Society.

1981 Invited speaker, "Artificial Cells Encapsulated Enzymes" in International Symposium on "Therapy of Inborn Errors of Metabolism", London, UK.
(Paper read in absence by Dr. M. Poznansky)

1981 Invited plenary speaker for **plenary lecture** on "Biomedical Applications of Immobilized Biologically Active Materials", 6th Biannual International Enzyme Engineering Conference, Kashikojima, Japan.

1981 International Symposium of Chemical Engineering, Montreal, Quebec, Canada.
Invited speaker plenary lecturer on "The Present Status of Research in Artificial Cells". Chairman, session on "Artificial Organs and Implants".

1981 Invited speaker, "Microcapsules" in "Colloquium on Microcapsules and Microcarriers in Biotechnology", Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.

1981 Invited speaker on "Biotechnology Research on Artificial Cells", McGill Biotechnology Symposium.

1981 Invited speaker, Biotechnology Seminars, McGill University, Montreal.

1982 **Chairman of Gordon Research Conference** on "Drug Carriers in Biology and Medicine", New Hampshire, USA (also session chairman and invited speaker on Artificial Cells).

1982 IVth International Symposium of Hemoperfusion and Artificial Organs, Ankara, Turkey.
Honorary President of symposium.
Invited speaker on "Past, Present and Future Perspectives of Hemoperfusion".

1982 Invited speaker, Canadian Science Writing Association Meeting, Montreal.

1982 Invited speaker on "Artificial Cells with Emphasis on Hemoperfusion in Uremia, Liver Failure and Acute Intoxication", Environmental Health Directorate

1982 Seminar Series, Bureau of Medical Devices, Health and Welfare Canada, Ottawa, Ontario, Canada.

1982 Invited lecturer on "Artificial Cells", Pediatric Travel Club, Montreal Children's Hospital, Montreal, Quebec, Canada.

1982 Invited lecturer on "Hepatic Coma", Medical Grand Round, Royal Victoria Hospital, Montreal, Quebec, Canada.

1982 Invited lecturer on "Present Status of Research on Artificial Liver Support", St. Luc Hospital, Montreal, Quebec, Canada.

1982 Invited speaker on "Artificial Cells: Applications of the biotechnology of microencapsulation and immobilized enzymes and cells", Seminar Program, McGill Chemical Society, Montreal.

1983 President, organizer and invited speaker, Fifth International Symposium on "Microencapsulation, including Artificial Cells", Montreal, Canada.

1983 Chairman and invited speaker, Symposium on Hemoperfusion, Congress of the European Society for Artificial Organs.

1983 4th Congress, International Society for Artificial Organs, Kyota, Japan. Invited speaker on artificial liver".
Program committee, Keyman on Hemoperfusion.

1983 Invited speaker on "Artificial Cells", symposium on "Plastics and Artificial Organs", American Chemical Society, Seattle, Washington, USA.

1983 Invited panelist on "Liver Support/Transplants and Artificial Organs", Annual meeting of the American Society for Artificial Organs, Toronto,
1983 Invited speaker on "Clinical Trial on Hemoperfusion" in Workshop on Hemoperfusion organized by Hopital Necker, Paris, France.
1983 Invited lecturer on "Basic Principle of Artificial Cells for Blood Substitutes" in symposium on Artificial Blood, Annual Meeting, Canadian Society of Immunohematologists, Ottawa, Ontario, Canada.
1983 Invited speaker, Pediatric Research Symposium and Workshop. Faculty of Medicine, University of Alberta, Edmonton, Alberta.
1983 Invited speaker on the Composite Artificial Kidney Reviews of indications and applications, Societe Quebecoise de Nephrologie Annual Scientific Meeting, Val David, Quebec.
1983 Invited speaker on Artificial Cells in the Newest in Drug Delivery Systems, Pfizer Dialogue, Annual Meeting, Association of Faculties of Pharmacy of Canada. Invited
1983 speaker on "Composite Artificial Kidney in Uremic Patients" Symposium on Hemoperfusion, Amsterdam, Holland. (Paper read in absence by Dr. P. Barre)
1983 Invited lecturer on "Artificial Cells", 57th Colloid and Surface Science Symposium, Toronto, Ontario.
1983 Invited speaker on "Artificial Cells", Symposium, Canadian Society of Cell Biology, CFBS, Ottawa, Ontario.
1983 Invited lecturer on "Artificial Cells", International Symposium on Biomaterials in Artificial Organs, Scotland.
1983 Invited speaker on Membrane Biotechnology in Artificial Cells in "Membrane Technology Conference", Oregon, USA.
1983 Invited speaker on "Artificial Cells", "Hemoperfusion in Uremia", "Hemoperfusion in Poisoning and Fulminant Hepatic Failure", Brazil National Society of Nephrology Congress on Hemodialysis and Transplantation.
1983 Session chairman and invited speaker, V International Symposium on Hemoperfusion and Artificial Organs, People's Republic of China.
1983 Invited speaker, Nankai University, Tianjin, People's Republic of China.
1983 Invited speaker, Chongqing Medical College and Chongqing Biomedical Engineering Society, Chongqing, People's Republic of China.
1983 Invited speaker, Shanghai First Medical College, Shanghai, People's Republic of China.
1983 Invited speaker, Institute of Biochemistry, Shanghai, People's Republic of China.

1984 Invited speaker and session chairman, Gordon Research Conference on "Drug Carriers in Biology and Medicine".
1984 Invited speaker, Biocatalysis Group, University of Iowa, Iowa, Ill.
1984 Guest Faculty, Postgraduate Medicine course on "Life Support Systems in Intensive Care", University of Michigan Medical School, Ann Arbor, Michigan.
1984 Invited lecturer, NATO Advanced Study Institute on Biopolymer, Turkey.
1984 Guest speaker, "Artificial Cells" Medical Grand Round Montreal General Hospital.
1984 Invited speaker in Seminar on "Hemoperfusion in Hemodialysis Patients", NJ, USA.

1985 Chairman of session on Immobilized Cells, 8th Biannual International Enzyme Engineering Conference, Denmark.
1985 5th Congress of International Society of Artificial Organs, Chicago, USA.
Chairman, Program Committee on "Artificial pancreas/artificial liver".
Chairman, Workshop on "Artificial Cells".
1985 Invited Speaker, Science Council of Canada/Canadian Plastics Institute Meeting on

1985 Invited Lecturer, "Artificial Cells", DuPont Co., Wilmington, DE, USA.
1985 Invited participant: "Think Tank: The Bowel as a Kidney", Downstate Medical Center, Brooklyn, New York.
1985 Invited speaker "Artificial Cells in Medicine and Biotechnology", Montreal Physiological Society.
1985 VIth International Symposium on Hemoperfusion, Mexico
Honorarpresident
Invited speaker.
1985 Invited speaker for special breakfast meeting on "Hemoperfusion in chronic renal failure

and aluminum removal", 25th Anniversary of Chronic Dialysis" to honour Professor B. Scribner, Seattle, USA.

1985 Invited participant, Science Council Workshop on Medical Devices, Toronto.

1985 **Opening Plenary Lecturer**, State art on "Artificial Blood", Annual Meeting of American Society of Artificial Internal Organs, Atlanta, USA.

1986 Invited speaker, International Conference on "Applications of New Technologies in Phospholipid Thin Membranes and Vesicles", US Naval Research Symposium, Tenefrice, Spain.

1986 **Honorary President of Symposium**, Cochairman, Program Committee, and invited speaker, 7th International Symposium on Hemoperfusion, Kiev, USSR, sponsored by the USSR Academy of Sciences, September.

1986 Invited speaker, Czechoslovakia Society of Nephrology and Czechoslovakia Academy of Sciences, Prague.

1986 Special invited lecturer and session chairman, Annual Meeting of the Controlled Release Society, Virginia, USA.

1986 Chairman of two sessions, invited speaker and Program Committee on Artificial Kidney "International Symposium on Biomedical Engineering, Artificial Organs, and Transplantation" to honour Professor W. Kolff, Utah, USA.

1986 Invited speaker, Gordon Research Conference on "Bioactive Polymeric Material in Biomedical and Agricultural Application", Oxnard, California.

1986 Invited speaker, Workshop on Drug and Enzyme Delivery Systems, Annual Meeting of the American Society of Artificial Internal Organs, U.S.A.

1986 Invited speaker on "Artificial Cells" Workshop on Biotechnology, Canadian Society of Biological Sciences, Guelph, Ontario.

1987 **Chairman of Symposium & Opening Plenary speaker**, III International Symposium on Blood Substitutes, Montreal.

1987 Chairman, panel on Blood Substitutes, Annual Meeting, American Society of Artificial Internal Organs, New York.

1987 Panel Chairman and invited speaker, panel on "Drug Delivery", 6th Congress of the International Society of Artificial Organs.

1987 Invited Speaker on "Immobilization of enzymes, liver cell cultures and hemoglobin" in Session on Medical Applications, 9th International Conference on Enzyme Engineering, Santa Barbara, California.

1987 Invited speaker and International Scientific Committee, International Symposium on Optimization of Blood Purification, Rostock.

1987 **Invited plenary lecturer** and chairman of session, 7th International Symposium on Microencapsulation, Zegreb, Yugoslavia.

1987 Invited speaker, NATO Workshop on Immobilized Enzymes, Italy.

1987 Invited panelist, Symposium on "Role of Hemoperfusion in acute liver failure", Georgetown University, Washington.

1987 Invited Guest speaker, American Society on Material (Edmonton, Alberta).

1987 Invited speaker, Grand Round, Faculty of Medicine, University of Alberta,Edmonton.

1987 Invited Speaker. Conference on Innovations in Protein modifications in therapeutics.

1988 **Opening Ceremony State Art Lecturer** on "Artificial Cells" 1988 Congress of the European Society for Artificial Organs, Prague, Czechoslovakia.

1988 **Honorary President and Opening Ceremony Festive Lecturer** on "Artificial Cells" 8th International Symposium on Hemoperfusion, Adsorbents and Immobilized Bioreactants, Rostock, Germany.

1988 Invited Speaker, session on Cell Biotechnology "Artificial Cells and Liposomes", 4th International Congress of Cell Biology, Montreal.

1988 Special invited speaker on "Artificial Blood". Symposium, Mexico City, Mexico.

1988 Invited lecturer on "Blood Substitutes". Mexican Academy of Surgery, Mexico City.

1988 Invited lecturer on "Blood Substitutes". Medical Centre, Mexico City, Mexico.

1988 Chairman of session and introductory lecture Gordon Research Conference on "Drug Carriers" New Hampshire, USA.

1988 Invited Speaker, Panel on New Trends in Artificial Organs, III World Biomaterials Congress, Kyoto, Japan.

1988 Special invited speaker on "Clinical Applications of hemoperfusion in intoxication and hepatic coma". Symposium, Mexico City, Mexico. 1988 Invited Lecture on Artificial Cells, Shiga University, Japan.

1988 Invited Speaker International Congress on "New Trends in Nephrology, Dialysis and Transplantation". 9th Centenary, University of Bologna,Bologna, Italy.

1988 Session chairman, Artificial liver/pancreas, Annual Meeting of the American Society Artificial Internal Organs, Reno, USA.

1988 Invited lecturer in symposium on Mimetic Enzymes. Annual Meeting of the American Chemical Society, Toronto.

1988 **Invited keynote lecture**, Hybrid Artificial Organs Symposium, Bordeau, France.

1989 **Honorary president and invited speaker**, 9th International Symposium on Hemoperfusion, adsorbents and immobilized bioreactants, Tokyo, Japan.

1989 Invited lecturer, Plenary session on "Enzyme Engineering in Medical Field". 10th International Conference on Enzyme Engineering, Kashikojima, Japan.

1989 Symposium Co-chairman, Invited lecturer, and Chairman of session, "In vitro and in vivo assessments of cross linked hemoglobin" in International Symposium on Red Blood Cell Substitutes. San Francisco, U.S.A.

1989 Invited speaker and chairman of session, International Symposium on Red Blood Cell Substitutes sponsored by the Japanese Red Cross Society.

1989 Invited lecturer. "Immunological aspects of modified hemoglobin as blood substitute" Biomedical Engineering Society, Symposium on "Blood Substitutes". Federation of American Biological Sciences, New Orleans, U.S.A.

1989 Invited lecturer, "Modified hemoglobin: in vivo studies" American Trauma Society Annual Meeting, Florida, USA.

1989 Invited lecturer, Red Blood Cell Substitutes, Waseda University, Tokyo Japan.

1989 Invited speaker "Modified Hemoglobin as Blood Substitutes past, present and future", Immunohematology Society, Canadian Red Cross Symposium on "Present Trends in Blood Transfusion", Banff, Alberta.

1989 Chairman and speaker, Workshop on Blood Substitutes, European Society of Artificial Organs, Brussels, Belgium.

1989 Invited speaker on Blood Substitutes, Montreal Red Cross Society, Montreal.

1989 Invited speaker, Biotechnological and Medical applications of Artificial Cells in International Conference on Biotechnology, Slamanca, Spain

1990 **Honorary president and invited plenary speaker**, X International symposium on Hemoperfusion, absorbent and immobilzed bioreactants, Rome, Italy

1990 **Invited plenary speaker** on Biotechnoligcal apporach based on artificial cells, Congress of the European Society for Artificial Organs , Bologna, Italy

1990 **Invited plenary speaker**, VI International Symposium on Microencapsulation, Glasgow

1990 Invited speaker on Artificial Cells. "International Conference on Membrane," Chicago, IL

1990 Invited speaker, symposium, American Chemical Soceity, Annual Meeting, Washington, DC, USA

1991 Invited speaker in panel on Hydribd Artificial Organs, Annual Meeting, American Society of Artificial Internal Organs, Chicago USA.

1991 Invited speaker and session chairman on "Blood Substitutes"; Annual Meeting, American Society of Artificial Internal Organs, Chicago, USA.

1991 Invited speaker, On "Red Blood Cell Substitutes by Modified Hemoglobin", CPTMQ CSLT Congress, Montreal.

1991 **Congress President VIII World Congress**, International Society of Artificial Organs, Montreal, Canada. **Opening ceremony speaker** on "35 years of artificial cells"

1991 Symposium Chairman and plenary speaker, on "Modified hemoglobin as blood substitutes", IV International Symposium on Blood Substitutes, Montreal, Canada.

1991 Invited lecturer on "Modified hemoglobin as blood substitutes", Symposium on "New Concepts in Blood Product Usage", Canadian Society of Hematology and Canadian Red Cross Blood Service, Annual Meeting, Royal College of Physicians of Canada, Quebec

City.

1992 Chairman of panel on "Blood substitutes", and speaker on "Modified hemoglobin and clinical safety", American Society for Artificial Internal Organs, Annual Meeting, Memphis, USA.
1992 **Invited plenary speaker** on Blood Substitutes., XIX Congress of the European Society for Artificial Organs,Rhode Island, Greece.
1992 **1st Julius Silver Lectureship, Julius Silver Symposium** organized by the Julius Silver Institute of Biomedical Engineering, Technion Institute, Israel and the Israel Society of Biomedical Engineering. International
1992 Invited speaker, 8th International Symposium on Microencapsulation, Dublin,Ireland,

1993 **Co-chairman and invited plenary speaker**, V International Symposium on Blood Substitutes, San Diego, California, USA.
1993 Chairman and opening speaker, IB Conference on Blood Substitutes, Philadelphia, USA.
1993 **Open plenary lecturer**, Inaugurate congress of the founding of the Japanese Society for Blood Substitutes. Tokyo

1994 **Honorary Congress President and Opening Plenary Speaker**, XI Congress of the International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology, with Professor R. Langer of MIT as organizer and congress president,Boston, USA.
1994 Conference Chairman and Opening Speaker IBC conferenece on Blood Substitutes. Washington, D.C.
1994 Invited speaker, on Blood Substitutes International Conference on Bioengineering, Krems, Austria.

1995 Invited speaker on "Artificial Cells Technologies" Meeting on Cell Transplantation. Technologies Applicable to Cell Therapy, Miami, U.S.A.
1995 Invited speaker Symposium on Tissue Engineering using Biomedical Polymers. Kyoto
1995 Invited Main Lecturer. (at last minute substituted by my recent Ph.D. graduate because too many invited lectures this year.) International Symposium on Polymer, Institute of Macromolecular Chemistry,Czech Academy of Science, Prague, Czech.
1995 Invited Special Lecturer on "Present Status of Modified Hemoglobin as Blood Substitutes" II Congress Japanese Society for Blood Substitute, Tokyo, Japan. This was followed by Invited Lecturer on "Specially designed modified hemoglobins" Waseda University,Tokyo and also Shonan Research Centre, Tokyo.
1995 Panel Chairman and opening speaker. Panel on Artificial Blood. Annual Meeting of the American Society for Artificial Internal Organs, Chicago.
1995 Chairman , Symposium on Tissue Engineering I: Basic Science and Chairman, Session Tissue and Cellular Engineering, 17th Annual International Conference of the IEEE Engineering in Medicine and Biology society & 21 Canadian Medical and Biological Engineering Conference, Montreal.
1995 **Presidential address & Key note speaker** on "Artificial Cells Biotechnology for Artificial Organs in the 21st Century". X World Congress of the International Society for Artificial Organs, Taipei, Taiwan.
1995 Opening speaker on "Present status of modified hemoglobin blood substitutes" International Symposium on the Technology of Blood Substitutes. Taipei, Taiwan.
1995 **Invited Plenary lecture** on "Microcapsule artificial cells containing enzyme, hepatocytes or genetically engineered microorganisms: implications in therapy and biotechnology" in the International Symposium on Microencapsulation, Drug Dynamics Institute, College of Pharmacy, U of T at Austin, Texas, U.S.A.

1996 Cochairman and invited speaker Session on "Safety and Efficacy of Artificial Oxygen Carrier" 24th Congress of the International Society of Blood Transfusion, Chiba, Japan.
1996 Co-chairman and invited speaker on "Deveopment of bioartificial liver" in Symposium on "Plasmapheresis and/or transplant for fulminant hepatic failure" International Conference for Apheresis. Kyoto, Japan.

1996 Co-chairman Session on Blood Substitutes. Annual meeting of the American Society for Artificial Internal Organs, Washington,D.C.
1996 Symposium Chairman and opening speaker, VII International Symposium on Blood Substitutes, Montreal
1996 **Invited opening plenary speaker:** Conference on Bioartificial Organs, Science and Technology, Sponsored by the Engineering Foundation, Nashville,Tennessee, USA

1997 **Hononary congress president and plenary lecturer**.XII Congress of the International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology.
Organized by the Chinese Academy of Medical Sciences ,Beijing, PRC. September.
1997 Symposium co-chairman and plenary lecturer of the VIII International Symposium on Blood Substitues, Tokyo, Japan.
1997 Invited speaker and co-chairman of session on Artificial Cells & Blood Substitutes. Congress of the International Society for Artificial Organs. Rhode Island, U.S.A.
1997 Invited speaker, Symposium on Blood and Surgery : a Multidisciplinary approach, Winnipeg, Canada.
1997 Keynote speaker, "Blood substitutes - present status and future relevance in national blood supply policies" Canadian Society for Transfusion Medicine, Ottawa.

1998 Invited opening plenary lecture on "Artificial Cells, Immobilization and Encapsulation", Bioartificial Organs II: Technology, Medicine and Materials, Engineering Foundation Conferences, Banff, Canada.
1998 **Invited Plenary Lecturer** on " Artificial Cells including Blood Substitutes" 8th Asian-pacific Congress of Clinical Biochemistry, Kuala Lumpur, Malaysia
1998 Invited "State of the art lecture" on hemoglobin-based blood substitutes. XXVth Congress of the Int. Soc of Blood Transfusion. Oslo, Norway,
1998. Panel speaker on “Polyhemoglobin-catalase-superoxide dismutase: a new blood substitute
Conference on Resuscitation Fluids, Institute of Medicine, National Academy of Science, Washington, D.C.

1999 Chairman and opening speaker. Panel on Artificial Blood. Annual Meeting of the American Society for Artificial Internal Organs
1999 Invited lecturer on Blood Substitutes in Conference on Biotech Alternatives to Blood & Plasma Products. London, UK
1999 Invited lecturere and chairman of panel on “Bioencapsulation” Innovation and Trends in Biotechnology, Laval, Quebec, Canada

1999 Invited lecturer on “Artificial Cells including blood substitutes”, Therapeutic Products Program, Continuing Education, Health Canada, Ottawa, Canada
1999 Invited speaker in symposium on “The bowel as an artificial kidney” Congress of the International Society for Artificial Organs, Edingburgh, UK.
1999 **ISBP Award Plenary Lecture**, Congress of the International Society for Blood Purification, Prague. (Sir Roy Calne was the winner of the 1998 ISBP Award Lecturer other previous winners have included Robert Rosenberg at the NIH, and Charles Dinarello then at Tufts)

2000 Invited Lecturer on Artificial Cells, Abbott Laboratory, Chicago
2000 Invited Lecturer on Blood Substitutes, International Conference on Transfusion Medicine 2001, Cambridge University, United Kingdom
2000 Invited Lecturer on Blood Substitutes, European Society for Trauma Surgery, Pisa, Italy
2000 Invited Plenary Speaker, Bionics for Human in 3rd Millenium, L’Aquila, Italy
2000 Chairman, Session on Award Lectures, Congress of the International Society for Blood Purification, Rome, Italy
2000 Session Chairman on Clinical Trials and Invited Lecturer on Present

Status(1)Blood Substitutes (2) Oral therapy for uremia, III Bioartificial Organ Conference, Switzland

2000 2000 Symposium Co-chairman, session chairman and invited plenary lecturer on New Products in hemoglobin based blood substitutes, VIII International Symposium on Blood Substitutes, San Diego

2000 Invited Lecturer, Poly2000, American Chemical Society, Hawaii

2001 Invited Open Plenary Symposium lecturer on Artificial Cells in the 48th Annual Conference, American Society for Artificial Internal Organs, New York City, U.S.A..

2001 Invited speaker on "Blood Substitutes" 11th European Congress of Anaesthesiology, Florence. Italy.

2001 Chairman & Invited Speaker in panel on "Artificial Organs". 6th Symposium of World Artificial Organs, Immunology & Transplantation Society, Ottawa, Canada

2001 Invited Speaker in panel on "Treatment of Type 1 Diabetes", 6th Symposium of World Artificial Organs, Immunology & Transplantation Society, Ottawa, Canada

2001 Panelist in public panel on "Ask the Experts". 6th Symposium of World Artificial Organs, Immunology & Transplantation Society, Ottawa, Canada

2001 13th Congress of the International Society for Artificial Organs, Osaka, Japan. International Scientific committee, chairman of Panel session on "Genetic Engineering and Biotechnology in Artificial Organs", and invited panel lecturer on "Artificial Cells for genetically engineered cells and modern biology in artificial organs"

2001 Invited speaker on Artificial Cells as visiting professor, Chinese Hong Kong University Medical School.

2001 Invited speaker on Artificial Cells. Capital Medical School Affiliated ChouYaung Hospital, Beijing.

2002 Invited lecturer on "Artificial Cells in Tissue Engineering with emphasis on oral therapy using artificial cells containing genetically engineered cells". Tissue Engineering Conference, Pittsburg, Penn.

2002 **Invited plenary speaker** on "Future generations of Blood Substitutes" and member of Organizing committee of Conference on Blood Substitute organized by Karolinka Institute, Stockholm, Sweden.

2002 Keynote speaker on "Artificial Cells in Biotechnology and Medicine", World Congress. Seoul, South Korea.

2002 Invited lecturer on "Blood Substitutes in trauma surgery:". International Congress of Surgery, Taiwan.

2002 Invited Keynote speaker on "Artificial Cells in Bioencapsulation: macro, micro, nano and molecular", Bioencapsulation Conference, Birmingham, U.K.

2002 Invited speaker on "Two new blood substitutes: polyhemoglobin-SOD-CAT and biodegradable polymeric Hb nanocapsules", Mini symposium on Oxygen carrying resuscitation fluid, ATACCC, Florida, U.S.A.

2003 **Invited Special Plenary speaker** on Artificial Oxygen Carriers, International Symposia for Life Science and Medicine, Keio University, Tokyo, Japan (March)

2003 Honorary president and invited plenary speaker, 9th International Symposium on Blood Substitutes, Tokyo, Japan (March)

2003 Invited Speaker, Symposium, Research Fund Bayer/Canadian Blood Service/Hema Quebec

2003 Invited speaker on Artificial Cells in Medicine and Biotechnology. CIHR Workshop Regenerative Medicine and Artificial Organs, Toronto, Canada. (March)

2003 Chairman and invited speaker, precongress workshop on Blood Substitutes: present and future. Joint congress of International Society for Artificial Organs/American Society for Artificial Internal Organs. Washington D.C., U.S.A. (June)

2003 Invited Speaker on "Blood Substitutes & Artificial Cells" 4th Regenerative Medicine Conference , Washington, D.C. (November)

2003 **Visiting Professor, Invited Lecture** on Blood Substitutes, Grand Round, Department of Anesthesia and Critical Care, Massachusetts General Hospital, Harvard Medical School, Boston, U.S.A. (December).

2003 **Invited plenary speaker. TEDA-Waston International Biotechnology Conference**, Tianjin , PRC

2003 Invited speaker. Life Sciences Faculty, Nankai University, Tianjin, PRC

2003 Invited speaker. Chinese Academy of Medical Sciences/ Beijing Union Medical College. Beijing, PRC

2003 Invited speaker. Pharmaceutical Sciences and Biotechnology Faculty,Tianjin University, Tainjin, PRC

2004 Keynote speaker, Graduate Program Conference, Department of Pharmaceutical Sciences, University of Toronto, Canada.

2004 Invited speaker, VIP guest, scientific committee, the 3rd TEDA-WATSON International Forum on Biotechnology and Biomedicine, Tianjin, China

2004 Invited plenary speaker and Investiture as Visiting Professor Shen Zhen University, National Symposium on Hemoperfusion. ShenZhen, China

2004 **Keynote speaker, 5th International European Molecular Biology Laboratory** Ph.D. Students' Symposium. European Molecular Biology Laboratory (EMBL),Heidelberg, Germany

2004 Invited plenary lecturer, International Conference on Chemistry Biology Interface: Synergistic New Frontiers. Delhi, India.

2005 **Honorary Sympoium President and invited opening plenary speaker** on "Evolution of Artificial Cells", X International Symposium on Blood Substitutes, Rhode Island, Providence, U.S.A.

2005 **Keynote Speaker on "Artificial Cells in Regenerative Medicine"** II World Congress Regenerative Medicine, Lipzig, Germany

2005 Invited speaker on "Blood Substitutes: molecular biotechnology to nanobiotechnology" International Conference on New Technologies in Medicine, Krems, Austria

2005 Invited speaker on "Artificial Cells of macro, micro, nano and molecular dimensions" Department of Biomedical Engineering Seminar Series , McGill Unversity.

2006 Invited speaker on "New Trends in Blood Substitutes: biological and synthetic oxygen carriers". Joint Conference of the Canadian Society for Transfusion Medicine/Canadian Blood Service/Hema-Quebec, Montreal.

2006 Invited Speaker, Biomedical Engineering Department Seminar Series, McGill University.

2006. **Opening Plenary lecturer** for the 3 days Business Conference section of the 9th International Conference on "Gene and Drug Therapy in Molecular Medicine" Crete, Greece. "Therapeutic Application of Polymeric Artificial Cells"

2006 Invited opening session lecture on "Therapeutic applications of polymeric artificial blood cells" International visions on blood substitutes. Hemoglobin-based oxygen carriers, from chemistry to clinic" University of Parma, Parma, Italy.

2006 Invited speaker: Technology in Liver Regeneration Conference on Stem Cells in Regenerative Medicine, Ankara, Turkey.(cancel because of airline security problem)

2006 Invited speaker on nano artificial red blood cell to the Nanoscience Group, University Duisburg-Essen in Western Germany (Postponed because of airline security problem) Inv

2007 **Opening keynote lecturer**, 2007 Oct XI International Symposium on Blood Substitutes, Organized by Chinese Academy of Medical Sciences and Beijing Union Medical College, Beijing, China

2007 Chairman and panelist, Satellite symposium of XI ISBS on Toxicology of Blood Substitutes, Xian, China.

2007 **Invited Opening keynote lecturer**, XI International Symposium on Blood Substitutes, Organized by Chinese Academy of Medical Sciences and Beijing Union Medical College, Beijing, China

2007 Co-Chairman and panelist, Satellite symposium of XI ISBS on Toxicology of Blood Substitutes, Xian, China.

2007 Invited Speaker, Faculty of Medicine, Shantou University, Shantou, China

2007 Visiting Professor and invited speaker, Northwest University in Xian, China

2008 Invited lecturer , International Conference on Drug Design and Discovery, Dubai, UAE Dubais invited speaker
2008 International Drug Discovery Science & Technology Conference (IDDST) Opening keynote session in seesion on Regnerative Medicine, Beijing, China.
2008 Plenary specker and chair of session, International Academy of Nanomedicine Symposium, Washington DC (Potomac MD) USA
2008 **Guest Professor award ceremony and invited lecture.** Shantou University, Shantou, China
2008 Plenary Keynote speaker, World Congress on Cancer, Shanghai, China (did not go because of unexpected illness)
2008 Invited Keynote speaker, Joint meeting of the 15th Japanese Society for Blood Substitutes and 6th Current Issues in Blood Substitutes, Keio University, Tokyo, Japan (did not go because of unexpected illness)

2009 **Honorary President, opening speaker**, invited speaker and panelist, XII International Symposium on Blood Substitutes, Parma, Italy.
2009 **Opening plenary lecturer**, First World Congress of the International Academy of Nanomedicine, Hainan, China
2009 Special invited speaker, Chinese Research Group on Blood Substitutes, Beijing China, Chinese Academy of Sciences.

2010 **Opening Keynote plenary lecturer**, 2nd World Congress of the International Academy of Nanomedicine, Antelya, Turkey
2010 **Opening Keynote plenary lecturer.** International Congress on Nanotechnoloy, Ottawa
2010 **Opening Keynote plenary lecture** BIOMED2010, Istanbul
2010 **Opening Keynote plenary lecturer** BIT 3rd Congress on Regenerative Medicine and Stem Cells, Shanghai, China.
2010 **Opening Keynote plenary lecturer** BIT 1st Congress on Nanomedicine, Beijing, China
2010 Invited Lecture, Tsinghua University, Beijing, China
2010 Invited Lecture, Peking University Health Sciences, Beijing, China
2010 Invited Lecture, Polytech University, Hong Hong, China
2010 Invited Lecture, Transfusion Institute, Beijing, China

2011 **Acceptance speech for being voted the "Greatest McGillian"** in McGill University's 190 years history. Result of a worldwide poll to vote on 700 nominee and 20 finalists to celebrate the 190th anniversary of McGill University.
2011 **Kjeldgaard Lecturer,** Department of Molecular Biology, Aarhus University, Denmark
2011 **Honorary president and opening lecture**, XIII International Symposium of Blood Substitutes, Mass General Hospital, Harvard Medical School, Boston, Symposium president is Professor W Zapol, previously chief of Critical Care and Anesthesiology at at Mass General Hospital of Harvard Medical School.
http://www.medicine.mcgill.ca/artcell/536.pdf
2011 **Opening Keynote Speaker**, Conference on Micro and Nano Systems, Chongqin, China
2011 Invited Speaker, Blood Transfusion Institute of the Chinese Academy of Medical Sciences and Peking Union Medical College.
2011 Invited Speaker, Ordos Blood Substitute Congress, Ordos, Inner Mongolia, China

2012 **Opening Keynote lecturer** on Frontier in Transfusion Medicine based on nanobiotechnological blood subsitutes, BIT International Congress on Hematology, Beijing, China.
2012 Invited lecturer, Microcirculation Institute of the Chinese Academy of Medical Sciences, Beijing, China
2012 Invited lecturer, Beijing Transfusion Institute, Beijing, China
2012 **Opening Keynote Lecturer** and honorary president , III International Academy of **Nanomedicine Congress, Ankara, Turkey.**
2012 Invited Speaker, XX Conference on Bioencapsulation, Ontario, Canada

2013 **Opening Plenary lecturer** and Honorary Symposium President of the XIV International

Symposium on Blood Substitutes and Oxygen Therapeutics. at the Blood Transfusion Institute of the Chinese Academy of Medical Sciences, China. Symposium president is the president of the Chinese Academy of Medical Sciences and the other honorary symposium president is the vice minister of health of China.

2013 "**Fronteir in Medicine" lecture** series, Shantou University Medical School. Title of lecture "Blood substitutes in transfusion medicine: present clinical status and future perspectives"

2013 "Distinguished speaker lecture series" title of lecture "Artificial Cells" Calgary University Biomedical Engineering group

2014 Opening Plenary Lecturer 3rd Congress of the International Society for Nanomedical Science (postpored because of unsettle condition in region)

2015 **Honorary President and invited speaker** on *Nanobiotherapeutics with enhanaced rbc functions*, 4th Congress of the International Society for Nanomedical Sciences, Turkey

2015 **Honorary Presdient and invited speaker** on Red blood cell replacement or Nanobiotherapeutics with enhanaced rbc functions?, XIV International Symposium on Blood Substitutes, Lund, Sweden

2015 Invited lecturer on Blood substitutes and nanobiotherapeutic Blood Transfusion Institute of the Chinese Academy of Medical Sciences

2015 Invited lecturer on Blood substitutes: Present status and future perspectives Tianjin International Biotherapeutic Research Institute, Tianjin, China.

2016 Invited "Eminent researchers" round table for Canada's Science Review, Toronto, Canada

2016 **Chinese Canadian Legend Award and address**, Toronto, Canada

2017 **Opening plenary speaker:**
60th Anniversary of the Invention of Artificial Cells in conjunction with of XVI International Symposium on Blood Substitutes and V ISNS Nanomedicine Conference,
Evolution of Artificial Cells to Nanobiotherapeutic, blood substitutes, Bioencapsulation, Hemoperfusion, Nanomedicine, etc.
www.medicine.mcgill.ca/artcell/60AC.m4v
2017 Keynote lecture
60th Anniversary of the Invention of Artificial Cells in conjunction with of XVI International Symposium on Blood Substitutes and V ISNS Nanomedicine Conference,
Individual Roles of (1) Oxygen carriers, (2) Oxygen carries with antioxidant and (3) Oxygen carries with antioxidant and CO2 transport.

2018. **Opening Plenary Speaker** on 3rd general blood substitute. Chinese Society Symposium on Blood Substitute, Chengdu, China

2018. Lecture on design of clinical trial, Chinese Society Symposium on Blood Substitute, Chengdu, China

2018. Closing remarks, Chinese Society Symposium on Blood Substitute, Chengdu, China

2018 Invited speaker, international workshop on Bioencapsulation and Industry, Montreal

2018 Invited speaker, Biomedical Symposium, University of Quebec at Montreal

2019. **Invited plenary speaker and Honorary Presiden**t, 2018 V ISNS World Conference on Nanomedicine, Delhi, India

2019. Plenary Lecturer 13th Asian Science Camp (ASC 2019) Shantou, China

2019. **Honorary President and opening presidential lecture**, XVII International Symposium on Blood Substitutes, Nara, Japan

2019 Plenary Lecture Pacific-Asia Society of Blood Purification Nephrology Subdivision, Shenzhen, China.

2019 A number of smaller invited talks during a visit to China for the planning of the "Chang Artificial Cell Research Centre"

2019 Invited Speaker, Shantou University First Affiliated Hospital, Shantou, China., (invited

speaker).

2020-2022 COVID pandemic did not accept invitations for personal participation in meetings
Placed my plenary lecture for all to view at **www.artcell.mcgill.ca**

PATENTS and PATENT APPLICATIONS:

1. T.M.S. Chang (1970) "Nonthrombogenic Microcapsules": U.S. Patent, 3, 522, 346
2. T.M.S. Chang, F.C. MacIntosh and S.G. Mason (1971) "Encapsulated hydrophilic compositions and Methods of Making them" Canadian Patent, 873, 815
3. T.M.S. Chang (1971) "Nonthrombogenic microcapsules" Canadian Patent, 876,100
4. T.M.S. Chang (1973) "Blood compatible microcapsules containing detoxicants" U.S. Patent, 3, 725, 113
5. T.M.S. Chang (1976) "Blood compatible microcapsules containing detoxicants" Canadian Patent, 982, 941
6. T.M.S. Chang and J. Daka (1990) "A novel method for bilirubin removal" Canadian Patent granted.
7. T.M.S. Chang, L. Bourget and C. Lister (1991) Novel method of amino acid removal by immobilized bioreactant based on new findings of enterorecirculation of amino acids USA Patent No. 5,147,641, Issued Sept. 15, 1992
8. T.M.S. Chang, L. Bourget and C. Lister (1989) Patent as above, Canada
9. T.M.S. Chang and H. Wong (1992) A novel method for cell encapsulation in artificial cells. USA Patent No. 5,084,350, Issued Jan. 28, 1992
10. T.M.S. Chang and C. Lister (1993) Screening test for modified hemoglobin blood substitute before use in human. U.S. Patent No. 5,200,323, Issued April 6, 1993
11. T.M.S. Chang and W.P. Yu (1992). Biodegradable polymer membrane containing hemoglobin as potential blood substitutes. British Provisional Patent No. 9219426.5, Issued September 14, 1992.
12. T.M.S. Chang and W.P. Yu (1997). Biodegradable polymer membrane containing hemoglobin for blood substitutes. U.S.A. Patent 5670173 September, 23, 1997
13. D'Agnillo F & TMS. Chang (1997) Modified hemoglobin blood substitute from Cross-linked hemoglobin-superoxide dismutase-catalase.US patent 5,606,025, Feb,1997
14. D'Agnillo F & T.M.S.Chang Hemoglobin-enzyme complexes. Canadian Patent 2,135,739
15. Satya Prakash & T.M.S.Chang (1996) Microencapsulated genetically engineered microorganisms for clinical application. British Priority Patent No 9601333-9, January 23, 1996
16 T.M.S.Chang & Satya Prakash(1998) Microencapsulated genetically engineered microorganisms for clinical application. International PTC application for Europe, Japan, U.S.A.& Canada.(removal of urea and ammonia)
17 Satya Prakash & T.M.S.Chang (April, 28,1999). Microencapsulated genetically engineered E. Coli DH5 cells for the removal of undesired electrolytes and/or metabolites. U.S.A. Provisional Application. Serial Number 60/131,468
18 Satya Prakash & TMS Chang (April27, 2000) Artificial Cells Microencapsulated Genetically Engineered E. Coli DH5 Cells for the Removal of Undersired electrolytes and/or metabolites. International Application No:PCT/CA00/00482
19 TMS Chang & Satya Prakash (2001) Microencapsulated genetically engineered microorganisms for clinical application. U.S. Patent 6,217,859 April 17 2001.
20 TMS Chang & Satya Prakash (2001) Microencapsulated genetically engineered microorganisms for clinical application. Japanese Patent 3228941 (September 7 2001).
21 TMS Chang, & WP Yu (2001) Biodegradable Polymeric Nanocapsules and uses thereof. U.S. Provisional Patent Application. No 60/316,001 (August 31, 2001)
22 TMS Chang, D.Powanda & WP Yu (2002) Biodegradable Polymeric Nanocapsules and uses thereof. International Patent Application No. PCT/CA02/01331- August 2002. WO 03/017989 A1 (2003)
23 TMS Chang, D.Powanda & WP Yu (2002) Biodegradable Polymeric Nanocapsules and uses thereof. Chinese Patent Application 2004

24 TMS Chang & Binglan Yu (2002) Composition for inhibiting tumour growth and methods thereof. US Provisional Patent Application 60/364,581 (March 18, 2002)
25 TMS Chang & Binglan Yu (2003) Composition for inhibiting tumour growth and methods thereof. US Patent Application (March 2003)
26 T.M.S. Chang and C. Lister (2003). Screening test for modified hemoglobin blood substitute before use in human. Canadian Patent (awarded)
27 TMS Chang, D.Powanda & WP Yu (2004) Biodegradable Polymeric Nanocapsules and uses thereof. U.S. Patent Application February 27 2004
28 TMS Chang, D.Powanda & WP Yu (2007) Biodegradable Polymeric Nanocapsules and uses thereof. Chinese Patent awarded
29 TMS Chang & Wong, N (2007) A novel blood substitute. U.S. Provisional Patent.60/968720 August 29, 2007
30 TMS Chang, & WP Yu (2008) Biodegradable Polymeric Nanocapsules and uses thereof. U.S. Patent Awarded Nov 2008
31 TMS Chang, & WP Yu (2008) Biodegradable Polymeric Nanocapsules and uses thereof. Chinese Patent Awarded 2008
32 TMS Chang & YZ Bian (2011) Novel Blood Substitute with complete red blood cell functions. U.S. Provisional Patent US 61/490.304
33 TMS Chang & YZ Bian (2021) Novel Blood Substitute with complete red blood cell functions. Canadian Patent approved
34 TMS Chang & M Hoq.(2023) Artificial blood substitutes. US Provisional Patent

COMMITTEES AND BOARDS:

1. Diocesan Boys' School, Hong Kong:
   Head Prefect of Boarding School. Captain,
   Featherstone House (sports).
   Pianist, General Assembly and Chapel services.
2. McGill University Undergraduate:
   Social Convenor and Student Council, Douglas Hall of Residence, McGill. McGill Intercollegiate Wrestling Team (Letter award).
   Sunday School Teacher, Christ Church Cathedral, Montreal.
3. Free voluntary community service in Montreal Chinese Hospital:
   First of the annually rotating chairmen, Medical Board, newly built Montreal Chinese Hospital (free voluntary service) (1966-1967).
   Attending staff and chief of laboratory (free voluntary service) (1966 until Medicare in Quebec);
   Consultant – free voluntary service (since Medicare started until 1982); Honorary Consultant,free voluntary service (1982-1987);
   Honorary Staff, free voluntary service (1987- present).
4. Board of Directors, Preville Presbyterian Church (1967-1968).
5. Advisory Board, Biannual International Enzyme Engineering Conference (1971).
6. Committee on the Standardization of Nomenclature in Enzyme Technology, (consisting of E Katchalski, Y Levin & A Patchornik from Israel; J Porath & K Mosbach from Sweden; MD Lilly from the UK; G Manecke from Germany; PV Sundarum from India; NO Kaplan, VH Edwards, AE Humphrey, EK Pye, HH Weetall & LB Wingard, Jr. from the USA; & TMS Chang from Canada (1971 +1973).
7. Canadian National Committee, National Research Council of Canada, International Union of Pure and Applied Biophysics (1971-1975).
8. Isotope Committee, McIntyre Building, McGill University (1967-1976).
9. Ad Hoc Committee on Contracts from Drug Systems, National Institute of Child Health and Human Development, National Institutes of Health, Washington, DC (1972).
10. Postgraduate Awards Committee, Faculty of Medicine, McGill University (1972-79).
11. Advisory Board, Biannual International Enzyme Engineering Conference (1973).
12. Project Site Visit and Special Study Section, National Institutes of Health (USA) (1974).
13. Project Site Visit and Special Study Section, National Institutes of Health (USA) (1975).
14. Advisory Board, Biannual International Enzyme Conference (1975)

15. Consultant, National Institute of Child Health and Human Development, National Institutes of Health, Washington, DC (1975-1977).
16. Promotion, Reappointment and Tenure Committee, Dept of Physiology, McGill University (1975-1977).
17. Statutory Committee for Professors in Medicine, McGill University (1975).
18. Statutory Committee for Professors in Biochemistry, McGill University (1977).
19. Advisory Board, Biannual International Enzyme Engineering Conference (1977).
20. Chairman and Organizer, International Symposium on "Some Novel Approaches in Artificial Kidney, Artificial Liver and Detoxification", (1st International Symposium on Hemoperfusion) Montreal (1977).
21. Canadian Standard Association Subcommittee on Kidney Dialysis (1977-1987).
22. International Council Member, International Society for Artificial Organs (1977 982).
23. Scientific Film Comm., American Society for Artificial Internal Organs (1977).
24. Video Committee, American Society for Artificial Internal Organs (1977).
25. Program Committee, American Society for Artificial Internal Organs (1978-81).
26. Project Site Visit and Special Study Section, National Institutes of Health (USA) (1978).
27. Search Committee for Physiology Chairman, McGill University (1978).
28. McGill University Patent Policy Review Committee (1979).
29. McGill University Ad Hoc Committee on visiting scholars, fellows and students from China (1979).
30. Cochairman, 2nd International Symposium on Hemoperfusion, Israel Institute of Technology, Technion, Israel (1979).
31. Organizer and initiator, Canadian Society for Artificial Organs, Artificial Organs, Artificial Cells and Medical Devices (1979).
32. Member of International Program Committee, Symposium on Control Aspects of Artificial Organs. International Federation of Automatic Control and International Society for Artificial Organs, Warsaw, Poland (1979-1980).
33. Co-chairman, Gordon Research Conference on "Drug Carriers in Biology and Medicine", New Hampshire, USA (1980).
34. Admissions Committee, Faculty of Medicine, McGill University (1979-1982).
35. Departmental Policy Committee, Dept. of Physiology, McGill Univ. (1979-1986).
36. Advisory Board, Biannual International Enzyme Engineering Conference, Japan (1981).
37. Founding President, Canadian Society for Artificial Organs, Artificial Cells and Medical Devices (1980-1982).
38. Standing Committee on Biotechnology, McGill University (1980-1981).
39. Biotechnology Research Group, Faculty of Graduate Studies and Research, McGill University (1981-1984).
40. Keyman on Hemoperfusion, Program Committee, International Congress of the International Society for Artificial Organs, Paris, France (1981).
41. Chairman, Gordon Research Conference on "Drug Carriers in Biology and Medicine", New Hampshire, USA (1982).
42. Honorary President, 4th International Symposium on "Hemoperfusion", Turkey and member of International Organizing Committee (1982).
43. Member, McGill University Regional Advisory Group of International Development Research Centre of Canada (IDRC) on People's Republic of China (1982-present).
44. Board of Trustees, International Society for Artificial Organs (1982-1986).
45. Symposium President and Chairman of Organizing Committee, Fifth International Symposium on "Microencapsulation, Including Artificial Cells", Montreal, Canada (1983).
46. Fifth International Symposium on "Hemoperfusion and Artificial Organs", People's Republic of China, International Scientific Committee (1983). Co sponsored by the Chinese Biomedical Engineering Society and the International Society of Artificial Organs.
47. Advisory Committee, VII International Conference on Enzyme Engineering, Engineering Foundation for 1983.
48. Organizing Committee and chairman of program committee on Hemoperfusion", 4th International Congress of the International Society of Artificial Organs, Kyoto, Japan (1983).
49. International Scientific Committee, International Symposium on Hemodetoxifications in Nonuremic patients, Italy (1983).
50. Chairman, International Committee of past symposium presidents, International Symposium on

Hemoperfusion, sorbents and immobilized bioreactants series (1983 to present)

51. Consultant, Dialaid International Ltd. (1981-1984), which became Biomicroencapsulation Technology Ltd., Montreal (1984 to 1986), which became Carbomed, Co. (19861990).
52. Scientific Advisory Board, Karyon Technology Co., Boston, Mass, USA (1983 to 1986).
53. Honorary president, 6th International Symposium on Hemoperfusion (1985), and member of International Scientific Committee, Mexico. Co sponsored by the Mexican Society of Nephrology and the International Society of Artificial Organs.
54. Organizing Committee (past chairmen), Gordon Research Conference on "Drug Carriers in Biology and Medicine", New Hampshire, USA (1984).
55. International Committee, NATO Advanced Study Institute on Biopolymer, Turkey (1984).
56. Advisory Committee, Biotechnology, McGill University (1984 to 1993).
57. 5th Congress of the International Society of Artificial Organs, Chicago, U.S.A. (1985) Chairman, Program Committee on "Artificial pancreas/artificial liver". Chairman, workshop on "Artificial Cells"; Specialty Chairman on "Plasmapheresis Blood Manipulation Field".
58. Chairman, Search Committee for Cardiovascular Physiologist, Dept. of Physiology, McGill University (1986).
59. Chairman, Advisory Committee Meeting on "Particulate Contamination in Medical Devices", Bureau of Medical Devices, Department of Health and Welfare, Government of Canada, Feb. 1986, Ottawa.
60. Honorary President, 7th International Symposium on Hemoperfusion, Kiev, USSR (1986). Sponsored by the USSR Academy of Sciences.
61. President, 3rd International Symposium on Blood Substitutes, Montreal, PQ, Canada (1987).
62. Committee on Appointment, Tenure and reappointment, Physiology, McGill (1983-85)
63. International Program Committee for the Joint World Congress of International Society of Artificial Organs and European Society of Artificial Organs, Munich, Germany, 1987.
64. International Program Committee: International Symposium on "Optimization of Blood Purification", Rostock GDR, 1987.
65. Program committee on Artificial Cells and Hemoperfusion. 1988 Congress of the European Society of Artificial Organs, Prague, Czechoslovakia.
66. Program Committee, Annual Meetings of the American Society of Artificial Internal Organs (1986 to 1992).
67. Program Committee, 7th International Symposium on Microencapsulation, 1987.
68. Scientific Advisory Board, Hemosol Co., Toronto, Canada.(1988-1998)
69. Member of Chairman"s Advisory Committee, Department of Physiology, McGill University (1988-present)
70. Honorary President, 8th International Symposium on Hemoperfusion, Sorbent and Immobilized Bioreactants, Germany, 1988.
71. Cochairman, 1989 International Symposium on Red Blood Cell Substitutes: Design and Clinical Application, San Francisco, U.S.A.
72. Honorary President, 9th International Symposium on Hemoperfusion, Sorbent and Immobilized Bioreactants, Tokyo, Japan, 1989.
73. Program Committee, 1989 Congress of the International Society of Artificial Organs, Sapporo, Japan.
74. Honorary President, 10th International Symposium on Hemoperfusion, Sorbent and Immobilized Bioreactants, Rome, Italy, 1990.
75. International Scientific Advisory Committee member, 7th International Symposium on Microencapsulation, Glasgow, Scotland, 1990.
76. Congress President, 8th World Congress of the International Society of Artificial Organs, in conjunction with the 4th International Symposium of Blood Substitutes, Montreal, 1991.
77. International Scientific Advisory Committee, 8th International Symposium on Microencapsulation, Ireland, 1992.
78. Member, McGill Biotechnology Committee (1984 to present).
79. Member, Subcommittee on Research Centers, Faculty of Graduate Studies (1991).
80. Board of Trustee, International Society of Artificial Organs. Reappointed for 1989 1993.
81. Honorary President, International Society for Artificial Cells and Immobilization Biotechnology (1991-present).
82. President-elect, International Society for Artificial Organs (1992-1994).

83. President, International Society for Artificial Organs (1994-1996).
84. International Scientific Advisory Committee, 9th International Symposium on Microencapsulation, Turkey,1993.
85. Honorary congress president, XI Congress of the International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology. (Congress president Professor R.Langer of MIT which organized this), Boston,1994.
86. Conference Chairman IBC Conference on Blood Substitutes, Washington D.C. 1994
87. International Scientific Advisory Committee, 9th International Symposium on Microencapsulation, USA ,1993.
88. Program Chairman, International Organizing Committee, Xth World Congress of the International Society for Artificial Organs, Taipei, Taiwan (1995).
89. Chairman, VI International Symposium on Blood Substitutes. Montreal 1996.
90. Organizing Committee, Congress of the International Society for Artificial Organs, Rhode Island, U.S.A.
91. Cochairman, VI International Symposium on Blood Substitutes Tokyo, Japan 1997
92. Honorary congress president, XII Congress of the International Society for Artificial Cells, Blood Substitutes and Immobilization Biotechnology. Organized by the Chinese Academy of Medical Science with president of academy as congress president) Beijing,PRC,1997
93. Cochairman and member of organizing committee, VIII International Symposium on Blood Substitutes, San Diego, 2000
94. Honorary Chairman, International Society for Artificial Cells, Blood Subsitutes & Immobilization Biotechnology XIV Conference on “Artificial Cells & Cells in Novel Medical Application” Istanbul, Turkey
95. Member of MRC and CIHR “Pharmaceutical Sciences” Grants Review committee. (1999-2001)
96. FRSQ & MSSS (Quebec Ministry of Health) Member of Working group on Research Priority in Transfusion Medicine (2000-2001).
97. Member, International Scientific Committee of the 13th Congress of the International Society for Artificail Organs, Osaka, Japan, 2001
98. Member, Organizing committee of Conference in Blood Substitute organized by Karolinka Institute, Stockholm, Sweden. 2002 June
99. Member, International Scientific Committee of the 13th Congress of the International Society for Artificail Organs, Washington, D.C. 2003 .June
100. Chairman and Organizer, precongress workshop on Blood Substitutes: present and future. Joint congress of International Society for Artificial Organs/American Society for Artificial Internal Organs. Washington D.C., 2003 June
101. Honorary President and Member of International Advisory Committee, IX International Symposium on Blood Substitutes, Tokyo, Japan 2003 March
102. Scientific committee and VIP guest, III International Symposium on Biotechnology and Biomedicine, Tianjin, PRC. 2004
103. Honorary President and Member of International Advisory Committee, X International Symposium on Blood Substitutes, Providence, Rhode Island 2005, June
104. Member, Scientific Board, 2nd World Congress on Regenerative Medicine, Germany
105. 2004 Olympic Summer Games, Athen. Expert consultant (blood substitutes) for the ad hoc Court of Arbitration for Sport(CAS) on doping related matters (e.g. blood substitutes).
106. 2006 XX Olympic Winter Games, Turin. Expert consultant for the ad hoc Court of Arbitration for Sport(CAS) on doping related matters (e.g.blood substitutes).

107. 2006 March XVIII Commonwealth Games, Melbourne. Expert consultant for the ad hoc Court of Arbitration for Sport (CAS) doping related matters (e.g. blood substitutes).
108. Honorary President and Member of International Advisory Committee, XI International Symposium on Blood Substitutes, Beijing, China 2007
109. International Scientific Board, Congress of ESAO 2007 Austria
110. Founding member, International Academy of Nanomedicine 2008-
111. NATO co-director of workshop on Advance Institute of Science 2008
112. Honorary President and Member of International Advisory Committee, XII International Symposium on Blood Substitutes, Parma, Italy. 2009
113. President and member of the board, International Academy of Nanomedicine, 2009- 2010
114. International Scientific Advisory Committee First World Congress of the International Academy of Nanomedicine, Hainan, China

115. International Scientific Advisory Committee 2nd World Congress of the International Academy of Nanomedicine, Antelya, Turkey
116. International Scientific Advisory Committee. 2010 International Congress on Nanotechnology, Ottawa
117. International Scientific Advisory Committee 2010 BIT 3rd Congress on Regenerative Medicine and Stem Cells, Shanghai, China.
118. International Scientific Advisory Committee BIT 1st Congress on Nanomedicine, Beijing, China, 2010
119. Honorary President and member, International Scientific Advisory Committee, 2011 XIII International Symposium on Blood Substitutes and Oxygen Carriers, Mass General, Harvard, Boston
120. International Scientific Advisory Committee 2012 3rd World Congress of the International Academy of Nanomedicine, Ankara, Turkey
121. Honorary President, International Scientific Advisory Committee 2013 XIV International Symposium on Blood Substitutes, Institute of Blood Transfusion, Chinese Academy of Medical Sciences, China
122. Honorary President and International Scientific Advisory Committee 2015XV International Symposium on Blood Substitutes, Lund, Sweden
123. Honorary President, 60th Anniversary of Artificial Cells in conjunction with 2017 XVI International Symposium on Blood Substitutes and V Congress of Nanomedical Sciences.
124. 2017, Honorary President, Quebec Branch of the Chiu Chow Association (Hometown of Shantou)
125. Chinese government's Overseas Chinese Expert Advisory Committee on Trade, Science and Technology 2017-2021
126. Honorary President, VI ISNS World Nanomedicine Conference, Delhi, India.
127. Honorary President and International Scientific Advisory Committee 2019 XVII International Symposium on Blood Substitutes, Nara, Japan
128. Key consultant, Chinese Research Alliance on Innovation, and Industrial developmentof Blood Engineered Products 2018-
129. 2019 Honorary President, 30th Anniversary of the Quebec Branch of the Chiu Chow Association (Hometown of Shantou)
130. 2022 Honorary President and International Scientific Advisory Committee XVIII International Symposium on Blood Substitutes, Berlin, Germany (Cancelled due to pandemic)
131. 2024 Honorary president and International Scientific Advisory Committee XIX International Symposium on Blood Substitutes, U.S.A.