總統科學獎委員會

Presidential Science Prize Steering Committee

2023 總統科學獎

表揚實錄

PRESIDENTIAL SCIENCE PRIZE
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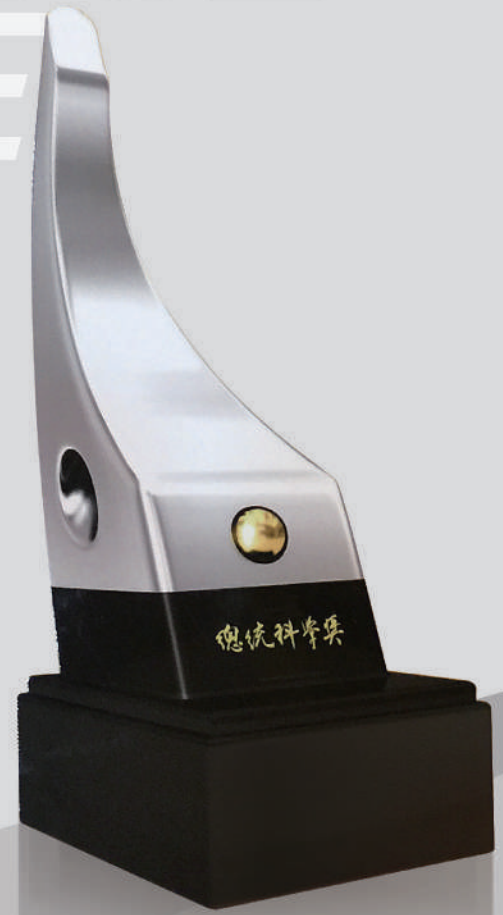
獎項紀要

總統科學獎設立於 2001 年，今年已經邁入第 12 屆，象徵國內學術研究的最高榮譽，由中央研究院院長邀集相關部會首長，以及專家學者共 15 人組成「總統科學獎委員會」籌劃總統科學獎項，每 2 年頒發一次，以獎勵國內在數理科學、生命科學、社會科學與應用科學領域，有重大貢獻的基礎學術研究者，並提升臺灣之國際學術聲譽。

總統科學獎得獎人的產生，係由中央研究院院士或總統科學獎得主，或總統科學獎委員會得邀請學術、研發單位或團體及社會賢達人士提名，分由 4 組遴選小組推薦候選人，再經聯席會議審議遴選得獎人。本屆總統科學獎歷經縝密的推薦及遴選程序，計遴選出 3 位得獎人，為生命科學組李文雄院士、應用科學組胡正明院士及數理科學組葉永烜院士（依姓名筆畫順序）。

藉由總統科學獎的頒發，表達國人對科學前景崇高的冀望、對人才培育的重視與對知識份子的無限尊崇，除了彰顯得獎人的崇高學術地位之外，更期盼將科學的精髓發揚光大，裨益民生。

PRESIDENTIAL SCIENCE PRIZE



生命科學組 —— 李文雄 院士

用數學探索生物演化五十載

證明分子時鐘非等速　創新並開闊演化論視野

李文雄院士專注於分子演化的研究。以 DNA 序列、基因結構與功能等分子資料，探索生物演化的歷程與機制。

分子演化概分為兩大主題，李院士皆開發出重要的計算工具。其一是分子演化的過程與機制。他在 1980 及 1990 年代開發的 DNA 序列比對分析和統計方法，被學界廣泛認可，是最常使用的方法。

另一則是演化史與物種間的親緣關係。1981 年，他考慮到如果分子演化不是等速進行時，該如何建構親緣樹。於是，考慮分子演化的不等速性，進而建立起親緣樹的建構方法。李院士這套方法在 1980 年代起廣泛被採用，堪稱此課題統計方法的先驅者。

一直以來，演化機制有個著名的爭論——到底是自然選擇重要？還是突變重要？面對「達爾文觀點與中性突變假說」之爭，李院士的研究團隊於 1981 年證明，一旦一個基因失去功能成為死基因，將不再受到自然選擇的影響，就會急遽加快核苷酸的取代速度。 這項研究結果顯示：自然選擇通常會減緩，而非加速核苷酸替換，進一步支持中性突變理論。該理論認為，突變與隨機漂移在分子演化中，比自然選擇更為重要。此外，他也發現重複基因的表達分歧速度很快，有利於重複基因在功能上的快速分歧。

另一方面，李院士團隊也率先發現，分子時鐘速度與世代長度相關，並開發出相應的統計分析方法。以往解釋 DNA 數據的關鍵假設是：DNA 序列的變化在演化時間上，以恆定速率進行（即分子時鐘）。該假設常被運用於估算譜系分歧的時間。然而在 1980 年代，李院士證明分子時鐘的運行速度，取決於世代的長短——意即世代越短，時鐘越快。李院士團隊估計，分子時鐘在大鼠和小鼠之間的演化速度，是猴子和人類之間演化速度的 5 倍。這個發現推翻當時的主流觀點，有助於深化對演化過程的理解，並能更準確估計物種分歧時間，進而打破過往認為 DNA 序列變化以恆速進行的觀念。

李院士運用數學和統計分析專業，為許多演化生物學的難題提出前瞻見解，多年後當資料數據完備時，都見證他的預估準確力。例如，他在 1991 年根據有限的人類 DNA 序列資料，預估人類的 DNA 多樣性低於 0.1%，遠較果蠅為低；10 年後，大量資料證明他當初的預估是正確的。他也發現非洲人的 DNA 多樣性，明顯高於歐洲和亞洲人，進而支持現代人起源於非洲的理論。

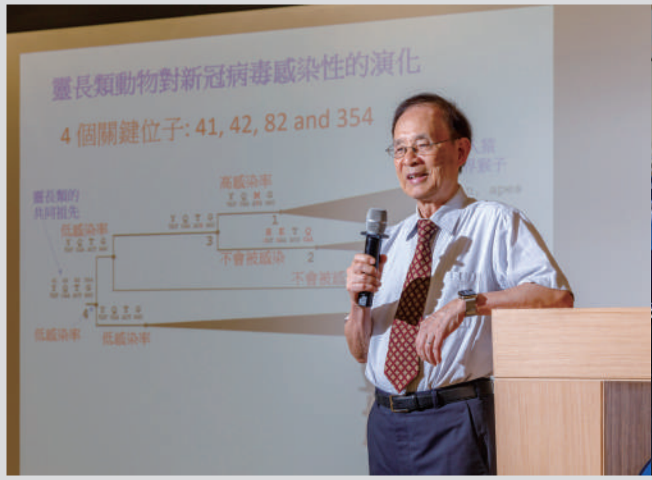
李院士於 1989 年創立分子生物學實驗室，以便結合理論與實驗。在 2001 年當黑猩猩的基因體資料極為有限時，李院士團隊就已取得資料預估出，人類與黑猩猩基因體的核苷酸序列只有相差 1.24%。這項預估引起很大震撼，因為人類與黑猩猩看起來非常不同。但當黑猩猩的基因體於 2005 年發表時，得到的答案與他的預估完全一樣。

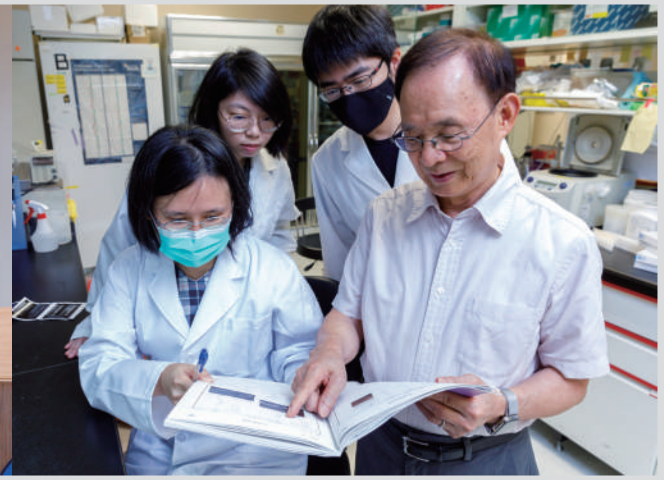
李院士又結合理論與實驗發現同一種動物的兩性生殖細胞突變速率不同，雄性比雌性更快，並在包括人類在內的高等靈長類動物與囓齒動物證明這點。原因是雌雄生殖細胞的複製和分裂次數不同。雌性的卵子在出生前已經形成，而雄性的精子則終身持續複製。因此，雄性生殖細胞的突變速率較快。

李院士團隊對病毒的演化亦有相當的研究。比如發現流感病毒常需要結合兩個或兩個以上的突變才可以逃避過宿主的免疫系統，使流感盛行。又如果人類與舊世界猴子的共同祖先的 ACE2 蛋白（血管緊張素轉化酶 2），第 82 個胺基酸沒有從天冬氨酸（threonine）突變為甲硫氨酸（methionine）的話，則新冠病毒的 spike protein（棘突蛋白）與人類的 ACE2 結合力就不好，也就不易感染人類，也許就不會有新冠病毒全球大流行。

而對於生命關鍵成分的氮，李院士團隊則推斷固氮能力起源自細菌而非古菌，以「生物固氮」的起源確立對演化研究的另一重大貢獻。

綜言之，李院士帶領團隊的研究成果，為分子演化和遺傳學領域帶來深遠的影響；不僅推動分子時鐘理論的應用，更在人類演化、病毒演化等議題上，持續不懈開創新的研究方向。





用數學解決生物學問題 分子演化研究的活歷史

開創 DNA 序列比對方法 巴仁獎亞裔第一人

活躍在分子演化研究第一線長達 50 年，李文雄院士被喻為分子演化研究的活歷史。1985 年，他在權威的《美國國家科學院院刊》(PNAS) 發表關鍵的 DNA 序列比較論文，推翻當代的主流觀點而一舉成名。此後，他一路從一小研究室不斷順勢發展，最終掌舵帶領由 16 位博士後及數位研究生組成的研究團隊，至今已訓練過 120 多位博士後及研究生。

雖然意識到自己有數學天份，李院士的求學之路卻多繞了幾個彎，直到進入布朗大學博士班，遇到此生最重要的遺傳學恩師才定錨。他直言人生沒有白走的路，能夠以數學技術探討與解答生物學的課題，是他畢生最好的選擇。李院士畢生貢獻於分子演化和生物遺傳學，在遺傳性別差異、人類演化、病毒演化及分子時鐘理論等方面，為相關研究領域帶來創新視野。

2003 年 11 月 7 日，在瑞士伯恩的聯邦議會大廈。這天，被譽為「義大利諾貝爾獎」的巴仁獎（The Balzan Prize），在此表彰 4 位對科學或人文研究貢獻卓著的國際學者。

當時，榮獲遺傳與演化獎項的中研院李文雄院士，已在美國投身分子演化研究逾 20 年。他是這項桂冠自 1978 年創設以來，獲得此獎項的第 3 位遺傳演化學家，更是亞裔學者的第一人。

雖然李院士謙稱：「以往都是這個領域的泰斗獲得遺傳和演化獎，所以當我收到巴仁獎基金會主席的通知時，感到非常驚訝。」但從巴仁獎基金會給予的得獎理由來看，李院士的獲獎實至名歸。

得獎理由如此敘述：「… 他開發且應用數學技術來解決廣泛的生物學問題，並成為該領域最常使用的方法。」、「… 他是 DNA 序列比較的演化關係推斷法設計師，在建立親緣樹推估準確度，以及統計置信度方面，特別有影響力。」、「… 他也是分子演化教育的核心人物，著作被公認是該領域的權威之一。」

Recipients of the Balzan Prize
4 位得獎者合影

出身屏東農家　數學天份高中時外顯

李院士 1942 年出生於屏東縣萬丹鄉的務農家庭。他每天都要早起，步行三公里到最近的萬丹小學就讀。五年級時，他因為記憶力好，可以輕鬆記得常識課程（自然博物與地理歷史）的內容，獲得「常識霸王」的美名而喜歡上學。

初中時期，他對數學、理化與音樂產生興趣。考上屏東高中後，對數學、物理與化學有興趣。李院士回憶：「高三的數學老師對我印象還不錯，說我一定會考上大學。」然而上大學時，他卻經歷了一段摸索繞路的學習之途。

考上中原理工學院（現改制為中原大學）土木系，李院士憑藉優異的數學能力，愉快度過新鮮人的第一年。然而，到了大二之後，卻因為不適應「工程畫」的繪圖、「地質學」的死背方式，而陷入學習苦惱。雖然一度考量有興趣的物理，但看到熱力學、電磁學、量子力學等基本科目，又感到卻步。

後來，他想到了數學。除了基本科目相對較少，又是自己喜歡的課程，於是下決心報考數學研究所。可惜報考臺大與清大數研所的目標，一則因學分不足無應試資格，一則落榜，還好考進了中央大學地球物理研究所。在大學時，李院士認知自己不是坐辦公室的料子，因此退伍後，就去中央大學唸碩士學位。

李院士說：「在念地球物理時覺得，跟我想的一樣，物理很難，真的很難。」他又說：「我其實是用數學解物理題目，題目會解，可是物理意義不太清楚。」對於物理真正的意義沒有深入瞭解，也讓他在這段時間更加確定自己的數學興趣，認定自己更適合讀數學。

幸逢遺傳學大師　用數學解生物課題

碩士畢業後，李院士在 1968 年如願申請到美國布朗大學應用數學系博士班，拿著獎學金出國深造。他回顧自己的學術生涯時，直言選讀布朗大學是成功的第一步。初到這個學習風氣開放又自由的環境，全心投入且優遊自得。

博二暑假時，他開始尋找博士畢業論文的題目。這一找，幸運遇到在生物系任教的日裔遺傳學家根井正利（Masatoshi Nei）。兩人相談甚歡，根井教授看中李院士的數學專業，鼓勵他往遺傳學發展。而當時他的指導教授 Fleming，也對他選擇跨領域研究相當支持。

在中央大學出版品的《院士的十堂課——探索之路》當中，李院士分享他這段經歷的體悟：「進到一個新領域，最好是找對老師。如果自己摸索，不容易曉得哪些是重要的？現在的潮流是什麼？根井正利教授是這行的先驅者，所以我能比較快進入那個領域。」

跟著根井正利，李院士起先做偏數學化的問題——先把生物問題變成數學問題，再解出來。後來接觸得越多，就越瞭解哪些是生物學的重要問題，才漸漸深入遺傳學。

根井正利是位治學嚴謹、學思敏捷的學者。一開始，每當李院士念遺傳學有疑問時，根井教授立即就能拿出某篇論文，指著說：「你的問題，這裡有答案。」另一方面，當根井教授碰到需要數學來解題的時候，李院士就派上用場。就這樣，師生兩人的專長相輔相成，彼此的合作也讓他在博四那年，以一篇在重要期刊發表的論文，順利拿到學位畢業。

接著，他到威斯康辛大學麥迪遜分校做博士後研究一年。1973 年，他前往德州大學休士頓分校任教，根井教授早一年已轉換到該校；師生再度聚首合作，自此展開他長達 50 年的遺傳演化研究生涯。

獲 PhD 時與 Host family 合照 (1972)

兩位女兒與指導教授 Fleming 合照 (2004)

研究 DNA 序列演化關鍵論文推翻主流

1973~1998 年間，李院士在德州大學進行遺傳學於演化的研究，也是他學術生涯的第一段黃金時期。

然而，最初七年，他幾乎是「單人秀」，研究室僅他一人。因為做理論研究，不需要實驗，所以可以盡情發揮想像；他每年提出至少 3 篇論文，有創見的主張，慢慢在學術界累積名聲。

分子演化是從遺傳學及分子生物學發展出來的一個領域。生物的遺傳訊息儲存在 DNA 分子，而基因是 DNA 的功能片段，指導蛋白質的合成，進而影響生物的特徵和行為。分子演化研究，在於關注生物隨時間推移而產生的遺傳變異，並透過比較 DNA、蛋白質等遺傳訊息的異同，揭示物種之間的親緣關係和演化歷程。

在研究分子演化的過程中，數學和統計方法扮演重要角色。因為基因的演化不僅是基因序列的變化，更涉及複雜的統計過程。透過數學模型和統計分析，可以定量評估遺傳變異的發生頻率和分布，並且揭示這些變異的模式和趨勢。這些分析方法有助於建構出演化樹，反映不同物種之間的親緣關係，從而更深入瞭解生物的演化歷程。

不過，李院士投入演化研究之初，科學界仍面臨諸多不利的研究條件。例如，1960~70 年代，木村資生 (Motoo Kimura) 和威爾森 (Allan Wilson) 等前輩科學家主要透過分析蛋白質序列，來深入探究生物的演化。但蛋白質定序過程耗時且昂貴，導致這種研究方式無法普及。直到 1977 年，桑格（Fred Sanger）提出 DNA 定序法，為研究者突破原有耗時價昂的基因定序障礙，逐漸讓 DNA 資料量快速增加。

這時，李院士意識到時機成熟，於是全心從數學與統計的專業切入。那個年代，全球只有兩間實驗室專門研究 DNA 序列的演化分析，其中一間就是由李院士主持帶領。「因為我有一些群體遺傳學理論的背景，加上懂統計、能分析 DNA 序列資料，就比別人跑得快一點。」

1985 年是李院士的關鍵年。他在權威期刊——《美國國家科學院院刊》(Proceedings of the National Academy of Sciences， PNAS），發表推翻當代主流觀點的論文，透過比較哺乳動物 DNA 序列資料，推測出鼠類的分子時鐘比人類的至少快兩倍。二年後，他再接再厲於《Nature》期刊，發表猴子的分子時鐘比人類的分子時鍾快的發現。李院士在分子時鐘多年的研究，讓他成為該課題的權威。

細緻建構親緣樹　分類學貢獻大

根據中研院科普媒體《研之有物》的李院士專訪指出，在分子演化興起前，不同生物間的親疏關係，是以透過生物形態的相似程度建構演化樹，但形態資料很有限。比較生物 DNA 或蛋白質的資料，可以細緻釐清物種間的親緣關係，而李院士發展親緣樹建構和統計評估方法，對分類學的貢獻很大。

例如，早期的演化學家會比較一群鳥類的嘴喙特徵，如果兩種鳥喙的形態差異較小，就代表親緣關係接近。但分子演化學家則透過比較這群鳥類的 DNA 或蛋白質序列差異，更細膩釐清彼此的親緣關係。

基因由三個核苷酸組成一個密碼子，並對應一個氨基酸（蛋白質的構成單位）。不過，核苷酸有 4 種可能性（A、T、C、G），可構成 64 個密碼子，而氨基酸只有 20 種，因此某些氨基酸可能會對應多個密碼子。

當改變 DNA 的核苷酸密碼子，可能出現兩種結果：沒有影響到氨基酸的稱為「同義突變」；有改變氨基酸的則稱為「非同義突變」。透過比較 DNA 和氨基酸序列的變異和保留比例，就能大致瞭解自然選擇對演化的影響，也就是傾向消除或選擇突變的過程。

分子演化研究更關注於微觀層面，將 DNA 或氨基酸位置視為形態的表現。這種方法提供更多比較特徵的資料，且更易於計算。由於分子資料相對容易取得，分析方法也更多元，因此在探討親緣關係時，多種證據的支持至關重要。

分子時鐘非等速　物種性別差異化

李院士的重要貢獻之一是：運用數學方法讓分子時鐘理論，實際應用在生物演化的分析。

以往分子時鐘的概念是：DNA 序列的演化速率是等速進行。當此假設成立時，就可以透過兩個物種之間 DNA 序列的差異，估計它們分化的時間。也就是，利用分子的變異程度，計算兩個物種分離的時間。這個假設的基礎在於，生物的遺傳序列會因突變而累積新變化。這種取代的數量與世代數成正比，例如每代新增 5 處取代，經過 10 代便有 50 處的變化。

然而，這種假設與傳統達爾文的天擇觀念大相逕庭，意味著大部分突變不影響天擇，對生存競爭的影響是中性的。這是李院士的恩師根井正利與前輩木村資生提出的「中性演化假說」。

木村資生主張，大部分遺傳分子的變化與天擇無關，個體間的遺傳多樣性多半是隨機變化的結果。雖然此論點一開始引起很大的爭議，但經過多次修改與補充，逐漸獲得廣泛接受。分子層次的遺傳變異往往不影響天擇，而新突變取代舊的遺傳訊息，往往只是個體的幸運。

這種中性演化理論為分子時鐘提供理論基礎，帶來多項突破。然而，在 1980 年代，李院士採用 DNA 序列，推翻分子時鐘的等速理論。他發現，新變化的取代速率並非固定。

李院士證實，分子時鐘速率與世代長短有關，世代愈短，時鐘運行愈快。例如，大鼠和小鼠的世代比人類短很多，它們的演化速度大約為人類與人猿之間的 5 倍。此發現有助於精確估算兩個物種分離的時間。

考慮分子時鐘受到世代長短的影響，李院士在 2000 年代初期指導的博士生陳豐奇（現為臺灣國家衛生研究院研究員），就透過比較人類與人猿非編碼區的 DNA 序列，推估人類與黑猩猩分離約 600~700 萬年。

另一方面，李院士還發現同一物種的兩性生殖細胞突變速率並不相同，男性比女性更快。原因是男女生殖細胞的複製和分裂次數不同。女性的卵子在出生前已經形成，而男性的精子則終身持續複製。因此，男性生殖細胞的突變速率較快。

名氣高揚合作上門　掌舵頂尖實驗室

李院士先後在重要期刊發表關鍵性論文後，名氣越來越響亮，找他做分子資料分析的合作邀約也越來越多。他發現，單純做理論的研究室已不敷使用。

1989 年，他在德州大學建立分子生物學實驗室，但學校給的經費很快就不夠用。他向美國國家衛生院（NIH）——聯邦首要的醫學生物研究機構，遞計畫申請經費。不料，當時審核小組認為，李院士雖擅長理論研究，對他做實驗獲取資料的能力打了問號。幸好 NIH 的院長設立一新辦法，補助有創意的計畫拿到一些資料來證明可行，李院士利用這筆錢拿到一些資料，說服審核小組，通過計畫。

此時，李院士也恰好遇到一名很會做實驗的香港籍的教授 Larry Chan，前來找他做資料分析。於是，兩人互補長短——你幫我訓練博士後研究生如何做實驗、我幫你分析資料。

就這樣，李院士邁大步一路向前。從 16 年前的單人研究室，一路擴張。他掌舵的實驗室曾經最多擁有 16 名博士後研究員，規模堪稱同業間數一數二。

雖然李院士謙稱不會做實驗，卻擁有提攜優秀技術研究員的眼光。例如，他在 2008 年回國後，在中研院成立次世代高通量定序中心（目前已是第三代），觀察到現職的呂美曄博士後擁有很好的分子生物學技術，進而發展出給全中研院內外使用的高通量基因體 DNA 定序核心設施，呂美曄於不久後升為研究技師。

「呂美曄研究技師出身植物分子生物學及酵母菌遺傳學。她的才華是可以依據用戶提出的計畫，告訴你需要怎樣的分子資料才合適？實驗如何優化？多少資料量才夠？有了她的建議，現在每一件上門的用戶需求都做到客製化，開創出意想不到的服務模式，學界少見。」對於優秀的共事夥伴，李院士非常樂於提攜及宣傳。

芝加哥大學力邀　巴仁獎桂冠表彰

李院士運用數學和統計分析專業，為許多演化生物學的難題提出前瞻見解，多年後當資料數據完備時，許多研究進展皆見證他的遠見和預估準確力。

例如，李院士在 1991 年根據有限的人類 DNA 序列資料，預估人類的 DNA 多樣性低於 0.1%，遠較果蠅為低；10 年後，大量資料證明他當初的預估是正確的。2001 年，當黑猩猩的基因體資料極為有限時，他也預估出，人類與黑猩猩的基因體只有相差 1.2%。這項預估引起很大震撼，因為人類與黑猩猩看起來非常不同。但當黑猩猩的基因體於 2005 年發表時，得到的答案與李院士的預估完全一樣。

1998 年，這些日積月累的好成績讓芝加哥大學盛情力邀，李院士轉換跑道加入該校生態與演化生物學系；最初五年擔任 George Beadle 講座教授，李院士得巴仁獎後，芝大特別為他設立 James D. Watson 講座教授，因為 Watson 是一位家喻戶曉的諾貝爾獎得主。（註：G. Beadle 也是一位諾貝爾獎得主，並當過芝加哥大學校長。）

2003~2009 年，是李院士學術成就獎賞的豐收期。他先後獲選為美國國家科學院院士（2003）、中原大學傑出校友（2005），中央大學傑出校友（2006）、世界科學院院士（2009）；也獲頒遺傳暨演化學界最高榮譽的巴仁獎（2003）、布朗大學賀拉斯曼獎（2004）、人類基因體組織 Chen Award（2008），以及英國遺傳學學會 Mendel Medal（孟德爾獎章）（2009）等。

回顧以亞裔身分，在美國遺傳暨分子演化學界闖蕩的漫長歲月，李院士認為無論是語言還是文化融入，並非單單努力就能突破。他把隱形牆視為必然，專注以研究實力打天下，很少有論文未能發表的情形。

「在我們這一行，我沒有感受到明顯的差別待遇。當然，外國人沒有美國人容易被認可。」李院士笑說，他這一生沒有敵人，也很少碰到他人的敵意。2000 年他當選該行國際最大學會「分子生物學與演化學會」的會長，可見其人和的一面。

與指導教授 Dr. Nei 於美國國家科學院（2004）

全職回臺培育後進　為年輕學者搭舞臺

去國 30 年後，李院士興起回歸臺灣、培育後進的念頭。他循序漸進，先擔任中研院基因體研究中心的訪問學者；接著在生物多樣性研究中心，擔任 3 年的學術諮詢主席，以熟悉本地研究環境的種種生態。2008 年，李院士全職回臺，接掌生物多樣性研究中心的主任。

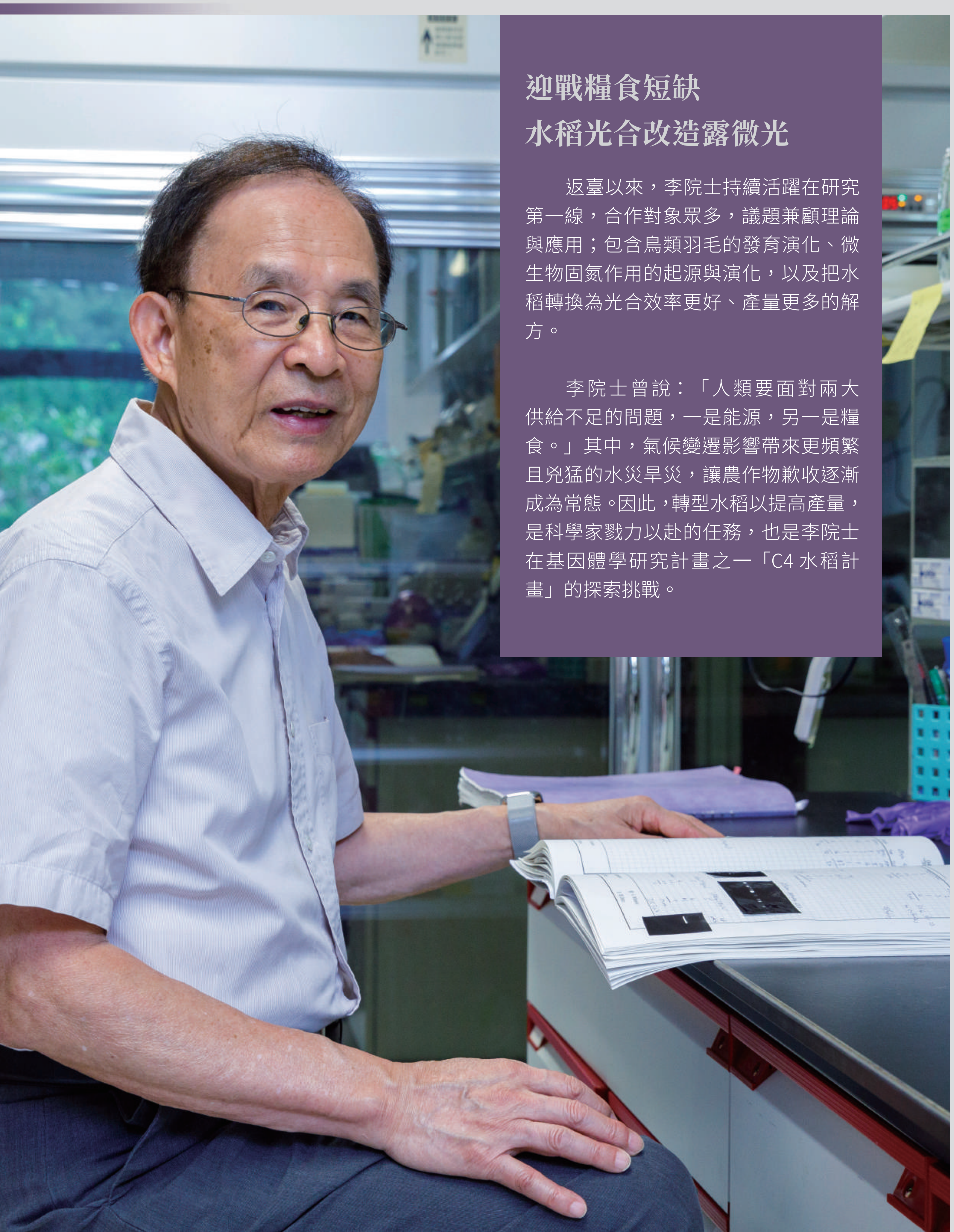
在執掌生物多樣性研究中心的 8 年期間（2008-2016），李院士除了關注研究主題，還落實培育後進的初心，推動博士學位學程；並積極為年輕研究者搭建發表舞臺，讓演化、生物資訊領域人才有集中交流的管道。

由於中研院與多所國立研究型大學共同合辦博士學位計畫（TIGP），李院士又有豐富的先進實驗室主持經驗，洞悉培育創新研究人才的需求所在。於是他回國後，便與臺灣師範大學共同設立「生物多樣性國際研究生的博士學程」。自 2012 年開辦迄今，為臺灣與國際的年輕研究人員提供全英語及先進的研究環境，已是重要的生科研究人才培育基地。

「沒有舞臺，自搭一個。」李院士回臺後，也觀察到本地研究演化的學者不多，欠缺交流管道。於是，他號召成立「臺灣演化與計算生物學會」，親自擔任兩屆理事長，讓演化與生物資訊領域的人才集中交流，更提供年輕研究者有練習發表的舞臺。

根據《研之有物》的報導，該學會在李院士奠定的基礎上持續發展。不但年年舉辦國際研討會，邀請海外學者參加，並特別安排新進學者的演講場次；也為博士生、博士後研究人員，設有專屬的口說與壁報比賽。甚至會議舉辦地點也遍及臺灣南北，兼顧不同區域研究者的用心可讚。

李院士一直鼓勵研究者多參加不同研討會，加入學會參與活動。他提醒：「做研究的人獲取新知是相當重要的事。參加活動，多看多聽多交流，都是寶貴的機會；不只能增加知識，有時候也能獲得他人幫助，有益於自己的研究。」



迎戰糧食短缺 水稻光合改造露微光

返臺以來，李院士持續活躍在研究第一線，合作對象眾多，議題兼顧理論與應用；包含鳥類羽毛的發育演化、微生物固氮作用的起源與演化，以及把水稻轉換為光合效率更好、產量更多的解方。

李院士曾說：「人類要面對兩大供給不足的問題，一是能源，另一是糧食。」其中，氣候變遷影響帶來更頻繁且兇猛的水災旱災，讓農作物歉收逐漸成為常態。因此，轉型水稻以提高產量，是科學家戮力以赴的任務，也是李院士在基因體學研究計畫之一「C4 水稻計畫」的探索挑戰。

簡單來說，這個計畫想要透過光合作用的基因體學及分子生物學的技術，讓水稻從目前的 C3 型變成 C4 型，以催生出更高的產量。

光合作用──利用陽光把二氧化碳與水，轉變為碳水化合物的過程，是植物產生能量的方法。光合作用有 C3 與 C4 兩種。前者的產物是三碳化合物，以水稻、小麥為代表；後者會再轉化為四碳化合物，以玉米、甘蔗為代表。C4 比 C3 生產速率高，植物產量也高出許多。

「世界上超過一半人口的主食是稻米，這是重要的糧食之一。」李院士表示：「但很不幸，水稻是 C3 型植物，現在的問題是要怎樣把水稻從 C3 型改成 C4 型。」他邀請在美國研究光合作用 40 多年的古森本（Maurice Ku）教授合作（時任教於嘉義大學），指導黃啟發博士研究全基因體複製在 C4 光合作用演化的角色，論文發表於分子演化頂級期刊《Molecular Biology and Evolution》。李院士結合實驗和生物資訊分析，研究 C3 和 C4 植物的轉錄因子和基因調控結合位點，建立了生物資訊分析的模型和重要數據庫，論文發表於《Plant Physiology》和《PNAS》。

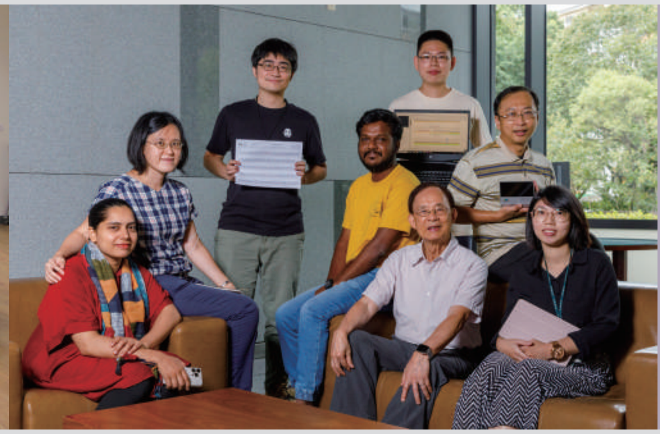
《中研院院士的十堂課──探索之路》記載，截至 2021 年，C4 水稻計畫的改良品種能夠比野生種長出更多稻穗，但穀粒較小，仍需要繼續改進。李院士表示，剛剛得到的新種，穀粒已比野生種大，產量增加 26%！

「這個光合作用牽涉到的生物學非常複雜，不是我們想像的那麼簡單。」但李院士相信，運用現代發達的科學知識與技術，解決當前人類面對的難題，只要堅持下去一定能成功。「只要能成功，很可能會帶來第二次綠色革命。因為同樣或類似的技巧，也可以應用到其他作物。」

此外，在肆虐全球三年多的新冠病毒議題方面，李院士與合作團隊也有新發現。他們探討新冠病毒棘蛋白的受體蛋白 ACE2 在靈長類動物的演化，發現舊世界猴子（獼猴、大猩猩與長尾猴）和人類一樣容易感染新冠病毒，而眼鏡猴與新世界猴子（如松鼠猴、金絨猴），則對新冠病毒具有很強的抵抗力。這篇論文同樣發表 在《Molecular Biology and Evolution 2021》。

李院士表示：「如果人類與舊世界猴子共同祖先的 ACE2 ──新冠病毒感染宿主的結合受器，沒有突變成與棘蛋白更容易結合的話，也許新冠病毒就不會造成全球大流行，或是病毒的危害不至於那麼廣、那麼深。」

欣慰後繼有人　樂於探索新鮮問題



回顧一路作育英才，李院士直言：「後繼有人，感到欣慰。」

迄今，他指導過 30 多位博士生、90 多位博士後，美國最多，臺灣其次，其他分布於歐洲、日本、韓國、印度與東南亞等地。很多人在學術界都已有相當成就，有些已是講座教授或研究中心主任；無論做的是更深入的研究，還是擴展延伸，亦或開創性研究，李院士都滿心歡喜後繼有人。

時光漫漫，李院士聚焦在遺傳與演化學研究的第一線已逾 50 年，很清楚分子演化學經歷怎樣的變革，特別是對研究者來說。在《研之有物》的報導中，李院士提出他的觀察。

「以前容易找到重要的題目，但取得資料速度很慢。隨著分子生物學與資訊科學技術的進步，現在比較容易取得大量資料；資料多，就容易找到題目，寫論文不難，內容也比較豐富。」但是，投稿門檻變高也是事實。新鮮議題不容易找，許多題目來自舊題目的延伸，獲得大突破的機會較小。

然而在李院士的視角中，一直都有新鮮課題可探索。例如，人類與黑猩猩的 DNA 分歧只有 1.2%，但兩者間的差異除了非編碼區外，也有很多來自基因調控不同的區域，尤其是腦部發育。過去這幾乎是不可能探索的議題，如今難度雖大，卻是有希望解決。

現在入行的新人，不但需要具備的知識量遠超過李院士當年，還需要勇於追求「跨領域」研究。對此，李院士提出中肯建議：「確認自己的喜好與專長，才能有計畫學習和投入。比如，雖然一開始我不會做實驗，但為了解決感興趣的生物問題，我設立了分子生物學實驗室，拿到很多實驗資料，進而解決不少演化的難題。」

持續運動熱愛閱讀　保持世界連結

獲頒「總統科學獎」的 2023 年，李院士 80 歲。聊起家庭生活，他露出和煦笑容，直稱很幸運，娶到好太太，兩人育有 3 名子女。李夫人徐淑娟女士的專業是會計統計，曾在休士頓的萊斯大學主計處任職多年，一直到隨同夫婿遷居芝加哥大學，才辦理退休。

運動與閱讀，是李院士強健身心的好習慣。「每天早上，我會做軟體操，去走路散步，下午或晚上就在家踩腳踏車 20 分鐘，保持心跳每分鐘 130 下左右。我們這個年紀的運動，最重要就是維持心臟的加速跳動力。」他說在週末常常與夫人去走步道。

至於閱讀，他受到大學英文老師的教導，就開始透過閱讀英文經典小說簡易版，學習文章的寫作，而非死背單字文法。他也熱愛閱讀各種報刊雜誌，邊吸收資訊、邊學英文。現在訂閱的是《經濟學人》與《紐約時報》。

訪談這天，他的電腦螢幕正是《紐約時報》的英文網頁。聽著這位孜孜不倦的科學家，分享他閱讀哪些有深度的好報導，延伸聊起了國際情勢。我們不禁受到啟發——向人稱 50 年分子演化活歷史的李院士，學習如何保有探索世界的好奇心，畢生不懈。

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應用科學組 —— **胡正明** 院士

臺灣半導體產業重要推手

突破電晶體瓶頸 延續摩爾定律

臺灣半導體業領先世界，胡正明院士在科技研發上的助力功不可沒。曾擔任台積電首任技術長的胡院士，長期任教於美國加州大學柏克萊分校，他領導研究團隊於 1990 年代末研發出「鰭式電晶體」(FinFET)，解決當時連英特爾（Intel）都無法克服的晶片過熱與微型化問題，使得摩爾定律得以延續。

胡院士提到，他與研究團隊之所以能夠突破瓶頸，關鍵在於肯下苦功，解題前把各種可能性都先想過，提出各種創新想法，然後每個方案去嘗試；對自己有信心，相信最後一定能找到解決方案。

胡院士跳脫傳統思維，將使用 50 年的平面式電晶體轉換為三維立體架構，使得電晶體密度得以繼續提高，同時透過蝕刻方式製造像魚鰭的垂直薄晶體，讓 FinFET 兼具高速度與低功耗的特性。2001 年胡院士回到臺灣，將 FinFET 技術第一時間在臺開發，帶領台積電研發團隊連續發表領先全球的 FinFET 原型，從而奠定基礎日後超越英特爾、三星電子等國際半導體大廠，成為臺灣的護國神山。

2011 年英特爾率先使用 FinFET 技術後，包括台積電、三星亦陸續跟進，如今人們所使用的網路、電腦及智慧型手機等電子產品，皆須仰賴 FinFET 晶片。胡院士讓實驗室裡的研究成果轉化成具商業價值的尖端技術，大幅提升人類生活福祉。

為表彰胡院士以創新研發對世界帶來貢獻，美國前總統歐巴馬親授「國家技術與創新獎章」；2020 年國際電機電子工程學會頒發最高獎章（IEEE Medal of Honor），並稱其為「微電子領航者」。

長期深耕學術教育的胡院士，基於對技術研究與作育英才的熱忱，撰寫 5 本半導體教科書，發表研究論文超過 1,000 篇，取得 150 項美國專利，因而榮獲 IEEE 教育獎、SRC 亞里士多德獎、柏克萊傑出教學獎等獎項肯定。

40 多年來，胡院士培育出許多優秀人才，在各自的產業領域嶄露頭角。他時常鼓勵年輕人要培養解決問題的能力，總是把做研究的目標放在解決問題，例如在 30 年前研發的 BSIM 軟體，國際標準電晶體模型，免費開放這項研究成果並至今持續每年開放新版，半導體業已用之創造萬億美元的產值，促成創新產品的誕生，推動了半導體產業的發展。

雖然長年旅居國外，胡院士仍不停為發展臺灣半導體技術與培育尖端研發人才而努力，曾參與「次微米計畫」指導委員會協助建立臺灣第一座 8 吋晶圓實驗室、長期提供國研院國家奈米元件實驗室研究輔導、以及協助領導美國加州大學與國立交通大學研發團隊合作計畫，為臺灣半導體技術扎根貢獻心力。胡院士也不吝多次提出建言，認為產業是由企業

來創造，政府應該用有限的教育資源提供人力，首先支持成功有競爭力的資通訊產業的繼續成長，透過「政府出錢、業界出題、學界解題」的合作模式，藉由教育為產業培養所需且可用人才。

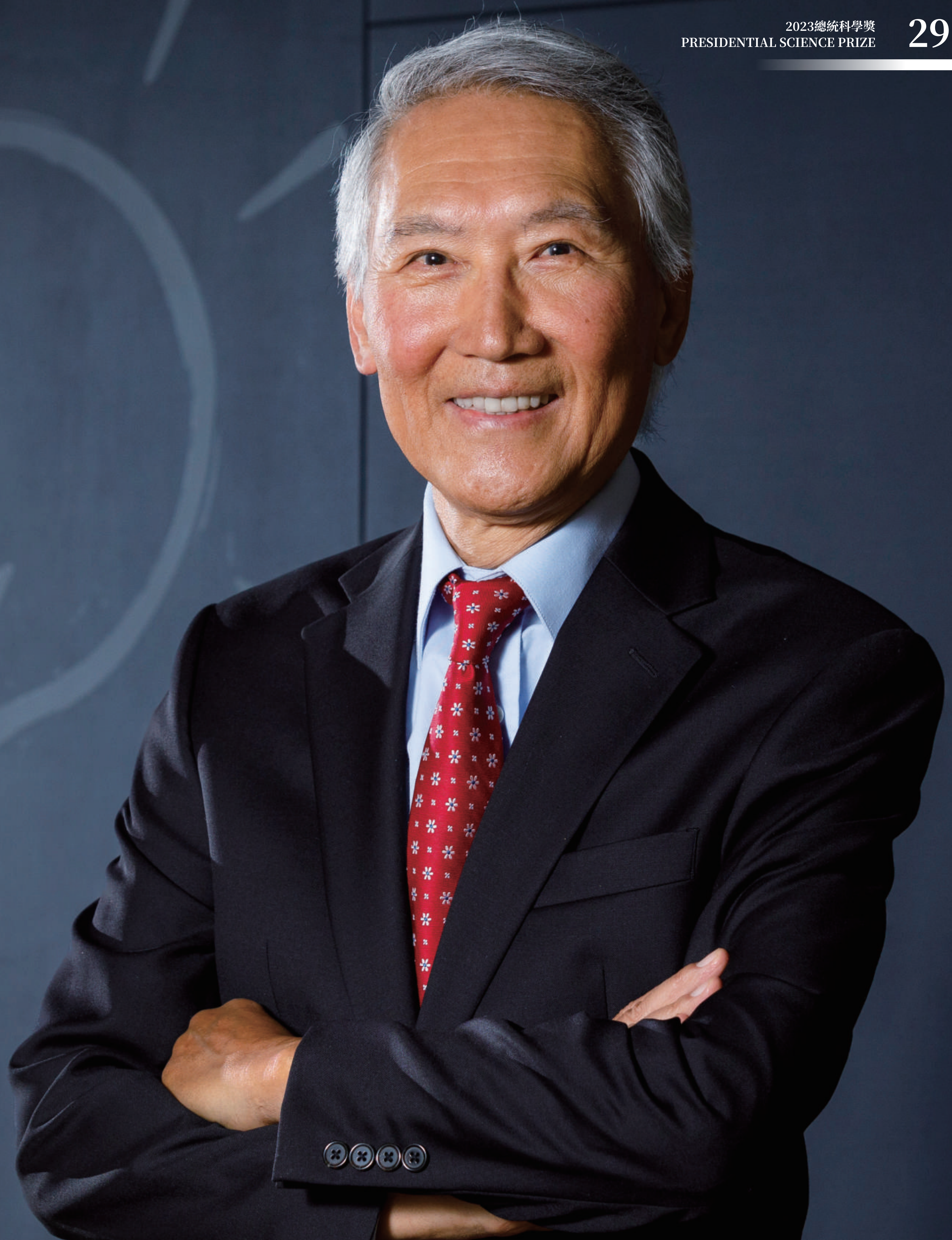
胡院士的科學研究成就，對臺灣學術界及產業界帶來深遠影響，更難能可貴的是自加州大學退休後，於 2017 年起擔任陽明交通大學講座教授，持續關注半導體技術發展，更將畢生所學回饋家鄉，協助產業建立持續領先優勢，厚植國力。

發明鰭式電晶體 克服半導體物理極限

推動前瞻技術研發　為臺灣半導體產業奠基

在臺灣成長、受教育的胡院士，在大四時接觸到半導體，便以此做為畢生的研究方向。他發明出「鰭式電晶體」（FinFET），解決了困擾產業界的晶片過熱和微型化問題，讓晶片尺寸可以縮得更小、效能更高。如今的智慧型手機、網路、人工智慧等，皆是採用 FinFET 晶片，對人類生活影響甚鉅。

長期任教於加州大學柏克萊分校的胡院士，也不忘回饋家鄉，並於 2001 年毅然返臺加入台積電擔任首任技術長。在此期間，他帶領團隊發表了多項先進的 FinFET 原型與專利，奠定日後台積電在國際半導體產業的領先地位。他不僅是科技研發的領軍人物，更是學術界的重要一員，與臺灣產學研界緊密合作，共同提升臺灣的研發實力和國際學術地位。他並且參與多項國家型計畫，培育出許多優秀高階研發人才，堪稱臺灣半導體產業創新發展的重要推手。



胡正明院士後排右邊第二，
站在椅子上

長期投入科學研究的胡院士，1947 年出生於北京，於戰亂中隨著家人遷居臺灣，並在臺灣完成大學學業，1968 年畢業於國立臺灣大學電機工程系，之後前往美國留學，鑽研半導體領域。

胡院士提及，當初之所以會選擇半導體領域，其實也是機緣。他記得大四時，學校邀請任職於 IBM 且在美國從事半導體物理及元件研究的方復博士擔任客座教授一學期，同時開了一門半導體入門課。在此之前，校內並沒有半導體課程，「我記得有位教授感嘆自己花了幾十年時間，總算把『真空管』弄懂，現在又出來一個『電晶體』，更難搞了。」胡院士笑著說。

對新事物懷有好奇心的胡院士不僅選修這門課，且成績十分優秀，得到方教授的鼓勵和肯定，因此在申請美國大學獎學金時，便決定朝著半導體領域發展。1970 年及 1973 年，胡院士分別獲得加州大學柏克萊分校電機及計算機碩士、博士學位，畢業後前往麻省理工學院擔任助理教授；1976 年起於加州母校任教，直至 2010 年榮譽退休。期間除了栽培無數優秀人才之外，曾憑藉出色的教學方法，獲得柏克萊加州大學的「柏克萊最高教學獎」。

柏克萊任教四十年 論文及專利成果豐碩

40 多年期間，胡院士撰寫了 5 本半導體教科書，發表研究論文超過 1,000 篇，並獲得 150 項美國專利，因其對教育的貢獻付出，相繼榮獲 IEEE 教育獎、SRC 亞里士多德獎、柏克萊最高教學獎等；對產業界的貢獻也極其深遠。值得一提的，他研發的電晶體電腦模式 BSIM 系列於 1996 年被選為國際標準作為半導體設計業與製造業之間的溝通語言，他免費開放這項研究成果並且每年研發開放新版至今，半導體晶片業已用之創造超過萬億美元的產值貢獻。

在豐碩的研究成果中，又以 1999 年研發成功的「鰭式電晶體」(FinFET) 最受世人矚目。胡院士分享當初的研究動機：「我是一個喜歡解決問題的人，做研究就是為了解決實際的問題，我很享受這種高難度的挑戰。」

當時半導體產業碰到的最大問題，就是使用的能量太多，導致晶片溫度太高。英特爾（Intel）技術長更公開警告，「在不久的將來，半導體晶片單位面積發熱會超過原子反應堆核心。」原因是電晶體微型化已達物理極限，產業界都陷入恐慌，卻沒有解決的方法，促使胡院士大膽往這個方向嘗試。

研究經費是讓科學研究能順利進行的重要一環，胡院士的研究計畫順利申請到「美國國防高等研究計畫署」(DARPA) 的研發經費，同時間 IBM 和美國空軍研究實驗室也獲得資助。DARPA 為美國國防部轄下的行政機構，負責研發用於軍事用途的高新科技，並長期資助顛覆性科技突破，包括電腦網路 (Internet)、NLS (第一個超文本系統) 都曾獲得其資助。

膽子要大
樂於解決無人能解的問題

1999 年胡院士與研究團隊開發出 FinFET，2000 年取得美國專利。他將使用 50 年的傳統平面式電晶體轉換為三維立體架構，克服半導體物理極限，讓電晶體密度得以繼續提高，兼具高速度與低功耗的特性。胡院士坦言：「醞釀、準備自己實力的時間遠遠超過真正投入解題的時間，開始做這項研究到完成的時間不到 3 年，可以說是機遇，也是團隊集體努力的成果。」

胡院士分享，有兩個原因讓他能夠看到別人沒注意到的創新方向，「一是在解題之前下苦功，徹底理解半導體、電晶體的原理，有時想到不同的解釋，而不是人云亦云，這樣才能提出新的想法，同時把所有的可能性在腦海裡一一考慮過。第二是對自己要有信心才能膽子大，才能不因為英特爾沒辦法解決，就不去嘗試。」

「信心其實是累積起來的。」胡院士認為，累積信心最好的辦法就是要有小的成功，有小成功以後，有人肯定稱讚，建立自信，才敢於解決較大的問題，一步一步地累積自己的知識和信心。

胡院士非常鼓勵年輕人嘗試解決問題，放膽去做，不要在還沒有行動前就否定自己，「許多人認為自己的數學能力不足，因而認為自己無法成為工程師或科學家。但事實上，只要有熱情和願意學習，就有可能投入理工和解決世界的問題。重要的是清楚自己喜歡解決問題，進而願意學習理工並累積信心，是讓自己成為解決問題者的關鍵因素。」

胡院士並以自己為例指出，「我的數學也只是一般，但從小熱愛探索事物，像是我的父親告訴我鬧鐘之所以會響，是因為裡面住了小人，但是我很懷疑，於是自己動手拆開鬧鐘，了解運作原理。」胡院士以自己的經歷告訴年輕人，真正的發明能力是源自於足夠的知識和探索實踐的熱情。

另外，他也提醒年輕人，要對自己有信心，有他人的誇獎自己要覺得幸運，沒有別人的讚賞時，就要自己肯定自己，如此才有能量一步一步走下去。

改變研發思惟　從平面轉向立體

「鰭式電晶體」論文於 1999 年 12 月發表之後，立刻受到全球半導體產業的高度關注，包括英特爾在內的許多企業，紛紛邀請他前去演講。

「鰭式電晶體」(FinEFT) 到底是什麼？簡而言之就是將原本 2D 構造的電晶體改為 3D，因為構造很像魚鰭，因此稱為「鰭式(Fin)」。胡院士帶領團隊領先全球做到了這件事，獲得「三維電晶體之父」的稱號。

水平和垂直的不同之處在於：水平就像在城市裡蓋平房，垂直則是建高樓，當城市發展到一個程度，不可能一直蓋平房，就要建高樓，而且會越蓋越高。FinFET 即是利用向上堆疊的方式，克服半導體物理極限，讓電晶體密度得以繼續提高。

FinFET 的設計還解決了傳統平面晶體管的許多限制，透過鰭片結構能夠更好地控制電流，減低漏電流就解決了晶片使用能量太多，導致晶片溫度太高的問題，這些優勢使得半導體能夠持續微型化，延續摩爾定律。值得一提的是，FinFET 三維架構也成為後續全包覆式（GAA）奈米線電晶體和奈米片電晶體等進一步發展的基礎，對半導體產業產生長遠的影響。

談到摩爾定律，胡正明談起自己在小學時候就曾想過類似問題，「當一張紙被剪半再次被剪半，能剪到多小呢？終會到達一個點，再也不能剪下去。」也許，正是這樣的好奇心引領他一路走進科學研究領域，最終投入發展微縮晶片技術，突破了半導體技術的瓶頸。

FinFET 的出現，對人類社會也帶來重大改變，例如現代人手一支的智慧型手機，不管哪個品牌，用的都是 FinFET 晶片；網路通訊、人工智慧（AI），所有先進的電子都需要 FinFET。電晶體是半導體技術的最基礎磚塊，晶片裡的電晶體數目越多，能做的工作就更多，目前已經發展到一個晶片裡有幾百億個 FinFET，原本無法做到的 AI，相繼都有了突破式的進展。

台積電首任技術長　推動臺灣半導體大步向前

儘管 FinFET 發表後受到國際矚目，但一開始並未引起臺灣政府和產業界的注意。在臺灣成長、受教育的胡院士，為了回饋家鄉，毅然決定回臺貢獻所學。2001 年春天，他返臺時見到台積電董事長張忠謀，於是毛遂自薦，表示願意在臺灣工作兩年。胡院士提及：「當時張董事長特別打電話給新竹的主管，安排我到新竹面談，談過之後，當天就敲定了，還為我新設一個職位叫『技術長』，成為台積電首任技術長。」

當時臺灣學界也積極延攬胡院士，但他認為，教育的確也很重要，但這是一條長遠的路，而當務之急是避免美國、日本的公司捷足先登，否則以後臺灣半導體產業就更難起飛，因而決定投入產業界。

胡院士指出，當時張董事長賦予他兩項任務，一是將技術發展的視線拉長，不僅要追趕國外的技術，還要超越，剛好 FinFET 技術就是大好機會。他領導台積電研發團隊持續發表領先全球的 FinFET 原型，包括 25 奈米（2002 年）、10 奈米（2003 年）與 5 奈米（2004 年）。另一項任務則是整頓專利，他發現問題在於專利品質而不在數量，除了透過內部的教育訓練、演講，強化研發同仁的專利知識，並成立專利管理部，人員全部是工程師。

「因為專利不僅是法務人員的責任，還要懂技術的人能夠寫出、做出好的專利揭露，才能提升專利的品質。」胡院士並且強調專利一定要活用：「比如 FinFET 的專利不是只有一個。因爲 FinFET 是有用的，就可以想想看 FinFET 是否可以跟其他的技術合在一起，而且這個結合也是不可或缺的，只要這個結合不是一般行內人都能夠想到的，就是好的專利。」

爾後胡院士在台積電待了 3 年多，期間協助台積電及早部署前瞻技術與強化專利，奠定與國際頂尖半導體公司競爭的基礎。英特爾在 2011 年率先使用 22 奈米 FinFET，並宣稱此技術是「50 年來半導體技術最劇烈的轉變」，不久台積電即推出 16 與 14 奈米 FinFET，此後一路領先全球推出 12、10、7、5、3 奈米 FinFET 技術。

2004 年胡院士獲選為第一位在科學工業園區任職的中央研究院院士。同年他在台積電的階段性任務完成後，再度返回美國加州大學柏克萊分校任教。總結胡正明的三年產業之旅，除了將其在微電子領域的研究，貢獻於臺灣半導體產業，也為台積電建立技術人員升遷制度，成為台積電長久發展的根基之一。

此後，即使身在美國，胡院士始終心繫臺灣，持續與臺灣學研界密切合作，共同發表學術論文數十篇，致力提升臺灣半導體研發能力與國際學術地位。

深化產學合作　產業出題、學校解題

胡院士表示，在台積電的這段經歷，對學界出身的他來說是很重要的學習過程，「學用相長，能夠把自己的知識拿去做真正的應用，在教學上也有所助益，而且和產業界合作的老師，通常也是學生心目中課堂裏最好的老師，因為學生都希望學習有用的知識、做有用的事。老師將產業資訊和經驗帶給學生，可以大幅提高學生的學習興趣和動機。」

關於產學合作，胡院士坦言，大部分的創新是在產業裡發生，「因為產業界知道問題在哪裡，但是人手不夠，所以總是優先解決明天的問題，沒有餘裕解決三五年以後的問題，透過產學合作，學生能接觸到最先進的產業知識，業界則能有人才投入尖端研究。」

胡院士認為產官學合作的最好方式，就是「產業出題、政府出錢、學校解題」。解題的過程也達到政府支持教育、培養人才的目的，「培養人才不光是讀書，還要學會如何解決問題，產學合作就是最好的練兵場。」

「產業和學校就像是唇齒相依，之前大家總是說舊金山灣區電資訊產業之所以發展得好，是因為有史丹福、柏克萊大學等名校，其實反過來講可能更對，為什麼史丹福、柏克萊是頂尖大學，因為有很好的產業在這裡。」胡院士進一步舉例，華盛頓大學本來不是名列前茅的學校，但因為微軟（Microsoft）、亞馬遜（Amazon）總部在西雅圖，華盛頓大學的計算機系躋身全美前四名；同樣的，加州大學聖地牙哥分校因為高通（Qualcomm）坐落該城市，該校的高頻電子專業全球聞名。臺灣的大學工科一定能夠成爲世界頂尖，重點是要與本土產業更緊密合作。政府也要注意教育直接影響未來經濟發展，應把握機會而不要強求科系平均發展甚至截強補弱。

市場供需決定 培養產業需求人才

胡院士長期旅居矽谷，從不忘回饋臺灣，包括 1985 年擔任第一屆行政院國家講座，在工研院講授先進半導體課程；1992 年擔任國家次微米計畫指導委員，協助建立臺灣第一座 8 吋晶圓實驗廠；2009 年至 2014 年與國研院國家奈米實驗室（NDL， 現爲 TSRI）研究人員每季遠距會議，經由指導建議，輔導研究人才創造研究成果。

2011 年胡院士與陽明交通大學合作，共同執行國科會國際頂尖研發中心 5 年計畫，整合加州大學柏克萊分校及交大研發團隊人力資源。自加州大學退休後，胡院士於 2017 年起擔任陽明交通大學講座教授，隔年親自主持教育部及國科會共同支持的特色領域研究中心計畫（智慧半導體奈米系統技術研究中心）。在胡院士的領導下，陽明交大團隊投入前瞻半導體技術研發，開創多項世界級成果，並培育出許多優秀研發人才。

面對全球半導體產業人才荒，胡院士以為，半導體很需要人才，政府不能過於使用教育資源創造新產業。產業要由企業界來創造，而不是由政府創造，政府更重要的任務是提供足夠人力資源給創造工作外匯經濟的好產業。

「美國政府給了學校很多經費，不見得是為了有突破性的研究成果，而是希望為國家、企業培育好的人才；美國的學校一切是由市場供需決定，校方可以因為某個產業需要人力而增加學生人數。」他以任教的加州大學柏克萊分校為例指出，從 2009 年到 2019 年，全校選修計算機學課程的人數，已從每年 3,000 人增加到 1 萬人，增加了 3 倍以上，因為不僅工學院科系，文理學院學生也都紛紛搶修程式課程，但是政府和學校不僅不限制，而且協助授課教授將上課學生人數增加數倍。

胡院士更提及：「在擔任台積電技術長期間，許多人認為『代工』就是低科技，而輕忽半導體與科技代工業的價值，但台積電就是晶圓代工，難道台積電不夠高科技，不夠創新？政府有時可能因為不了解產業細節，或是不熟悉每家公司的情況，往往就被幾個名詞誤導，其實只要能創造附加價值、提供高薪工作機會、遵守法律保護環境的產業，就值得政府持續挹注政策資源支持。」

針對當前激烈的半導體市場競爭，他建議臺灣政府及法人研究單位需重新思考策略。臺灣已擁有大型且具備國際競爭力的私人企業，政府策略不應再沿襲採用過去「政府為產業做研發」的思維，而應透過教育供應符合目前產業需求的人才，將技術創新及研究開發的重責交予產業界。同時，法人組織也需有新方針，應該為產業界培訓釋出人才，而不是與產業界爭搶人才，進而為國家經濟注入新動力。

「半導體產業仍將是未來的主流產業，如果年輕人有興趣，應該不用擔心出路問題。」胡院士指出，在數位時代，世界是靠半導體撐起來的，不管是網路、人工智慧等都需要數位處理，仰賴半導體。

他也提醒年輕人要對自己有信心，要有好奇心、樂於學習新知，而且願意努力。「美國半導體產業碰到的問題是，年輕人覺得科技很難，或是認為數學不好就不適合當科技家，其實只要肯努力，喜歡解決問題、願意動手做，就可以投入科技產業，為社會做出貢獻。」

奈米製造成關鍵 布局先進半導體研發

2016 年美國總統歐巴馬（Barack Obama）在白宮頒發「國家技術和創新獎章」予胡院士，表揚其以技術創新為世界帶來卓越貢獻，同年也獲得工研院院士的榮銜；2020 年國際電機電子工程學會頒發其最高獎章（IEEE Medal of Honor），稱他為「微電子領航者」。

胡院士一生致力於電子科學研究，他也坦言，任何物質總有它的極限，摩爾定律（晶片上可容納的電晶體數目約每隔兩年便會增加一倍）終究會有結束的一天，學界和產業界都在試圖改變電晶體結構設計、材料、元件，盡可能地延續摩爾定律。

「FinFET 的創新之處在於，不管是把電晶體越做越薄，還是向上堆疊越來越高，都還有繼續往下走的空間，我相信半導體之後一定是往這兩個方向發展。」胡院士強調，科技發展日新月異，半導體材料一定會隨著時間有新的變化，甚至在晶片上加入更多非半導體材料；但更重要的是，不管採用什麼材料，都免不了很多很細微、很複雜的構造，因此奈米製造才是半導體產業的核心技術，這也是臺灣的強項。台積電未來不僅會繼續發展，而且還會有新的舞臺。

熱愛學術及生活 不忘回饋社會公益

一路走來，胡院士不僅以科學研究造福人類，他更從其他方面投注己力，以創造一個更好的世界。例如，胡正明及其太太梁淑玲（Margaret Hu）曾捐贈 100 萬美元給位於加州奧克蘭（Oakland）屋崙華埠社區的「亞健社」成立「胡正明和梁淑玲醫療中心」(Dr. Chenming and Margaret Hu Medical Center)。這座大樓是由原有的亞健社行政大樓改建而成，配備最先進的兒科和家庭護理中心。屋崙亞健社於 1974 年成立，當時僅是一間由志願者運營的診所，過去的幾十年裡，該中心服務的醫療對象數量擴增至數萬名，其中 95%是低收入兒童和家庭的患者。醫療設施的擴充將能為更多病患提供更佳的醫療服務。

胡正明的公益精神其來有自，他的父親於中國就曾設立獎學金，他的兩個兒子也繼承此種胸懷。兒子胡安宇（Raymond Hu）為醫療中心貢獻許多美麗畫作；胡安元（Jason Hu）則遠赴非洲迦納從事公益愛滋病預防工作。值得一提的是奧克蘭市政府為了感謝胡正明和梁淑玲夫婦對社區的貢獻，特地將 2018 年 8 月 31 日命名為「胡正明和梁淑玲日」。

胡院士不僅鑽研學術研究，興趣也十分多元，生活多彩多姿。

值得一提的是，儘管有著卓越的成就，胡院士還利用空餘時間，與兒子共同探索帆船和潛水等活動，分享父子之間的特別時光。他更曾經健行至珠穆朗瑪峰登山基地。胡院士的妹妹胡海燕曾於接受媒體採訪時談及：「哥哥不僅是理科專家，連文學也非常出色。從小，家中的兄弟姐妹參賽的講稿都是由他來撰寫，他在詩歌、作詞和繪畫方面都有很高的造詣。」她並且回憶小時候每當在學業上遇到困難時，胡院士皆會耐心教導並用巧妙的方式幫她解答，「無論問題有多複雜，經過他的解說，都會變得簡單明瞭。」胡院士做為人師的天分，原來從小就表露無遺。

獲獎無數的胡院士，回顧一路以來，每一步都是滿滿的感謝，從引領他進入半導體領域的方復博士、臺灣大學和加州大學給予他的教育，以及學生、同事們的團隊合作，到進入業界台積電，讓他有很好的學習機會，達成回饋臺灣社會的夢想。他也很感謝父母對他的教育，經常給予鼓勵和讚美，幫助他建立自信；家人的支持、陪伴，讓他能全力以赴投入到科研創新上。

胡院士特別提到「自信」對於自己的重要影響，「年輕人首要的任務是建立自信。當他人真心讚賞你，要欣然接受；即使感覺他人的稱讚帶有保留，還是要嘗試相信。總之，應把握任何增強自信的機會，即便沒人稱讚你，也要自我鼓勵。」胡正明在許多場合都強調自我肯定的重要性，「要相信自己，這樣你才有力量解決更加困難的挑戰。」

開創多項世界級成果的胡院士豪情表示：「取之於社會，用之於社會，只要有機會，我還會繼續為產業、學校貢獻所能。」

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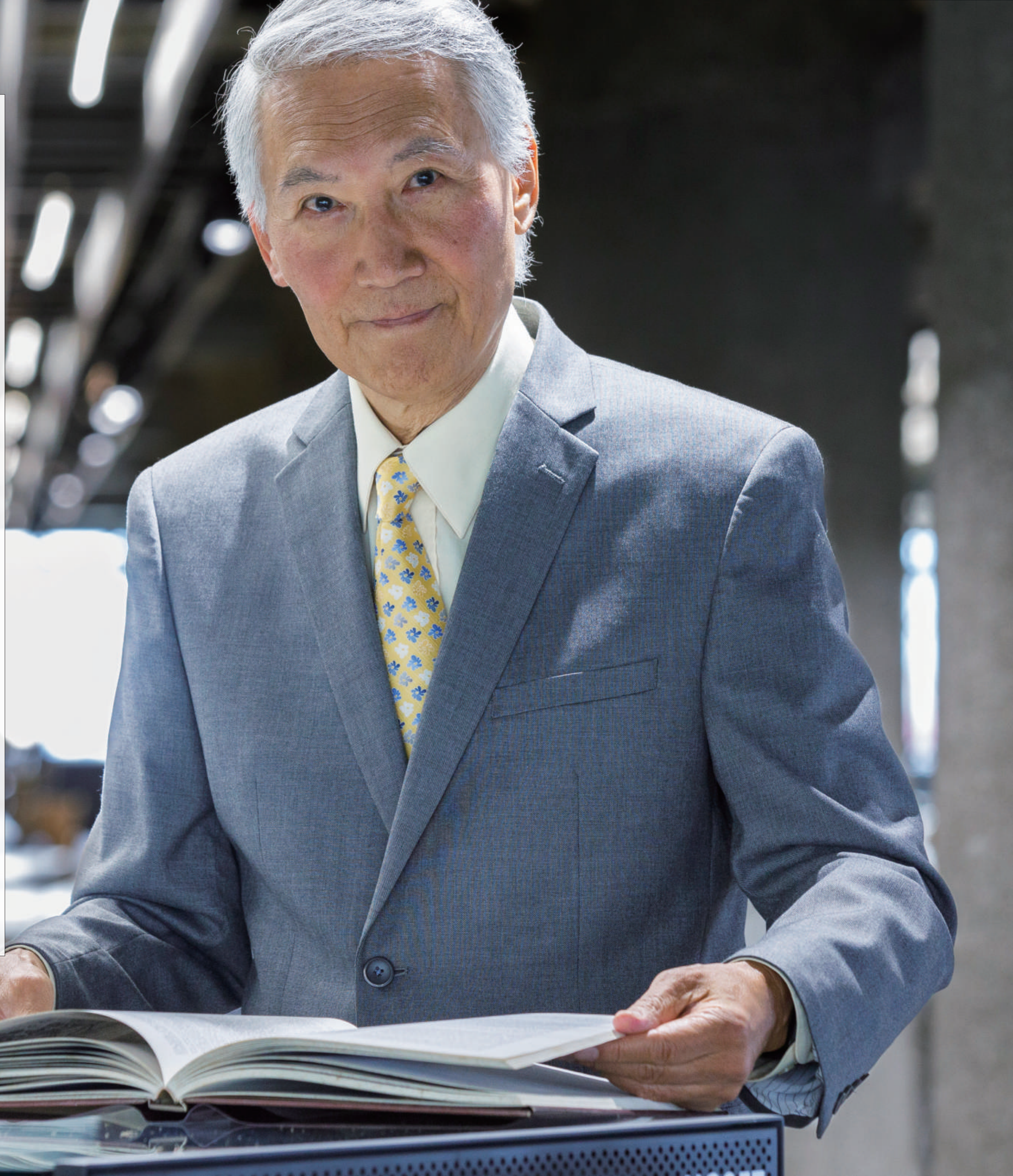


數理科學組 —— 葉永烜 院士

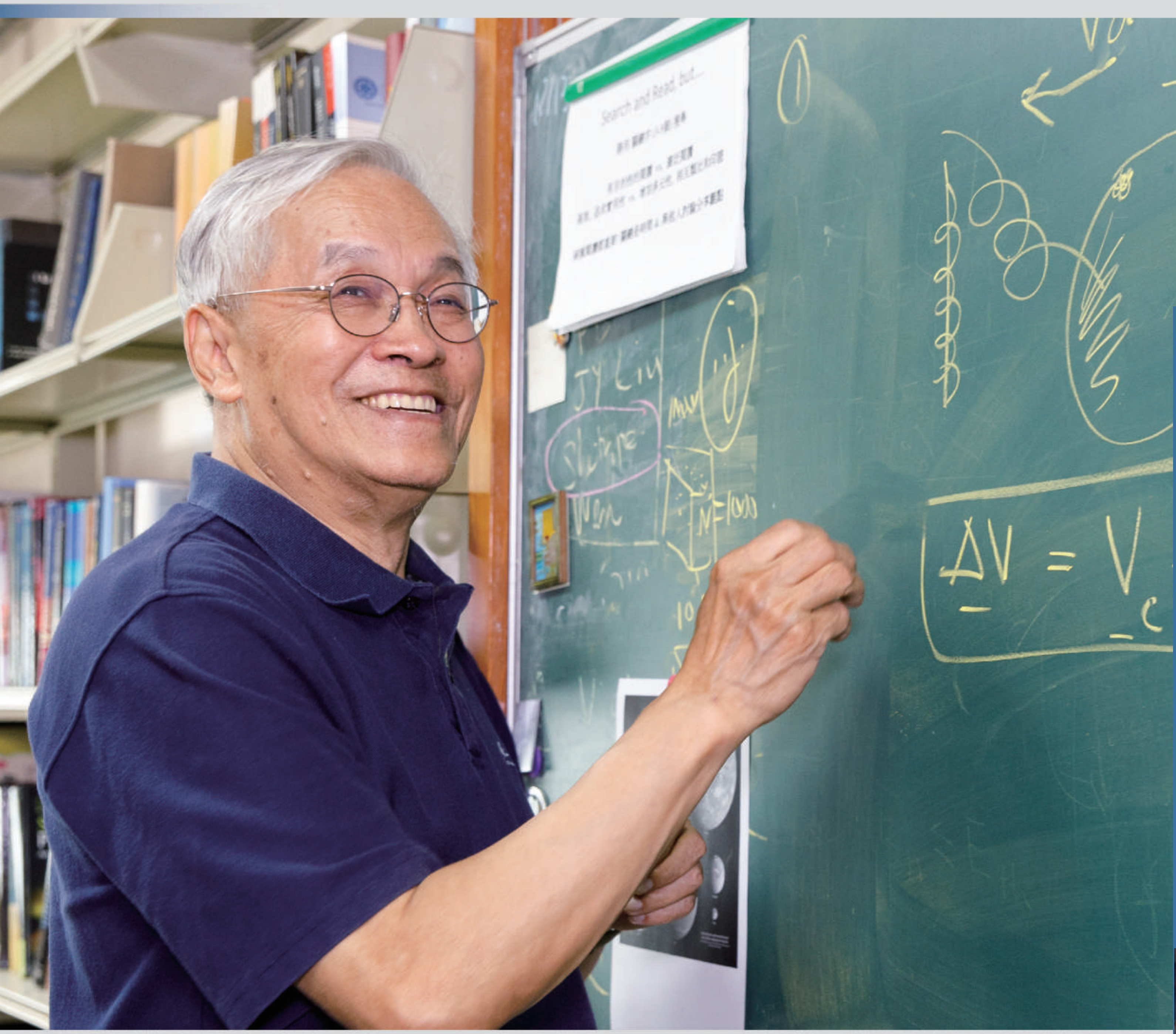
開創臺灣行星科學研究新篇章

深入探索土星系統 國際學術聲望卓著

葉永烜院士致力研究彗星物理學、行星動力學，以及衛星與磁層之間的相互作用，成果極為豐碩，累計發表超過 500 篇的期刊論文，其中包括 60 多篇發表於國際頂尖的期刊如《自然》和《科學》上的論文。其中關於彗星大氣與太陽風交互作用的基礎研究，對於瞭解太陽系的形成及行星的起源，有著不可或缺的價值。他更是歐洲太空總署（ESA）與美國太空總署（NASA）合作「卡西尼 - 惠更斯號計畫」的三位主要創議者之一。他提出土星環的大氣模型和帶電粒子在電磁層動力學中的作用，並且帶領國立中央大學研究團隊參加土衛二的噴氣中含有大量水氣的研究，這些開創性的貢獻，讓人類得以進一步認識土星系統，探索外星宜居環境可能性及生命起源。

葉院士 1947 年出生於南京，舉家來臺短時間後即遷移至葡屬澳門。在聖公會蔡高中學及香港中文大學新亞書院的求學歲月，啟發了他對於知識的好奇和熱情。之後他赴美深造，1970 年於匹茲堡大學取得物理學碩士學位；1974 年於加州大學聖地牙哥分校取得應用物理學及資訊科學博士學位，之後並繼續於該校進行博士後研究。1978 年，德國馬克斯普朗克研究院高空物理所聘請葉院士加入擔任研究員，服務長達 20 年。

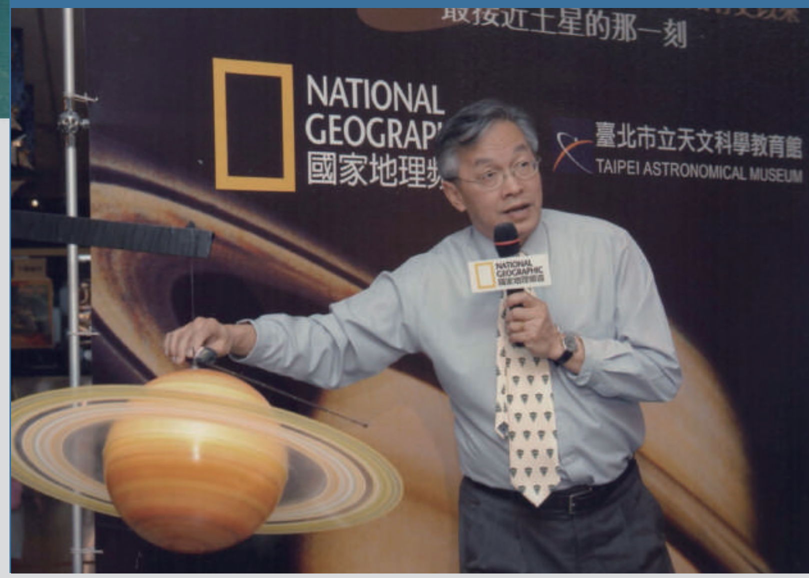
1991 年和 1992 年間，葉院士擔任行政院國家太空計畫室籌備處的首席科學家，致力於臺灣第一顆科學衛星的任務定義，以及科學酬載的設計和選擇，為臺灣的太空科技發展奠定堅實基礎。1998 年定居臺灣，並應國立中央大學的邀請擔任理學院院長，六年任期中充分運用自己的通才素養和協調規劃能力，成功建立認知神經科學所、生物物理所及生物資訊所，並於天文所成立太陽系實驗室，開創了臺灣行星科學研究的新篇章。



葉院士協力籌建國立中央大學的鹿林天文臺，使其成為國家級的設施，推動時域天文學的發展，鹿林天文臺躍升成為產出重大科學價值國際合作及太陽系研究亮點的重要平臺。葉院士率領的國內團隊成功參與多項國際太空任務，包括 ESA 和 NASA 合作的卡西尼土星任務、ESA 的 Rosetta 彗星任務、火星快車，以及日本宇宙航空研究開發機構（JAXA）和 ESA 的 Bepi Colombo 水星任務等。2020 年，成立臺灣太空科學聯盟（TSU）並擔任主席，促成產官學的緊密合作，進一步整合我國學界的太空科技能量。葉院士並向業界募款，與台達電子文教基金會共同設立「年輕天文學者講座」，希望能延攬國外的優秀年輕學者來臺推動天文教育。葉院士致力於科學人才的培育，成功培養出眾多的高教英才，並投入 K-12 的科教領域，尋找和培育特殊的人才。

葉院士的學術影響力極為深遠。他以臺灣名義發起和組織亞洲大洋洲地球科學學會組織（Asia Oceania Geosciences Society, AOGS），並在 2002 年擔任籌備委員會主席，以及第一屆的理事長。如今，該組織已經擁有超過 54 國 11,000 名會員，與美國地球物理聯盟（American Geophysical Union, AGU）及歐洲地球科學聯盟（European Geosciences Union,EGU）齊名，對提升亞洲地區相關學術地位貢獻卓著。

身為一位享有國際盛譽的學者，葉院士多次獲獎。對於卡西尼計畫的貢獻，使其獲得 NASA 頒發的特殊公共服務榮譽勳章。他被授予亞洲大洋洲地球科學學會的艾克斯弗獎章（Axford Medal），更有一顆小行星 18730 以他的姓名命名，以表彰他在天文學領域的貢獻。葉院士於 2016 年獲選為第 31 屆中央研究院的院士。2020 年，葉院士獲得美國天文學會行星科學學部頒發的「傑拉德·柯伊伯獎」(Gerard P. Kuiper Prize)，此獎項旨在表彰在行星科學領域做出突出貢獻的天文學家，為一項終身成就獎。

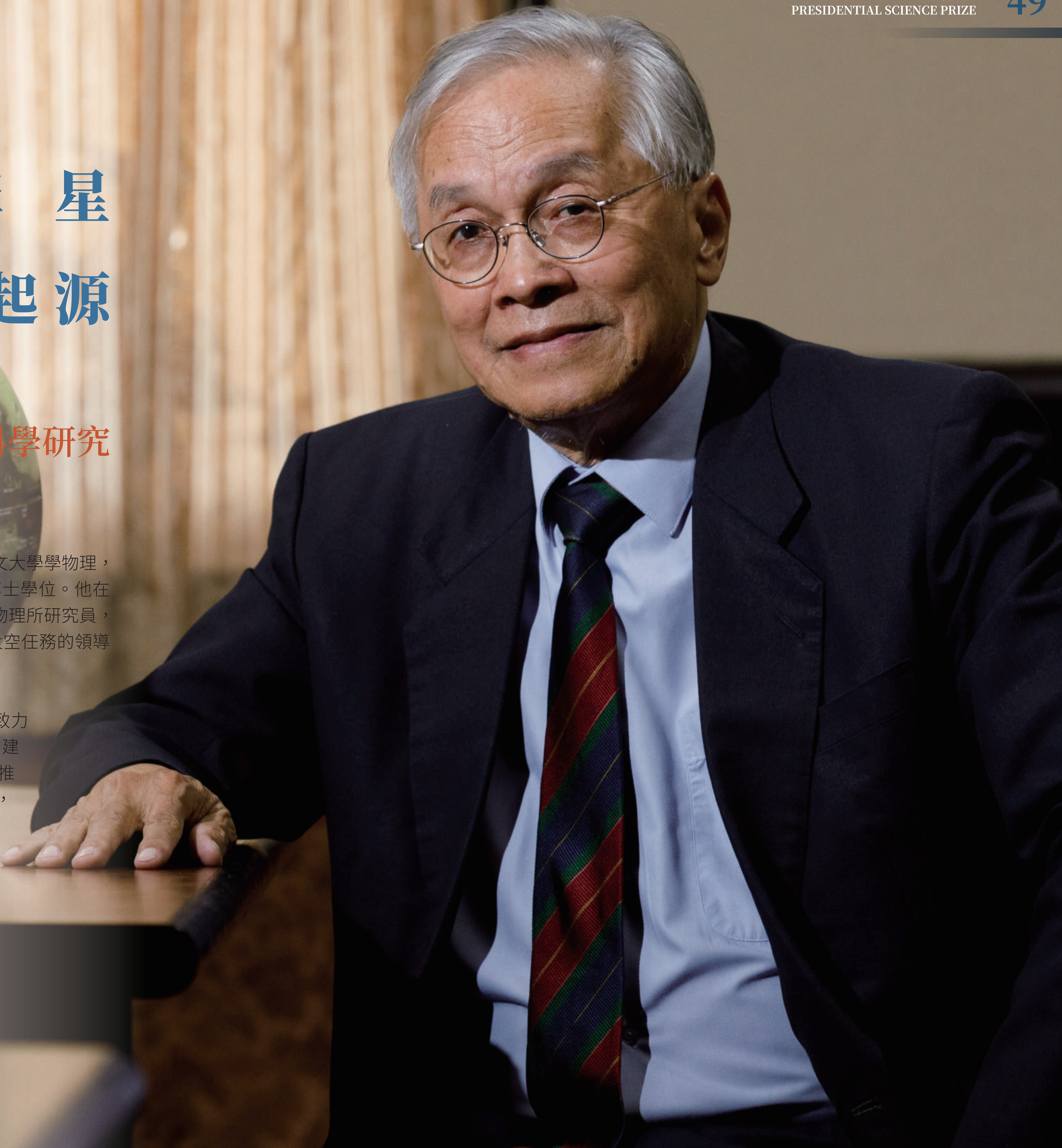


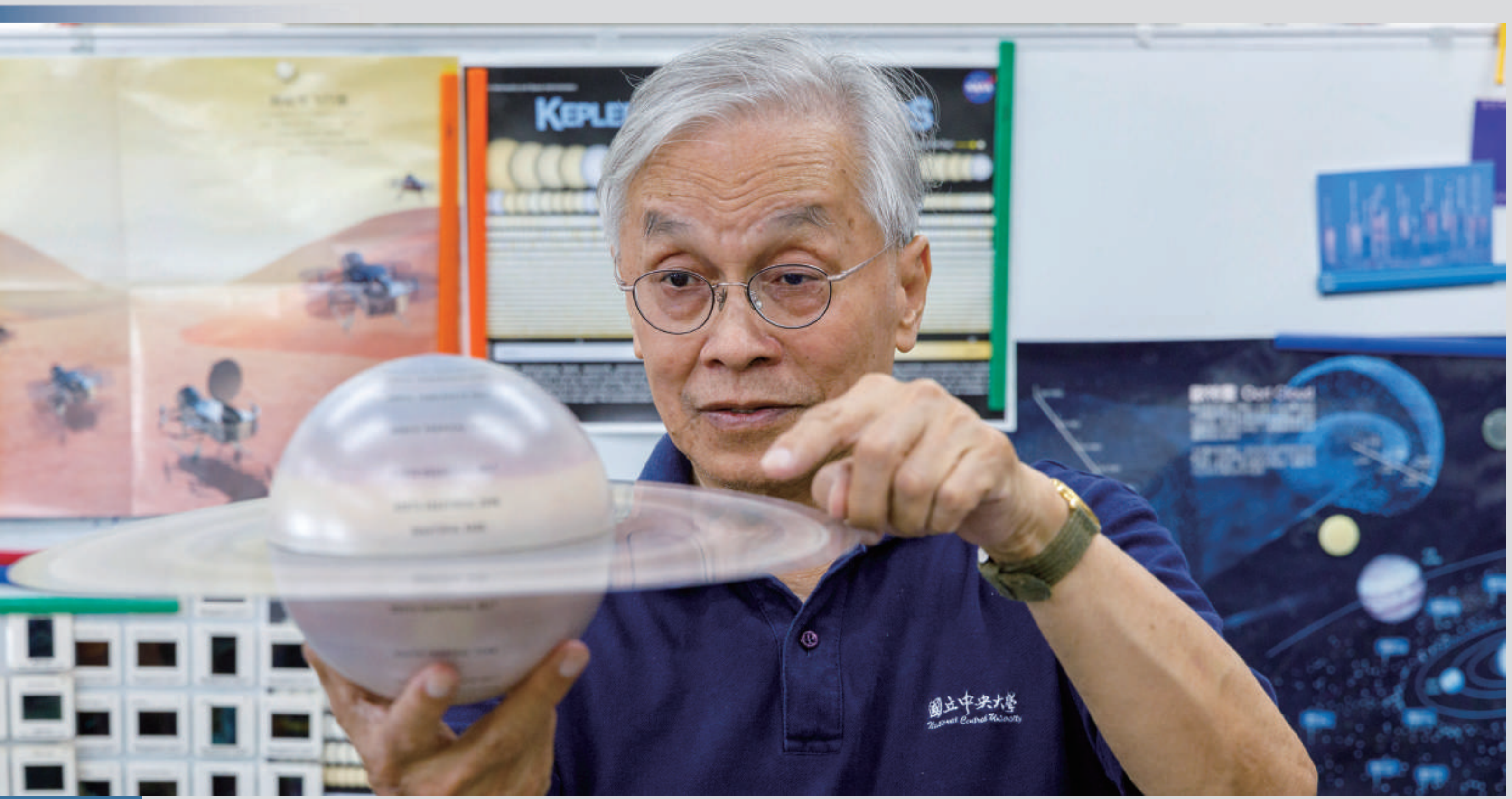
研究土星及彗星 探究太陽系及生命起源

參加多項國際太空任務 推動臺灣行星科學研究

葉永烜院士，1947 年出生於南京，童年於澳門渡過。大學時期在香港中文大學學物理，隨後於美國進修，取得匹茲堡大學的物理碩士及加州大學聖地牙哥分校的博士學位。他在 1978 年獲得德國馬克斯普朗克研究院（Max Planck Institute）邀聘擔任高空物理所研究員，服務達 20 年。葉院士的研究涵蓋彗星、行星、太陽系等領域，為多項國際太空任務的領導者，學術生涯至今累計超過 500 篇的學術論文。

葉院士於 1998 年返臺後在中央大學成立多個研究所及太陽系實驗室，致力推動臺灣行星科學研究及國家太空科技。他於學術界的影響力極為深遠，創建亞洲大洋洲地球學會且擔任首任理事長。他積極籌建中央大學鹿林天文臺，推動時域天文學發展，並在 2020 年成立臺灣太空科學聯盟，促進產官學合作，並致力推動科學教育及培育人才。





在 1977 年 8 月及 9 月，美國太空總署（NASA）接續發射航海家 2 號、1 號，這兩艘無人外太陽系太空探測器進入土星系統，首次傳回了土星及其衛星的高解析度照片。當時年僅 30 歲的年輕科學家葉永烜受震撼，「伽利略於 1610 年利用望遠鏡首次看到土星環，從那時到現在過了 400 年，人類終於能夠近距離看到土星面貌！」

「初見土星」的興奮之情引發更大的想望，葉院士提到當年的想法：「當時的兩艘太空船僅是快速掠過，如果想要真正了解土星系統，尤其是泰坦（土衛六）就需要更深入的探測計畫。」土衛六是太陽系第一顆被發現擁有濃厚大氣層的衛星，因此被高度懷疑有生命體的存在，科學家也推測大氣中的甲烷可能是生命體的基礎，一般認為土衛六探測，有助人類了解地球最初期的情況，揭開地球生命的誕生之謎。

初生之犢有「憨膽」 提案卡西尼計畫

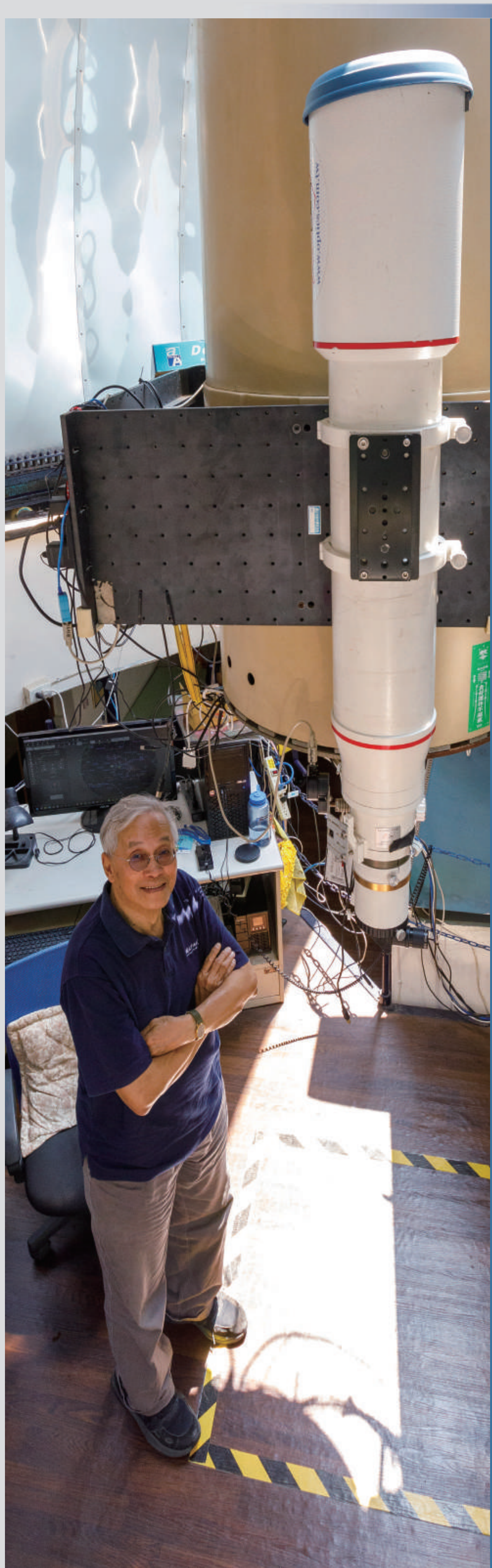
探索熱情驅動出「憨膽」，當時獲邀擔任德國馬克斯普朗克研究院（Max Planck Institute）高空物理所研究員僅四年的葉院士與法國科學家 Daniel Gautier，共同於 1982 年向歐洲太空總署（ESA）提案「卡西尼探測土星計畫」。葉院士透露當年說服這位法國同事的小花絮，「他是土衛六的大氣專家，原本不太願意幫襯一個年輕科學家，於是我決定將計畫取名為『卡西尼計畫』，喬凡尼·卡西尼是法國天文學的代表性人物，他在 1675 年首次發現土星環之間的細縫（卡西尼縫，Cassini Division）。當我把這個想法告訴丹尼爾，他在沉默片刻後接受提議，願意與我合作。」其實當時大多數人都不看好這個計畫能通過，這也是預料中的事，畢竟葉院士在當時只是個初出茅廬的年輕學者，甚至有其他科學家與他打賭，只要計畫能通過，就送他一大箱香檳。

結果當然是葉院士打賭贏了，之後在他與丹尼爾，以及美國天文學家 Toby Owen 的共同推動下，促成歐洲 ESA 和美國 NASA 共同合作這項當時耗資 34 億美元、聚集 18 國 256 位科學家智慧和心血的計畫。2009 年，NASA 頒發「特殊公共服務榮譽勳章」予葉院士與兩位夥伴。

1997 年 10 月，「卡西尼號－惠更斯號（Cassini-Huygens）」正式啟程，飛向土星。卡西尼號裝載多項研究土星的儀器，其中，惠更斯探測器具有降落傘功能，能夠著陸於泰坦上進行探索；太空船卡西尼號則繞行土星觀測。經過漫長的飛行歲月，「卡西尼號－惠更斯號」於 2004 年成功進入土星軌道，「惠更斯號」探測器在 2005 年成功降落於泰坦，這是人類有史以來第一次在外太陽系的天體上著陸。「惠更斯號」以卡西尼號為中繼將資料傳回地球，累積的科學成果超出當初預期，因此原定於 2008 年結束的計畫，NASA 決定延長至 2017 年。

這趟長達 13 年的探索任務，讓科學家對於土星的大氣、土星環、衛星有了更深的了解，最令人驚喜的發現之一，是發現泰坦除了有大氣層，還有湖泊與山脈；另外一個衛星「土衛二」也可能存在生命跡象。期間，葉院士帶領國立中央大學研究團隊參加土衛噴氣含大量水氣的重大發現，提出土星環大氣層及游離層的大氣模型，並且開創帶電粒子電磁層動力學作用理論，對於土星環構造及來源研究提供關鍵貢獻。

卡西尼計畫的成果，推進了人類探索宇宙及生命起源的進展，在太空研究歷史中，與阿波羅、航行者及哈伯太空望遠鏡等計畫齊名。



投入彗星探測研究　探索太陽系的形成之謎

「太陽系如何形成？」、「生命如何發生？」葉院士的許多研究皆是圍繞這兩個「大哉問」，彗星研究就是其一。從在 1986 年參加哈雷彗星的太空探測開始至今，葉院士一直用心於彗星的前沿研究。他領導中央大學團隊參與的 ESA 羅塞塔（Rosetta）計畫，讓人類得以更靠近真相。葉院士道出此研究的重要性：「彗星可能是我們了解太陽系、甚至生命如何開始的鑰匙。」彗星被認為是太陽系遺留下來的古老物體，它在太陽系內的變化相對較少，透過對彗星結構的物理特性進行研究，可以對太陽系早期形成環境有更深入的了解，並揭示太陽系形成的重要訊息。

ESA 於 2004 年發射的 Rosetta 太空船，歷經 10 年飛行後抵達彗星 67P/C-G，除了跟著這顆彗星繞轉之外，之後並將另一個小型探測器 Philae 降落至彗星 67P/C-G 上，這是第一個成功登陸彗星表面的探測器，傳回許多關於彗星結構的寶貴資料。從馬克斯普朗克研究院至回到臺灣於中央大學任教，葉院士始終致力於太陽系小物體的觀察資料分析及相關理論研究。

從最初提出合作規劃，到探測器真正將資料傳回地球，整整歷時 30 年。「大家會覺得這段時間很漫長，然而放在人類歷史來看，不過就是一瞬間。」也許是身為天文學者，葉院士慨嘆宇宙之浩瀚、時間之河的綿長，「人類壽命有限，唯有靠著一代代科學家的接力、一筆筆資料的累積、一次次實驗的發現，才能一點點揭開宇宙及生命的奧秘。」

行星探測動輒數十年，相關研究的開花結果，未必是由發起計畫者採摘，因此，葉院士坦言自己近乎一甲子的天文研究生涯，並未出現戲劇性的 Eureka Moment，也就是突然恍然大悟的時刻，「只有在提出一些太空計畫被通過時，會覺得非常興奮，因為知道又有資源可以繼續探索未知！」

葉院士曾用「前人種樹，後人乘涼」描述科學研究的發展，「科學成果不是幾個人的成果，而是很多人的努力，你可能是別人的大樹，也可能是在某處樹蔭下乘涼的那個人。」他舉了一個例子：過去， 科學家認為太陽系行星在由小變大的過程中，運行軌道不會有太大改變，有點像所謂「三歲定八十」一樣。然而，葉院士與一位烏拉圭籍年輕科學家（Julio Angel Fernandez）在 1984 年共同建構的一個理論模型，推翻了這個認定，「根據這個模型，我們認為行星吸收及拋出微星體過程中產生的角動量交換，會導致一些木星和土星逐漸靠近太陽，而天王星和海王星則會大幅外移。」這個理論在提出當下並沒有受到太多的注意及肯定，然而在多年後，有位美國科學家運用此理論解釋冥王星特殊的軌道共振現象，引起了極大關注，「我還記得這位科學家在受訪時，特別提到我們當年的論文，表示對她的研究很有幫助。」

葉院士認為探索未知的樂趣，就是科學研究的最好回報。不過，他並非從小立志成為科學家，「我只是順水推舟、順勢而為吧！」回顧一路走來，葉院士雲淡風輕地說著。

在自由探索環境成長 養成一生的好奇心

從南京到臺灣、再到澳門和香港，之後踏足美歐，現在回到臺灣。葉院士一路走來集滿了「兩岸三地」、美國、德國，他的故事，猶如大時代的縮影。1947 年，葉院士誕生於南京；1948 年，葉家決定舉家遷往臺灣臺中。一年後，也就是 1949 年，中國國民黨領導下的中華民國政府，從中國大陸撤退至臺灣。


葉永烜院士兒時與母親合照

落腳於臺灣，但葉家長輩並不認為臺灣是安家的最理想之處，「家裡長輩多是職業軍人，曾經歷長達 10 年的八年抗戰和國共內戰，不願再被戰火牽扯，想生活在沒有戰爭陰影的土地上，於是選擇離開臺灣，前往當時仍由葡萄牙管轄，堅持中立政策的澳門落地生根。」葉院士娓娓道來他的成長歷程。

舉家遷徙至澳門，少年葉永烜進入聖公會蔡高中學就讀，回想這一段校園歲月，他給予的註腳是「自由探索」和「主動學習」，他認為這樣的學習態度養成，以及教會學校長期塑造的利他價值觀，是促成他之後投入科學研究領域的關鍵之一。「當時澳門沒有聯考制度，也沒有大學，許多學生念到高中畢業就覺得夠了，所以我一路念到高二，從來沒有想過上大學這件事，我們是在沒有升學壓力下學習各種各樣的知識，那是非常快樂的。」數十年前的中學歲月，啟蒙了他樂於探索的精神。

懷抱著對於知識的好奇心，當知道原來有「大學」的存在，葉院士在高三開始努力準備考大學，香港和臺灣的大學都在選擇之列。「當時我並不確定自己究竟喜歡哪個科系，所以填了 10 個不同領域的志願，像是物理、化學、醫學和水利工程等等。」葉院士特別提及填志願之事，是因為他從中得到啟發，「對於我念大學這件事，我的父親只有一個要求，就是不能去念水利工程，因為他說澳門根本沒河川，沒有水利需求，當時我也覺得很有道理，沒想到現在因為氣候變遷，各地水災頻發，水利工程成為顯學，即使在澳門也不例外。這件事告訴我們，知識不會無用，總會派上用場，所以應該要盡其所能求知和學習。」

後來，葉院士決定就讀臺灣的大學並錄取國防醫學院，然而，事情有了轉折。「我原本已經準備好到臺灣念書，行李都打包好了，但是我的母親捨不得我離家太遠，於是在出發前夕硬生生改為入學香港中文大學。」這次的決定左右葉院士日後的志業選擇，不過，他與臺灣的緣份並未就此結束，日後以臺灣女婿的身分回臺定居並為臺灣天文學界貢獻良多。

進入香港中文大學新亞書院就讀物理系，葉院士非常感念書院給予的全人教育。新亞書院是由錢穆先生及一群來自中國大陸的學者，於 1949 年極艱困的環境中創立，「書院老師當中不乏哲學家、歷史學家、文學家等，他們共同創建了新儒家學派，這種在困境依然不改憂國憂民初衷的精神，讓我非常敬佩，我自覺價值觀深受這些老師們言教及身教的影響。」學術研究生涯出現挫折是常態，前人風範提醒葉院士在困頓時依然前行，另一個支持葉院士度過關卡的力量則是，「我是客家人，我們天生就有的『硬頸』精神，讓我可以堅持下去。」葉院士說。

在新亞書院的日子，葉院士沉浸於人文及理工並重的教育中。然而，同樣的，他並非為了分數而用功，而是因為真心喜愛學習知識，「我甚至是到了大三，才知道原來大學畢業後還有念研究所這個選擇，老師也鼓勵我出國深造。」之後葉院士於美國匹茲堡大學取得物理學碩士學位，並於美國加州大學聖地牙哥分校取得應用物理學及資訊科學博士學位。

從匹茲堡轉去聖地牙哥念博士班，葉院士至今仍記得下機後初見當地景色的震撼感受，「我是在澳門、香港長大的小孩，從沒見過棕櫚樹搖曳的景象，直覺來到一個好地方了。」到了學校，有人跑來告訴葉院士：「你們香港中文大學的蘇林官老師很誇讚你，說得好像你是天上才有的人才呀！」至此，葉院士才知道蘇老師的美言幫了自己許多忙，「我其實並不認為自己有多好，一路走來得到許多人的幫助，我覺得是自己運氣很好，我非常謝謝蘇老師，他改變了我的一生。」葉院士也想藉此提醒年輕人，「很多事情你盡力了，總有人默默看在眼裡，願意在必要時給你機會，拉你一把。」所謂的「人必自助而後人助之」，即是如此。

拜入諾貝爾獎得主門下 踏上太空物理之路

為何選擇投入太空物理領域，這又是另一段故事了。就讀博士班，葉院士急著找到經濟來源，他唯一的想法是：哪個研究室願意提供獎學金，就去哪裡。同學建議他優先去找太空物理領域，「因為在 1970 年左右，特別是在阿波羅登陸任務之後，太空物理在美國受到關注，資金想來比較充足。」幾番周折，葉院士找上諾貝爾物理學獎得主漢尼斯．阿爾文（瑞典語：Hannes Olof Gösta Alfvén），他是瑞典電漿體物理學家、天文學家，致力於磁流體動力學領域的研究。「聽完我的來意，阿爾文丟給我一本講義，要我自己回去看完後再決定。」葉院士邊回憶邊笑著說道：「我就翻了幾頁講義，有看沒有懂，再回去找他時，直接說我想進來這間研究室。」從此，葉院士投入太空物理領域。


Graduation Party at the Alfvéns in La Jolla in December 1973. From left: Diana and Wing-Huen Ip, Bibhas and Gopa De.
(Hannes Alfvén would joke to Asoka Mendis: "Between the two of my graduate students, I have a grand total of four letters in the last names!")
[*Photo: Kerstin Alfvén*]

「成為諾貝爾獎得主的學生，讓我覺得頗有壓力。」葉院士還提到另一個困擾：「阿爾文很喜歡挑戰權威，總是與一些知名學者論戰，這讓他的學生們連帶受到影響，常常被牽進這些爭鬥中。」即便如此，葉院士非常肯定這位老師的確教會學生保持思辨的能力，不要盲目相信權威，「不過，你不能質疑他的權威，要完全遵從他的指示。」葉院士戲而不謔地描述阿爾文的學術風格。

從 1980 年代開始，葉院士也深入研究小行星和彗星，這個題目在那時並不受到大家關注。「許多人不明白為什麼要投入，我自己倒是很清楚。」葉院士進一步說明：「地球上所需的有機物質，都是可能由這些小物體帶來的，研究小行星及彗星，有助我們了解生命的起源。」1978 年到 1986 年期間，除了理論工作，他亦曾參與哈雷彗星的研究計畫。

在加州大學聖地牙哥分校念完博士班及從事 3 年的博士後研究員之後，葉院士開始找尋下一份工作。只有兩個機構回應他的申請，一是中央大學大氣系，另一個是委內瑞拉某處的天文臺，「我還記得當年收到中央大學寄來的信件是用毛筆寫的，讓我印象深刻。」幾經考量，他決定前往委內瑞拉，然而，「人生的際遇真是很難預料，我沒去成委內瑞拉，倒是在 20 多年以後來到中央大學，一直到現在。」

委內瑞拉之行喊卡，是因為馬克斯普朗克高層大氣研究所（今馬克斯·普朗克太陽系研究所）前來搶人。原因是當時的一個所長便是以前在 UCSD 的阿斯福特（W. Ian Axford）教授，正在建構該所的太空探測計畫，於是葉院士前往德國，從 1978 年至 1998 年，長達 20 年。在這裡，葉院士參與卡西尼計畫、喬托號、深度撞擊號、羅塞塔號等太空探測任務，累積無數研究成果，從一個當初急著找工作的青年學者，一路榮耀加身成為行星科學領域的權威科學家。1998 年之後，葉院士從歐洲移居臺灣。

回臺任教中央大學　推動太空科技及行星科學

葉院士與臺灣的緣分始於二十世紀中期，當時他還是襁褓中的嬰兒；迎接二十一世紀之前，五十歲的葉院士決定來到臺灣。「我一直在歐美工作和求學，但是與臺灣的關係其實很深厚，因為我的妻子是臺灣人。」談起決定回到臺灣的緣由，葉院士娓娓道來：「我在德國與劉兆漢院士相識，他在臺灣積極推動太空計畫，邀請我加入，所以我一邊在德國研究，一邊提供協助。」葉院士於 1991 年至 1992 年間，接受國科會邀請，擔任行政院國家太空計畫室籌備處首席科學家，致力於臺灣第一顆科學衛星（ROCSAT-1）的任務定義及科學酬載的設計與挑選，奠立臺灣太空科技發展的基礎。

葉院士並以臺灣名義發起並籌組亞洲大洋洲地球科學學會組織（Asia-Oceania Geosciences Society， AOGS），2002 年擔任籌備委員會主席，及第一屆理事長（2004-2006）。目前 AOGS 有全球逾 54 國 11,000 名會員，與美國地球物理聯盟（American Geophysical Union， AGU）及歐洲地球科學聯盟（European Geosciences Union，EGU）三強鼎立，對提升亞洲地區相關學術地位具深遠影響力。

「劉兆漢接任中央大學校長後，又力邀我到學校任教及繼續協助推動太空計畫，再加上我的太太非常想念臺灣，當兩個女兒相繼念完中學，我們就回來重新開始了。」1998 年回到臺灣定居後，葉院士應邀擔任中央大學理學院院長，在六年任期中，憑藉其豐富的跨領域知識與協調規劃能力，成立認知神經科學所、生物物理所及生物資訊所，於天文所成立太陽系實驗室，首開臺灣行星科學研究之先河。從理學院院長到之後擔任中央大學副校長、臺灣聯合大學系統副校長，以及現任天文及太空科學 —— 國鼎講座教授，拜葉院士國

際學術聲望卓著所賜，臺灣及中央大學在天文及太空領域的國際能見度持續上升，獲得許多國際合作機會。

例如，隨著美國政府對小行星撞擊地球的風險提高關注度，夏威夷大學於 2005 年展開泛星計畫（Pan-STARRS Project）。某次，葉院士造訪夏威夷大學，並與當地天文研究所所長深入討論，進而促成中央大學參與此項國際研究。泛星計畫首先建造一套完整望遠鏡系統 （PS 1） 安裝於夏威夷茂宜島之 Haleakala 天文臺， 由美國、德國、英國與臺灣的大學及研究機構合作營運。葉院士表示：「由於臺灣位於太平洋西側，與夏威夷相對，地理位置給了我們獨特的觀測機會。」因此，葉院士積極推動中央大學的鹿林天文臺設置一臺兩米口徑的望遠鏡。此外，關於赫赫有名的歐洲太空總署 Rosetta 計畫，中央大學是亞洲唯一參與的學校。相關例子不勝枚舉，透過這些國際研究合作，葉院士不僅推進行星科學研究發展，也培育出許多臺灣年輕行星科學家。

喚醒學子的學習熱情 激發探索知識的動機

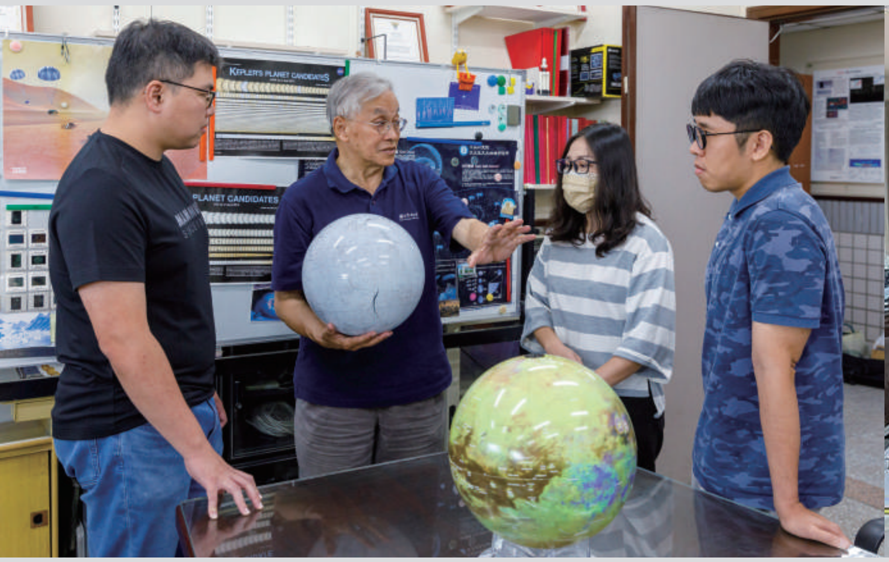
對於教育推動，葉院士始終不遺餘力，他尤其想將自己年少時期那種「發自內心對於知識的熱愛」分享給臺灣年輕世代。

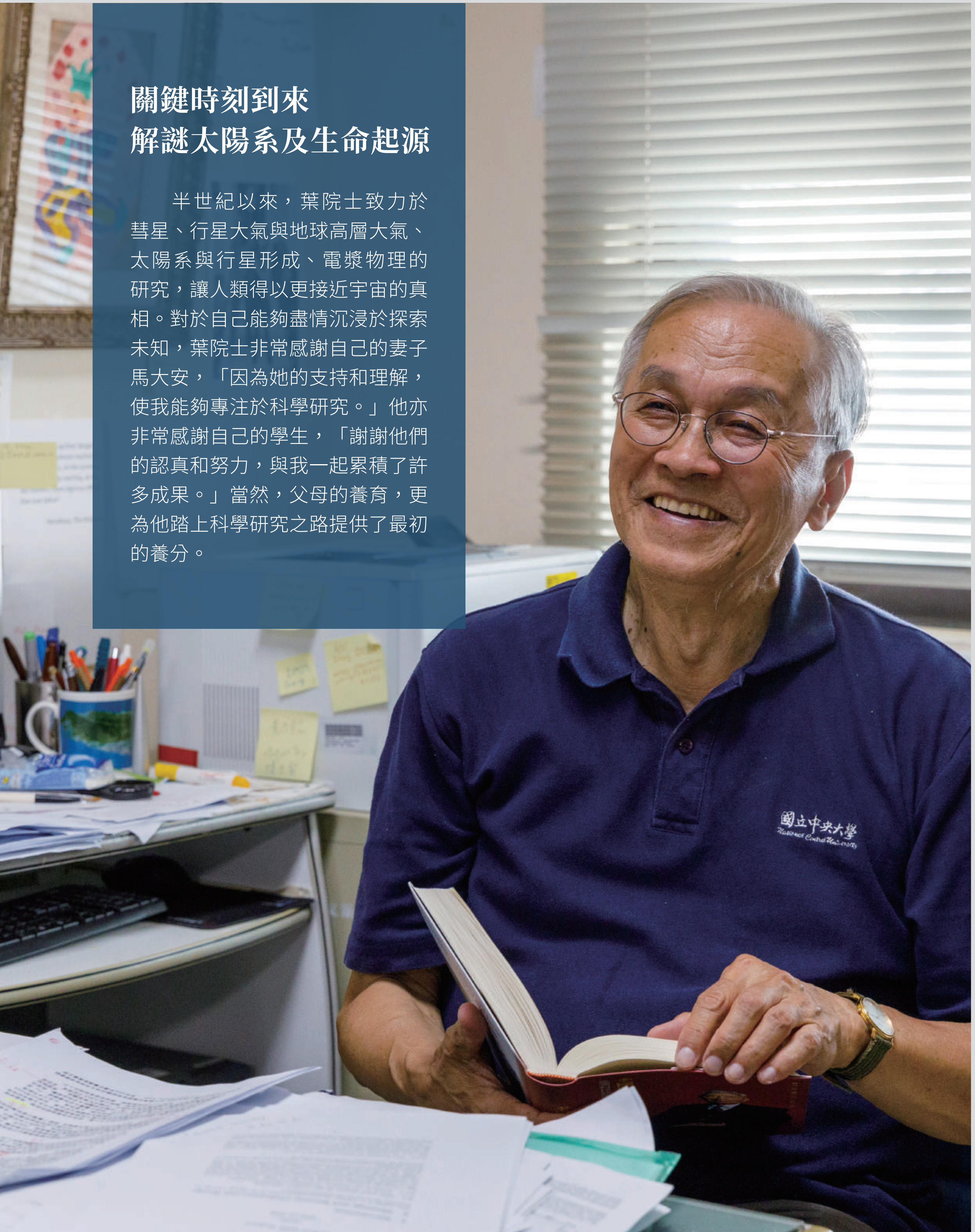
已返臺定居 20 餘年的葉院士，從國立中央大學理學院院長到現職天文及太空科學── 國鼎講座教授，無論在哪一個位置上，他始終關注臺灣學子的科學教育養成，不僅向業界募款，成功促成由中央大學與台達電子文教基金會共同設立「年輕天文學者講座」，延攬國外優秀年輕學者推動臺灣天文教育推廣，他更致力人才培育、往下紮根，投入 K-12 科學教育發掘特殊人才。K-12 教育涵蓋從幼稚園至高中的學習階段，目的是培育學生的綜合能力和協助他們從幼兒成長為成年人。此教育模式於 19 世紀末在美國興起，後由多國採納。臺灣於 2018 年開始實施 12 年國民基本教育，為學生提供更全面的教育。K-12 不僅關乎個化 K-12 教育是當前全球許多政府的重要課題。

葉院士毫不諱言對於臺灣教育現狀的擔憂：「臺灣學生面臨龐大的考試壓力，壓得他們不再是尋求知識的探索者，變成只是應付考試的機器。」他很驚訝發現有教育界人士表示臺灣學生的模仿能力是一大優勢，「就我的觀點而言，在這個日新月異的時代，僅僅模仿恐怕難以適應未來，所以這實在無法被說成是優勢！」

葉院士直言：「重複性的學習模式，是臺灣教育的問題所在，我們必須從基層做起，想辦法培養學生的興趣，喚起他們的學習動機。」有哪些方法呢？「我們在博物館總是能看到幼小孩子的眼睛閃閃發亮，充滿了對知識的好奇，這樣的經驗若能持續，會是他們未來源源不絕的學習動力，所以我們希望透過一系列活動的舉辦，創造豐富的科學體驗機會，讓學生能對科學始終懷抱好奇及熱情。」葉院士語重心長地表示：「年輕人沒有夢想，世界不可能變得更好。」此外，許多一路在試場順風順水的學生，在日後面對人生中的挫折時，常常無法好好地應對，然而科學研究成果其實就是由一次次的挫折累積而成的，因此他提醒臺灣教育必須重視養成學生面對及處理挫折的能力。

他也疾呼臺灣教育界應重視素養教育的真正精神：「素養，不僅是知識的累積，更重要的是培養思考和解決問題的能力，無論是科學或其他知識領域，皆該如此。」他並且一針見血指出現有的迷思，「培育學生具備素養，並非是以讓他們考上好大學為目標，而是要幫助他們找到一個明確的人生目標，追求卓越，並且勇於改變世界。」





關鍵時刻到來
解謎太陽系及生命起源

半世紀以來，葉院士致力於彗星、行星大氣與地球高層大氣、太陽系與行星形成、電漿物理的研究，讓人類得以更接近宇宙的真相。對於自己能夠盡情沉浸於探索未知，葉院士非常感謝自己的妻子馬大安，「因為她的支持和理解，使我能夠專注於科學研究。」他亦非常感謝自己的學生，「謝謝他們的認真和努力，與我一起累積了許多成果。」當然，父母的養育，更為他踏上科學研究之路提供了最初的養分。

科學研究是一條寂寞多於繁華的道路，然而每一次的研究進展，總是讓葉院士感到振奮，無論是當年那個初出茅廬的年輕科學家，或是如今這位德高望重的科學界耆老，對於知識的好奇及熱情從未稍退，「關於行星和天文科學的發展，我們正處於一個關鍵時刻。」葉院士進一步說明，行星科學研究行星的起源，天文學則是研究黑洞、重力波等現象，這兩者過去與地球科學的連結不多，「然而隨著人類的太空探索有了進展，甚至有可能在火星或其他星球上建立人類活動的基地，使得行星科學、天文學與地球科學的交集變多了，因為我們要瞭解生物圈、大氣層、海洋和火山等要素，這些資訊是地球科學的一部分。」葉院士興奮表示：「未來 20 年，我們將能見證對太陽系的廣泛探索，進一步尋找可能的海洋和生命的跡象。」

仰望星空，展望未來，「四百年前的天文學革命，改變了我們對宇宙的認識，而我們現在探索太陽系外行星有了進展，這些重大發現表明地球之外可能有著生命的存在，我認為在接下來的四百年，人類將能解謎宇宙的起源、太陽系的形成及生命的源起。」葉院士無限嚮往地說著。

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（任期 2022 — 2023）

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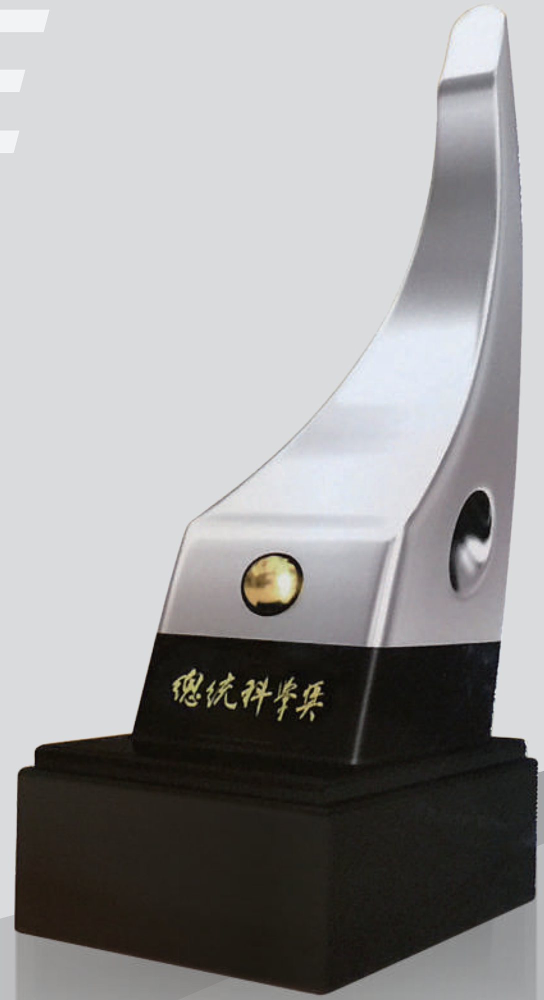


About the Award

Established in 2001 and presented every two years, this is the 12th Presidential Science Prize. This prize symbolizes in the highest academic honor to pay respect to the most outstanding scientists in the Republic of China (ROC).

To promote Taiwan's position in the international science community, the Office of the President has established the Presidential Science Prize to recognize innovative researchers who have made monumental contributions to international research in the fields of Mathematics and Physical Sciences, Life Sciences, Social Sciences, Applied Sciences, especially those scholars whose works have had major impact on the development and applications of these fields in Taiwan.

To implement the selection and award of this prize, the President of Academia Sinica has convened a steering committee of fifteen distinguished scientists and related cabinet ministers. Nominees for the Presidential Science Prize are only taken into consideration when

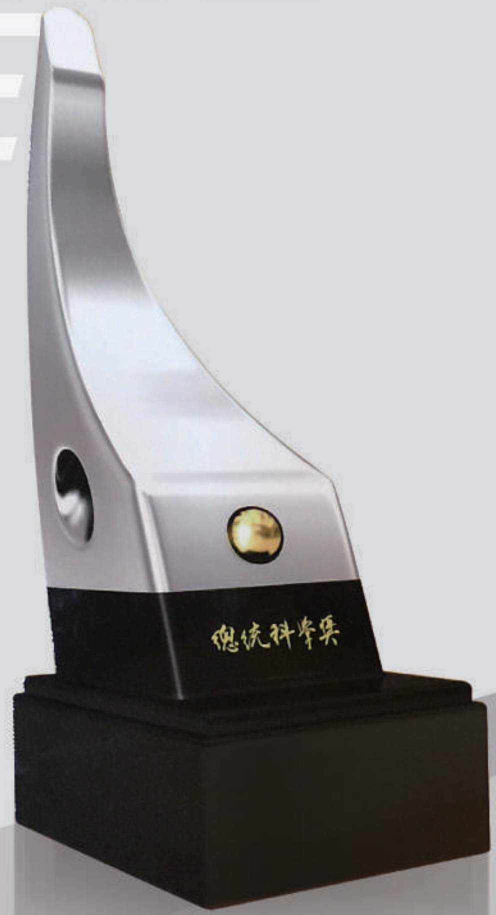
(1) they are nominated by academicians of Academia Sinica and/or Presidential Science Prize awardees;

(2) they are nominated by academic and research institutions and associations and leaders of the community invited by the Presidential Science Prize Steering Committee.

After nomination, four selection committees in the fields mentioned above perform nominee screening tasks. This year, through a careful nomination and selection process, the three awardees of this prestigious honor have been chosen as: Dr. Wen-Hsiung Li (Life Sciences), Dr. Chenming Hu (Applied Sciences), Dr. Wing-Huen Ip (Mathematics and Physical Sciences) .

Conferred by the head of state, the Presidential Science Prize gives recognition to those scientists for their long-term efforts at conducting scientific research and cultivating young researchers. This prize also aims to pay respect to outstanding scholars who have made top-notch academic achievements and to have scientific R&D fully benefit people's livelihood.

PRESIDENTIAL SCIENCE PRIZE



Life Sciences Category

Wen-Hsiung Li

50 Years in Exploring Biological Evolution using Mathematics

Developing Mathematical Methods to Solve Evolutionary Problems and Bring New Insights into Mechanisms of Evolution

Academician Wen-Hsiung Li is devoted to the study of molecular evolution. Molecular data such as DNA sequence and genomic structures and features are used in exploring the process and mechanism of biological evolution.

Molecular evolution consists of two major themes and Academician Li developed important computing tools for both. One of them is the process and mechanism of molecular evolution. The mathematical methods he developed in the 1980s and 1990s for DNA sequence comparison have been widely recognized and are among the most frequently used methods.

The other theme is the history of evolution and phylogenetic (evolutionary) relationships. In 1981, he thought of how to build the phylogenetic tree if molecular evolution does not happen at a constant speed. Therefore, taking non-constant rates in molecular evolution into consideration, he created a method to build a phylogenetic tree. Li 's approach was widely adopted in later studies; he can be said to be a pioneer in this topic.

There has been a well-known debate regarding the mechanism of evolution - which is more important? Natural selection or mutation? While the debate over "Darwinism and the hypothesis of neutral mutation" persisted, Academician Li and coauthors found in 1981 that once a gene loses its function and is dead, it is no longer subject to natural selection and nucleotide substitution is dramatically accelerated. The study showed that natural selection usually slows down, instead of expediting nucleotide substitution, supporting the hypothesis of neutral mutation. This hypothesis holds that mutation and random drift are more important than natural selection in molecular evolution.

More significantly, Academician Li's team took the lead in discovering the inverse correlation between the molecular clock and the generation length and developing corresponding statistical analysis methods. A key hypothesis in explaining DNA data in the past was that DNA sequence changes at a constant rate in evolutionary time (that is, the molecular clock). The hypothesis was often applied to estimate lineage divergence time. In the 1980s, however, Academician Li showed that the molecular clock does not run at a constant rate but is inversely related to generation time. That is, the shorter the generation time, the faster the clock. For example, Academician Li's team estimated that the clock evolves between rats and mice at a rate roughly five times that between monkeys and humans. This discovery rejected the prevailing view of a constant clock and contributed to a deeper understanding of the evolutionary process. The species divergence time can be more accurately estimated when a nonconstant clock is considered.

Academician Li applied his expertise in mathematics and statistics to make far-reaching predictions based on very limited molecular data. In 1991, for example, he predicted that the DNA diversity in humans is below 0.1% using very limited human DNA sequence data, which is considerably lower than that of fruit flies. Ten years later, abundant data proved that his prediction was correct. He also found that the DNA diversity of Africans was much higher than that of Europeans and Asians, which supported the view that modern humans originated from Africa, that is, the "Out of Africa" hypothesis.

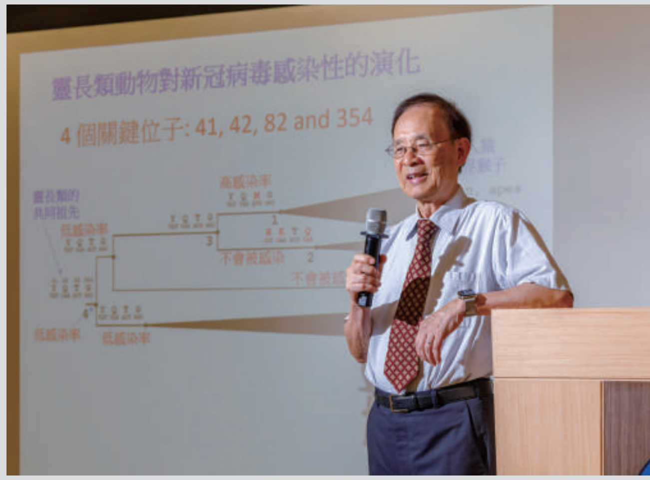
Academician Li founded a molecular biology laboratory in 1989 to facilitate a combination of theory and experimentation. In 2001, when there were very limited genomic data in chimpanzees, Academician Li's team obtained some data from chimpanzees and estimated that human and chimpanzee genomes diverged only 1.24% in terms of nucleotide substitution. This estimate was shocking because humans look very different from chimpanzees. When the chimpanzee genome was published in 2005, however, the answer was identical to his prediction.

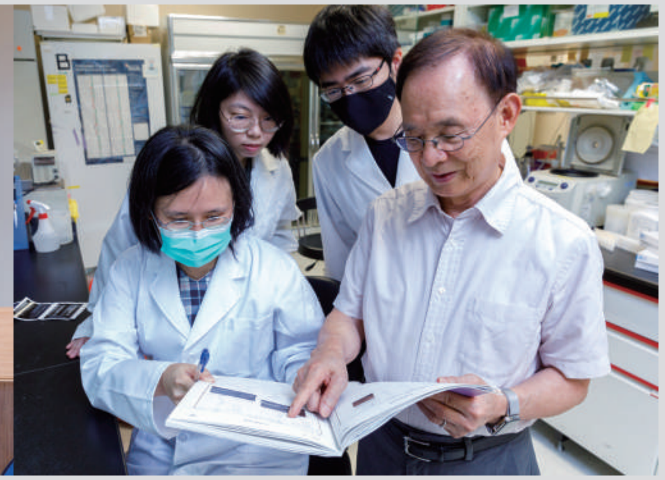
Academician Li also combined theory and experimentation and found that germ cells of opposite genders of the same species mutate at different rates, with males having a faster rate than females. This is because male germ cells undergo many more rounds of DNA replication than female germ cells. Female eggs are formed prior to birth, while male sperm is constantly dividing throughout one's life. As a result, male germ cells mutate faster. The Li lab found that this is true in both humans and rodents.

Li's team has done significant research on the evolution of viruses, too. His team has found, for example, that a flu virus often needs to combine two or more mutations in order to evade the immune system of the host to trigger a flu outbreak. In addition, if the 82nd amino acid of ACE2 (angiotensin-converting enzyme 2) of the common ancestors of humans and old world monkeys had not mutated from threonine to methionine, the spike protein of SARS-CoV-2 would have a weak binding affinity to ACE2 in humans and humans would not be easily infected, so that the COVID-19 pandemic probably would not occur or would be milder.

For nitrogen, an essential key element to life, Academician Li's team inferred that nitrogen fixation evolved in bacteria, rejecting the prevailing view that nitrogen fixation first evolved in archaea. It is another significant contribution to evolutionary research.

To sum up, the research accomplishments of Academician Li and his team has had a far-reaching influence in the fields of molecular evolution and genetics. They not only facilitated the application of the molecular clock theory but also contributed to constant innovation in new research directions regarding issues such as human evolution and virus evolution, among others.





Solving Biological Conundrums with Mathematics: A Vibrant Chronicle of Molecular Evolution Research

The Vanguard of Molecular Evolution: The First Asian Recipient of the Balzan Prize

Active at the forefront of molecular evolution research for an impressive span of five decades, Academician Wen-Hsiung Li hasbeen hailed as a living legend in the realm of molecular evolution. In 1985, he catapulted to fame by publishing a pivotal DNA sequence comparative paper in the prestigious Proceedings of the National Academy of Sciences (PNAS) of the United States of America, rejecting the mainstream view that the molecuclar clock runs at a constant rate. Subsequently, he steadily advanced from a small research lab before ultimately helming a research team of 16 postdoctoral fellows and several graduate students. To date, he has mentored over 120 postdoctoral fellows and PhD students.

Despite recognizing his mathematical aptitude, Li's academic journey took several detours until he entered the applied mathematics doctoral program at Brown University and encountered his most significant mentor in the field of genetics. He says that every path he walked in life had its reward, and choosing to apply mathematical techniques to explore and unravel biological questions was, undoubtedly, the best decision he had ever made. Li's contributions have had a profound impact on the fields of molecular evolution and genetics, not only advancing the application of molecular clock hypothesis, but also pioneering novel research directions in areas such as genetic gender differences, human evolution and virus evolution.

The Balzan Prize

On November 7, 2003, in the Federal Palace in Bern, Switzerland, the Balzan Prize, often hailed as the "Italian Nobel Prize," was awarded to four international scholars who had made outstanding contributions to sciences or humanities.

At that event, Academician Wen-Hsiung Li from the University of Chicago, who had already dedicated over 20 years to molecular evolution research in the United States, received the Genetics and Evolution Prize. He was the third evolutionary geneticist to receive this prestigious accolade since its establishment in 1978, and the first Asian scholar to do so.

Although Li humbly stated, "In the past, it was only titans in this field that have received recognition through the Genetics and Evolution Prize, so when I received the notification from the International Balzan Prize Foundation, I was truly surprised," his achievement was well-deserved, as evident from the citation provided by the Foundation.

The citation described Li's achievements as follows: "...he developed and applied mathematical techniques to solve a wide range of biological problems, becoming the most commonly used approach in the field." "...... he is the architect of evolutionary relationships inferred through DNA sequence comparisons, particularly influential in establishing the accuracy of phylogenetic tree construction and statistical confidence." "...he is also a key figure in molecular evolution education, and his works are recognized as authoritative in the field."

Recipients of the Balzan Prize
4 位得獎者合影

A Farmer's Son from Pingtung with Mathematical Talent Evident in High School Years

Academician Wen-Hsiung Li was born in 1942 into a farming family in Wandan Township, Pingtung County. He had to wake up early every day and walk three kilometers to Wandan Elementary School. In fifth grade, due to his exceptional memory, he could easily memorized the content of general knowledge courses (natural science, geography, and history). He earned the nickname "The Master of General Knowledge" and developed a passion for learning.

During junior high, he became interested in mathematics, physics, and music. Upon entering Pingtung High School, he developed a strong interest in mathematics, physics, and chemistry. Looking back, Li recalled, "My math teacher in my senior year of high school had a favorable impression of me and said that I would definitely make it to university." However, during his university years, he went through a period of exploratory and meandering learning journey.

Li gained admission to Chung Yuan Christian College of Science and Engineering (now Chung Yuan Christian University) in the Civil Engineering Department, where he thoroughly enjoyed his freshman year thanks to his excellent mathematical abilities. However, during sophomore year, he struggled with some classes, finding it challenging to adapt to the "engineering drawings" and the rote memorization required in "geology." Although he briefly considered physics, Li became somewhat apprehensive when considering subjects like thermodynamics, electromagnetism, and quantum mechanics.

Later on, he turned his attention to mathematics. With fewer required foundational subjects and a curriculum he loved, he decided to apply for the mathematics graduate program. Unfortunately, his goal of being accepted into the mathematics graduate programs at National Taiwan University and National Tsing-Hua University was not realized. He lacked the credits required for eligibility at one university, and was rejected by the other. Fortunately, he secured a place in the graduate program of Geophysics at National Central University. During his time in college, Li came to know himself better and realized that he wasn't cut out for a desk job. So, after completing his military service, he went to pursue a master's degree in National Central University.

Li said, "While studying Geophysics, I found it to be as I had anticipated – physics was indeed very challenging." He went on to say, "I often solved physics problems using mathematics. I could solve the problems, but the physical meaning wasn't always clear to me." His limited understanding of the true essence of physics during that time reinforced his belief in his interest in mathematics.

A Fortunate Encounter with a Master of Genetics– Unraveling Biological Enigmas with Mathematics

After completing his master's degree, Wen-Hsiung Li, in 1968, successfully secured admission to the doctoral program in the Division of Applied Mathematics at Brown University in the United States, embarking on his academic journey with the support of a prestigious scholarship. Reflecting upon his scholarly path, he candidly asserts that enrolling at Brown University constituted the first step toward his eventual success. Upon arriving in this intellectually liberated and open-minded academic environment, he wholeheartedly immersed himself, reveling in its boundless freedom and scholarly opportunities.

During the summer break of his second year in the doctoral program, he began searching for a topic for his doctoral dissertation. In this quest, he was lucky to cross paths with Professor Masatoshi Nei, a Japanese geneticist in the biology department. The two scholars had delightful discussions, and Professor Nei, recognizing Li's expertise in mathematics, encouraged him to delve into the realm of genetics. Li's advisor at the time, Professor Wendell Fleming, strongly supported his decision to pursue interdisciplinary research.

Within the pages of the National Central University publication, "Ten Lectures by Academicians - The Path of Exploration," Li shares his profound insights on this chapter of his journey: "When venturing into a new subject, it is paramount to find the right mentor. If you fumble around on your own, it's not easy to determine what's important, and you might not be aware of the current trends. Professor Masatoshi Nei was a pioneer in this field, so I was able to enter that field more quickly."

Under the guidance of Masatoshi Nei, Li initially tackled mathematical aspects of biological questions – first converting biological problems into mathematical ones and then solving them. As he became more involved, he gained a deeper understanding of the significant issues in biology, gradually delving into genetics.

Masatoshi Nei was a scholar known for his rigorous scholarship and agile thinking. Whenever Li had questions about genetics, Professor Nei would promptly retrieve a research paper or book and point to it, saying, "The answer to your question is here." On the other hand, when Professor Nei encountered problems requiring mathematical solutions, Li's expertise came to the fore. In this manner, the symbiotic synergy between mentor and student thrived, ultimately allowing Li to earn his PhD degree with a paper published in a prestigious journal during his fourth year.

Subsequently, he spent a year as a postdoctoral researcher at the University of Wisconsin-Madison. In 1973, he moved to the University of Texas Health Science Center at Houston (UTHealth Houston) for a faculty position, where Professor Nei had already moved to a year earlier. This reunion of teacher and student sparked a renewed collaboration, setting the stage for his illustrious 50-year career in the study of genetic evolution.

獲 PhD 時與 Host family 合照

兩位女兒與指導教授 Fleming 合照

Pursuing DNA Sequence Evolution with Key Publications

Between 1973 and 1998, Academician Wen-Hsiung Li's research in evolutionary genetics at UTHealth Houston marked the first golden era of his academic career.

However, during the initial seven years, he operated a "one-man show," being the sole occupant of his research laboratory. Given the theoretical nature of his work, with no need for experiment, he could freely unleash his imagination. Each year, he published no fewer than 3 papers, gradually amassing a reputation within the academic community.

Molecular evolution emerged as a distinct field that sprouted from genetics and molecular biology. Genetic information in organisms is stored in DNA molecules, and genes are functional segments of DNA that guide protein synthesis, thereby influencing the characteristics and behaviors of organisms. Molecular evolution research focuses on genetic variations that occur in organisms over time. By comparing genetic information such as DNA and proteins, it reveals the relationships between species and their evolutionary processes.

In the process of studying molecular evolution, mathematical and statistical methods play a crucial role. Evolutionary study involves not only changes in gene sequences but also complex statistical processes. Through mathematical models and statistical analyses, the frequency and distribution of genetic variations can be quantitatively assessed, thereby revealing patterns and trends in these variations. Mathematical methods help construct evolutionary trees that reflect the relationships between different species and provide a deeper understanding of the evolutionary process.

However, when Li first embarked on evolution research, the scientific community faced several unfavorable research conditions. For example, in the 1960s and 1970s, pioneering scientists such as Motoo Kimura and Allan Wilson primarily analyzed protein sequences to delve into the evolution of organisms. However, the process of protein sequencing was time-consuming and costly. It wasn't until 1977, when Fred Sanger introduced DNA sequencing, that researchers began to overcome the time and cost barriers associated with gene sequencing, resulting in a rapid proliferation of DNA data.

At this point, Li realized that the time was ripe and wholeheartedly transitioned into the evolution of DNA sequences. During that era, there were only two laboratories worldwide exclusively dedicated to the analysis of DNA sequence evolution, one under Li's leadership. He explained, "Because I possessed a foundation in population genetics theory and mathematical skills, enabling the analysis of DNA sequence data, I was able to advance more swiftly than others."

1985 was a pivotal year in Li's career. In the esteemed pages of the Proceedings of the National Academy of Sciences (PNAS), he published a groundbreaking paper that challenged the prevailing contemporary view. Through comparative analysis of mammalian DNA sequence data, he estimated that the molecular clock of rodents ticks at least twice as fast as that of humans. Two years later, he continued his work by publishing a discovery in the journal "Nature" that the molecular clock of monkeys runs faster than that of humans. Li's years of research on the molecular clock established him as an authoritative figure in this field.

Profound Contributions to Taxonomy through Elaborate Phylogenetic Tree Construction

According to an interview with Academician Li by the science communication media "Research with Substance" at Academia Sinica, before the rise of molecular evolution, the relationships between different organisms were constructed based on the degree of morphological similarity. However, the availability of morphological data was severely limited. Comparing biological DNA or protein data allowed for a more detailed clarification of the relationships between species. In the realms of phylogenetic tree construction and statistical assessment methods, Li made significant contributions to the field of taxonomy.

For example, early evolutionary biologists would compare the beak characteristics of a group of birds. If the differences in the morphology of two bird beaks were small, it indicated a close evolutionary relationship. On the other hand, molecular evolutionists finely clarified these relationships by comparing the DNA or protein sequence differences among these bird species.

Genetic codes are each composed of three nucleotides, forming a codon corresponding to one amino acid (the building blocks of proteins). However, there are four possible nucleotides (A, T, C, G), which can form 64 codons. Yet, there are only 20 amino acids, which means that some amino acids can be coded for by multiple codons.

When changing nucleotides in codons, two different results may occur: those that do not affect the amino acid are called "synonymous mutations," and those that change the amino acid are called "non-synonymous mutations." By comparing the variations and retentions of DNA and amino acid sequences, we can roughly understand the influence of natural selection on gene evolution, which is the process of favoring or eliminating mutations.

Molecular evolution research focuses more on the micro-level, treating the positions of DNA or amino acids as expressions of morphology. This approach provides more data on comparative features and is easier to compute. Since molecular data are relatively easy to obtain, and there are diverse analytical methods available, having multiple lines of evidence is crucial when exploring phylogenetic relationships.

Non-constant Molecular Clocks and Genetics of Gender Differences in Species

One of Li's significant contributions is the application of mathematical methods to the study of "molecular clocks" for practical analysis in the field of biological evolution.

In the past, the concept of a molecular clock suggests that the evolutionary rate of DNA sequences progresses constantly. When this assumption holds true, the differences in DNA sequences between two species can be used to estimate the time of their divergence. In other words, the extent of molecular variation is used to calculate the separation time between two species. This assumption is based on the idea that genetic sequences accumulate new changes through mutations, and the number of substitutions is proportional to the number of generations. For example, if there are 5 substitutions per generation, there would be 50 changes after 10 generations.

However, this assumption contradicts the traditional Darwinian concept of natural selection, implying that most mutations do not affect selection and have a neutral impact on survival and competition. This is known as the "neutral theory of evolution," proposed by Li's mentor, Masatoshi Nei, and his predecessor, Motoo Kimura.

Kimura argued that most genetic variations in organisms are not driven by natural selection; instead, genetic diversity among individuals mostly results from random changes. While this idea initially sparked big controversy, it gradually gained widespread acceptance after multiple revisions and supplements. Genetic variations at the molecular level often do not affect natural selection, and new mutations replacing old genetic information are often a matter of chance for individuals.

This neutral evolution theory provided the theoretical foundation for the molecular clock and led to several breakthroughs. However, in the 1980s, Li used DNA sequences to challenge the constancy of the molecular clock. He discovered that the rate of substitutions for new changes was not constant.

Li confirmed that the molecular clock's rate is inversely related to the length of generations, with shorter generations leading to faster clocks. For example, rodents like rats and mice have much shorter generations than humans, and their evolutionary rates are approximately five times faster than the divergence rate between humans and apes. This discovery greatly improved the accuracy of estimating the time when two species diverged.

Taking into account the influence of generation length on the molecular clock, Li, in the early 2000s, guided his doctoral student, Feng-Chi Chen (now a researcher at the National Health Research Institutes), in estimating the separation of humans and chimpanzees to be between 6 and 7 million years ago by comparing non-coding DNA sequences.

Furthermore, Li also found that the mutation rate of male and female reproductive cells differs between genders within the same species, with males undergoing at a faster rate. This is due to differences in the number of divisions and DNA replications of male and female reproductive cells. Female eggs are formed before birth, while male sperm continue replicating throughout a male's lifetime, resulting in a faster mutation rate in male reproductive cells.

Soaring Reputation, Collaborations, and Leadership in Top Laboratories

Following the publication of papers in prestigious journals, Li's reputation continued to grow, leading to an increasing number of collaboration requests for molecular data analysis. Also, he realized that a theoretical research laboratory alone was no longer sufficient.

In 1989, he established a molecular biology laboratory at the University of Texas, but the funding provided by the university quickly proved inadequate. He applied for funding from the National Institutes of Health (NIH), the primary federal agency for biomedical research in the United States. The review committee at the time had doubts about Li's ability to conduct experiments and gather data despite his expertise in theoretical research. Fortunately, the director of the NIH had introduced a new funding that allowed innovative projects to receive some preliminary data as proof of feasibility. This enabled Li to obtain the necessary data and convince the review committee, securing an approval for his proposal.

Around the same time, Li also crossed paths with Professor Larry Chan from Hong Kong, who was skilled in experimentalist and sought Li's expertise in data analysis. Consequently, the two complemented each other—Professor Chan assisted Li in training postdoctoral researchers in experimental techniques, while Li helped Professor Chan in data analysis.

In this manner, Li continued to make significant strides. From a single-person research laboratory 16 years ago, he expanded exponentially. The laboratory under his leadership once housed up to 16 postdoctoral researchers, making it one of the largest in its field.

Although Li humbly admitted to not conducting experiments himself, he possessed a keen eye for nurturing talented technical researchers. For example, after returning to Taiwan in 2008, he established the Next-Generation High-Throughput Sequencing Center at the Academia Sinica (now in its third generation). There, he recognized the molecular biology skills of Mei-Yeh Lu, who was a postdoctoral researcher at that time. She subsequently developed core HTS DNA sequencing services for both internal and external users. Shortly after, Lu was promoted to research specialist.

"Research specialist Mei-Yeh Lu has a background in plant molecular biology and yeast genetics. Her talent lies in understanding the needs of users based on their project proposals—she can tell you what kind of molecular data is suitable, how to optimize experiments, and how much data is needed. With her guidance, every user's requirements are now customized, creating an unprecedented service model which is rare in academia." Li is very enthusiastic about mentoring and promoting exceptional colleagues.

Invitation from the University of Chicago and Balzan Prize

Leveraging his mathematical and statistical analysis expertise, Li provided forward-thinking insights into various challenging problems in evolutionary biology. Many years later, as data became more comprehensive, numerous research advancements would attest to his foresight and accuracy in his predictions.

For instance, in 1991, based on limited human DNA sequence data, Li estimated that human DNA diversity was less than 0.1%, significantly lower than that of fruit flies. A decade later, a wealth of data confirmed the accuracy of his initial estimate. In 2001, when the genome data of chimpanzees were very limited, he also estimated that the genomic sequence difference between humans and chimpanzees was only 1.24%. This estimate was startling because humans and chimpanzees appear very different. However, when the chimpanzee genome was published in 2005, the answer was exactly the same as Li's earlier estimate.

In 1998, Li's remarkable accomplishments led to a prestigious invitation from the University of Chicago, where he made a career transition to join the Department of Ecology and Evolution in the university. For the first five years, he held the "George Beadle" Professorship. Then, after receiving the Balzan Prize, the University of Chicago established the James D. Watson Professorship in his honor. Watson is a renowned Nobel laureate. (Note: G. Beadle was also a Nobel laureate and served as the President of the University of Chicago in the 1960s).

The period from 2003 to 2009 was a harvesting season for Li's academic achievements. He was successively elected as a member of the National Academy of Sciences in the United States (2003), an Outstanding Alumnus of Chung Yuan Christian University (2005), an Outstanding Alumnus of National Central University (2006), a Fellow of The World Academy of Sciences (2009). He received numerous prestigious awards, including the Balzan Prize (2003), the Horace Mann Medal from Brown University (2004), the Chen Award from the Human Genome Organization (HUGO) (2008), and the Mendel Medal from the Genetics Society (2009) in the United Kingdom, which is a prestigious honor in the field of genetics and evolution.

Looking back on his long journey in the field of genetics and molecular evolution in the United States as an Asian, Li thinks that breaking through barriers related to language and culture is not solely achieved through effort. He considers these invisible walls inevitable but has focused on establishing his research prowess. It's rare for him to encounter situations where his papers were not accepted for publication.

"In our field, I haven't felt significant differential treatment. Of course, foreigners may not be as readily recognized as Americans," Li remarked with a smile. Throughout his life, he has had no enemies and has encountered very little hostility from others. His election as the President of the "Society for Molecular Biology and Evolution," which is the largest society in the field, in 2000 reflects his amicable and harmonious nature.

與指導教授 Dr. Nei 於美國國家科學院合影 (2004) 合照

Returning to Taiwan: Nurturing Future Generations and Providing a Stage for Young Scholars

Thirty years after leaving Taiwan, Li felt the calling to return and nurture the next generation of scientists. He took a gradual approach, initially serving as a visiting scholar at the Genomics Research Center of Academia Sinica. Later, he served as co-chair of the Scientific Advisory Board of the newly established Biodiversity Research Center of Academia Sinica. In 2008, Li returned to Taiwan and assumed the role of director at the Biodiversity Research Center.

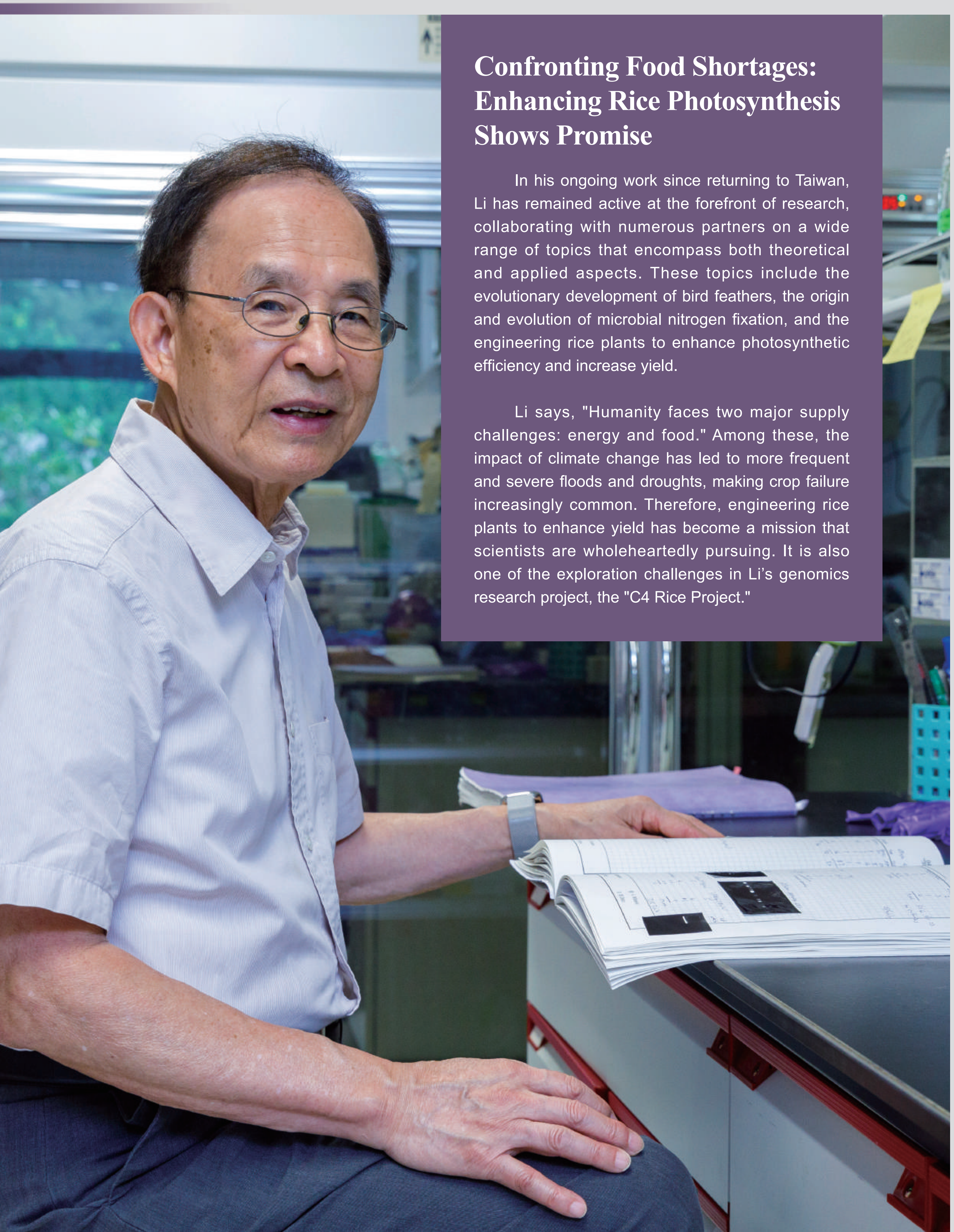
During his eight-year tenure as director of the Biodiversity Research Center (2008-2016), Li not only focused on research but also remained true to his mission of cultivating young talent. He hired many young PIs. Also, he initiated doctoral degree programs and actively provided young researchers with platforms for showcasing their work, creating a channel for idea exchange in the fields of evolution and bioinformatics.

Due to Academia Sinica's long-standing collaboration with many national research universities in jointly conducting the Ph.D. program (TIGP), and considering Li's extensive experience in leading advanced laboratories, he had a deep understanding of the need to nurture innovative research talents. Therefore, after returning to Taiwan, he collaborated with National Taiwan Normal University to establish the "Taiwan International Graduate Program" in biodiversity. Since its inception in 2012, the program has provided a research environment conducted entirely in English, catering to young researchers from Taiwan and around the world. It has become an important incubator for talents in the field of biodiversity.

If there's no stage, then build one yourself. Having noticed the scarcity of scholars in the field of evolutionary research and the lack of platforms for academic exchange upon his return to Taiwan, Li took the initiative to establish the "Taiwan Society of Evolution and Computational Biology." He personally served as the chairman for two terms, fostering interactions among talents in the fields of evolution and bioinformatics while providing a stage for young researchers to practice and present their work.

According to a report by "Research with Substance," the society has continued to grow based on the foundation laid by Li. It not only organizes international conferences annually, inviting overseas scholars to participate, but also arranges speaking slots for young scholars. The society also has dedicated oral and poster competitions for doctoral students and postdoctoral researchers. Moreover, the conference venues are spread across Taiwan, catering to researchers from different regions.

Li has always encouraged researchers to participate in seminars and become involved in social activities. He reminds them that, "Acquiring new knowledge is crucial for researchers, and participating in such events, listening to others, and engaging in exchanges are valuable opportunities. They not only help increase one's knowledge but can also lead to assistance from others and benefiting one's own research."



Confronting Food Shortages: Enhancing Rice Photosynthesis Shows Promise

In his ongoing work since returning to Taiwan, Li has remained active at the forefront of research, collaborating with numerous partners on a wide range of topics that encompass both theoretical and applied aspects. These topics include the evolutionary development of bird feathers, the origin and evolution of microbial nitrogen fixation, and the engineering rice plants to enhance photosynthetic efficiency and increase yield.

Li says, "Humanity faces two major supply challenges: energy and food." Among these, the impact of climate change has led to more frequent and severe floods and droughts, making crop failure increasingly common. Therefore, engineering rice plants to enhance yield has become a mission that scientists are wholeheartedly pursuing. It is also one of the exploration challenges in Li's genomics research project, the "C4 Rice Project."

In simple terms, this project aims to use genomics and molecular biology techniques to convert rice from its current C3 type to C4 type, resulting in higher yields.

Photosynthesis, the process by which plants convert carbon dioxide and water into carbohydrates using sunlight, is how plants generate energy. There are two types of photosynthesis: C3 and C4. C3 plants, such as rice and wheat, produce three-carbon compounds. In contrast, C4 plants, like corn and sugarcane, convert these into four-carbon compounds. C4 photosynthesis has a higher efficiency and significantly higher crop yields.

"Rice is one of the staple foods for over half of the world's population. Unfortunately, rice is a C3 plant, and the current challenge lies in how to convert it into a C4 plant," Li states. To tackle this challenge, Li collaborated with Professor Maurice Ku, who had over 40 years of experience researching photosynthesis in the United States (then back to National Chiayi University in Taiwan). They guided Dr. Chi-Fa Huang in studying the role of whole-genome duplication in the evolution of C4 photosynthesis. This research was published in the prestigious journal "Molecular Biology and Evolution." Li combined experiments and bioinformatics analysis to study transcription factors and gene regulation binding sites in C3 and C4 plants, establishing a model for bioinformatics analysis and an important database. These findings were published in Plant Physiology and PNAS.

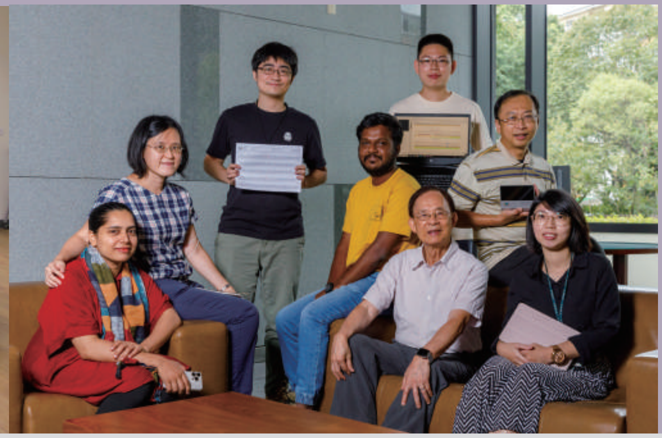
According to "Ten Lectures by Academicians - The Path of Exploration," as of 2021, the improved varieties from the C4 Rice Project could produce more rice grains per plant than wild varieties. However, the grains were smaller, and further improvement is needed. Li says that with the latest new varieties, the rice grains are already larger than those of the wild varieties, and the yield increased by 26%!

"This photosynthesis process involves highly complex biology, much more intricate than we might imagine," says Li. However, he believes that utilizing modern scientific knowledge and technology can solve the challenging problems humanity faces today. He emphasizes that with persistence, success is achievable. "Once we succeed, it may very well usher in a second green revolution because similar techniques can be applied to other crops."

Additionally, Li and his research team have made discoveries related to the global issue of the COVID-19 virus, which has been wreaking havoc worldwide for over three years. They explored the evolution of the ACE2 receptor protein, which interacts with the spike protein of the novel coronavirus, in primates. They found that Old World monkeys (macaques, gorillas, and baboons) are as susceptible to the novel coronavirus as humans, while New World monkeys (such as squirrel monkeys and golden lion tamarins) show strong resistance to the virus. This research was also published in "Molecular Biology and Evolution" in 2021.

Li explains, "If the ACE2 receptor, which the novel coronavirus uses to infect hosts, in the common ancestor of humans and Old World monkeys hadn't mutated to bind more readily to the spike protein, perhaps the COVID-19 pandemic would not have occurred, or would not have been as widespread and severe."

Glad to See Successors and Eager to Explore New Challenges



Reflecting on his journey of nurturing young talents, Li expresses, "It's gratifying to see that there are successors."

To date, he has mentored over 30 doctoral students and more than 90 postdoctoral researchers, with the majority being in the United States, followed by Taiwan, and others spread across Europe, Japan, South Korea, India, and Southeast Asia. Many of these individuals have achieved significant success in the academic world, with some holding endowed professorships or leading research centers. Whether they delve deeper into research, expand it, or pioneer new areas, Li is delighted to see the legacy continues.

As time has passed, Li has remained at the forefront of genetic and evolutionary research for over 50 years. He is well aware of how the field of molecular evolution has evolved, particularly from the perspective of researchers. In a report by "Research with Substance," Li shares his observations.

"In the past, it was easy to find important topics, but data acquisition was slow. With the advancements in molecular biology and information science technologies, it's now easier to obtain vast amounts of data. More data means it's easier to find topics, write papers, and the content is richer." However, it's also a fact that the paper standards have become higher. Fresh topics aren't easy to find, and many topics are extensions of old ones, which means the less chance of getting a big break.

Nevertheless, from Li's perspective, there have always been fresh topics to explore. For example, the divergence in DNA between humans and chimpanzees is only 1.2%, but the differences between them, apart from non-coding regions, also include many areas related to different gene regulation, especially in brain development. In the past, this was nearly an impossible topic to explore, but now, while challenging, there is hope for resolution.

Newcomers to the field today not only need a greater knowledge base than Li did in the early days, but also a willingness to pursue interdisciplinary research. In response to this, Li offers a practical piece of advice: Identify your interests and talent to plan your learning and subject selection effectively. "For instance, even though I couldn't do experiments, I established a molecular biology laboratory to address biological questions I was interested in. This allowed me to collect a lot of experimental data and subsequently solve many challenging evolutionary problems."

Continuous Exercise and a Love for Reading to Remain Connected to the World

In 2023, at the age of 80, Li was awarded the "Presidential Science Prize." When speaking of his family life, he wears a warm smile and acknowledges how fortunate he is to have married a wonderful wife and raised three children. His wife's profession is in accounting and statistics, and she worked in the Comptroller's Office for many years at Rice University in Houston, Texas, until she retired when they moved to the University of Chicago.

Exercise and reading are habits that have kept Dr. Li physically and mentally fit. "Every morning, I do some stretching exercises and go for a walk. I used to go to gym every day. Now, in the afternoon or evening, I spend about 20 minutes cycling at home to maintain a heart rate around 130. At our age, it is important to keep the heart pumping. During weekends, we often go trail hiking."

As for reading, he was inspired by his English teacher in college to learn English through reading simplified versions of English classic novels, rather than just memorizing vocabulary and grammar rules. He also loves reading various newspapers and magazines, absorbing information while improving his English. Currently, he subscribes to The Economist and The New York Times.

During the interview, his computer screen displayed the English webpage of "The New York Times." Listening to this tireless scientist sharing the in-depth articles he reads and then delving into discussions about international affairs, we couldn't help but be inspired. Li, with his remarkable 50-year history in molecular evolution, serves as a reminder of the importance of maintaining curiosity and a lifelong commitment to exploring the world.

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3. Wu CI and Li WH* (1985) Evidence for higher rates of nucleotide substitution in rodents than in man. Proc Natl Acad Sci U S A 1985 Mar;82(6):1741-5

4. Li, W.H.* and M. Tanimura (1987) The molecular clock runs more slowly in man than in apes and monkeys. Nature 326:93-96.

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6. Shyue, S.-K., D. Hewett-Emmett, H. G. Sperling, D.M. Hunt, J.K. Bowmaker, J.D. Mollon and W.H. Li* (1995) Adaptive evolution of colour vision genes in higher primates. Science 269:1265-1267

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8. Gu, Z., L. M. Steinmetz, X. Gu, C. Scharfe, R. W. Davis, and W.H. Li* (2003) Role of duplicate genes in genetic robustness against null mutations. Nature 421:63-66.

9. Tan, Y., A. D. Yoder, N. Yamashita and WH Li* (2005) Evidence from opsin genes rejects nocturnality in ancestral primates. Proc. Natl. Acad. Sci. USA. 102: 14712-14716.

10. Bhattacharjee MJ, Lin JJ, Chang CY, Chiou YT, Li TN, Tai CW, Shiu TF, Chen CA, Chou CY, Chakraborty P, Tseng YY, Wang L HC, Li WH* (2021) Identifying primate ACE2 variants that confer resistance to SARS-CoV-2. Mol Biol Evol. 38:2715-2731.

Applied Sciences Catgory

Chenming Hu

A Key Figure in the Advancement of Taiwan's Semiconductor Industry

Breaking Through Transistor Bottlenecks to Extend Moore's Law

Taiwan's semiconductor manufacturing industry leads the world, and the contributions of Academician Chenming Hu to technology research and development cannot be overstated. Academician Hu, who previously served as the inaugural Chief Technology Officer of TSMC (Taiwan Semiconductor Manufacturing Company), also devoted an extensive period to teaching at the University of California, Berkeley. Under his leadership, his research team pioneered the development of the "FinFET" in the late 1990s, a groundbreaking innovation that successfully resolved the issues of chip overheating and miniaturization—challenges that even Intel struggled to conquer at the time. This significant advancement enabled Moore's Law to continue.

According to Hu, the key to their breakthrough was hard work, thinking deeply before solving a problem, and having innovative ideas. They then proposed two different approaches while maintaining confidence that they would find a solution. Both approaches succeeded.

Breaking away from conventional thinking, Hu revolutionized the 50-year-old planar transistor design by transitioning it into a three-dimensional structure, thereby allowing significant augmentation of transistor density. This involved an etching process to create vertical, thin, fin-like crystals, endowing FinFET with the capacity to combine high-speed performance with low power consumption. In 2001, Hu returned to Taiwan, where he pioneered the development of FinFET technology. Under his leadership, TSMC's research and development team published record breaking FinFET prototypes every year, surpassing international semiconductor giants like Intel and Samsung Electronics, establishing a foundation for Taiwan's future ascent to prominent position in the semiconductor industry.

After Intel took the lead in using FinFET technology in 2011, TSMC and Samsung followed suit. Today, electronic products such as the internet, computers, and smartphones rely on FinFET chips. Academician Hu transformed laboratory research into commercially valuable cutting-edge technology, significantly improving the quality of human life.

In recognition of his innovative contributions to the world, Academician Hu received the "National Medal of Technology and Innovation" from former U. S. President Barack Obama. In 2020, he was awarded the highest honor, the "IEEE Medal of Honor" by the Institute of Electrical and Electronics Engineers, and was hailed a "microelectronics visionary."

He has dedicated his life to education, research, and cultivating talents. Hu authored five semiconductor textbooks, published over 1,000 research papers, and received 150 U. S. patents. He earned many educational awards such as the IEEE Education Award, SRC Aristotle Award, and Berkeley Distinguished Teaching Award.

Over the past forty years, Hu nurtured many outstanding talents who excelled in their respective industries. He encouraged young people to cultivate problem-solving skills and focused on research aimed at addressing real-world problems. He developed the BSIM software 30 years ago, an international standard transistor model, and has been continuously updating it and providing it royalty free for the semiconductor industry to design chips with cumulative value of a trillion US dollars.

Despite living abroad for many years, Hu tirelessly worked to advance Taiwan's semiconductor technology and nurture research talents. He contributed to the "Submicron Project" steering committee, which established Taiwan's first 8-inch wafer laboratory, provided long-term guidance to the National Nano Device Laboratory (NDL) of Taiwan's National Applied Research Laboratories, and assisted in leading collaborative project between the University of California and National Chiao Tung University. He advocated that industries are created by businesses, and governments should draw upon limited education resources to provide human resources to support the continued growth of the competitive information and electronics technology industries. He promoted a collaborative model in which "government provides the funding, industry identifies the challenges, and academia searches for the solutions and cultivates the talents that industries need through this process."

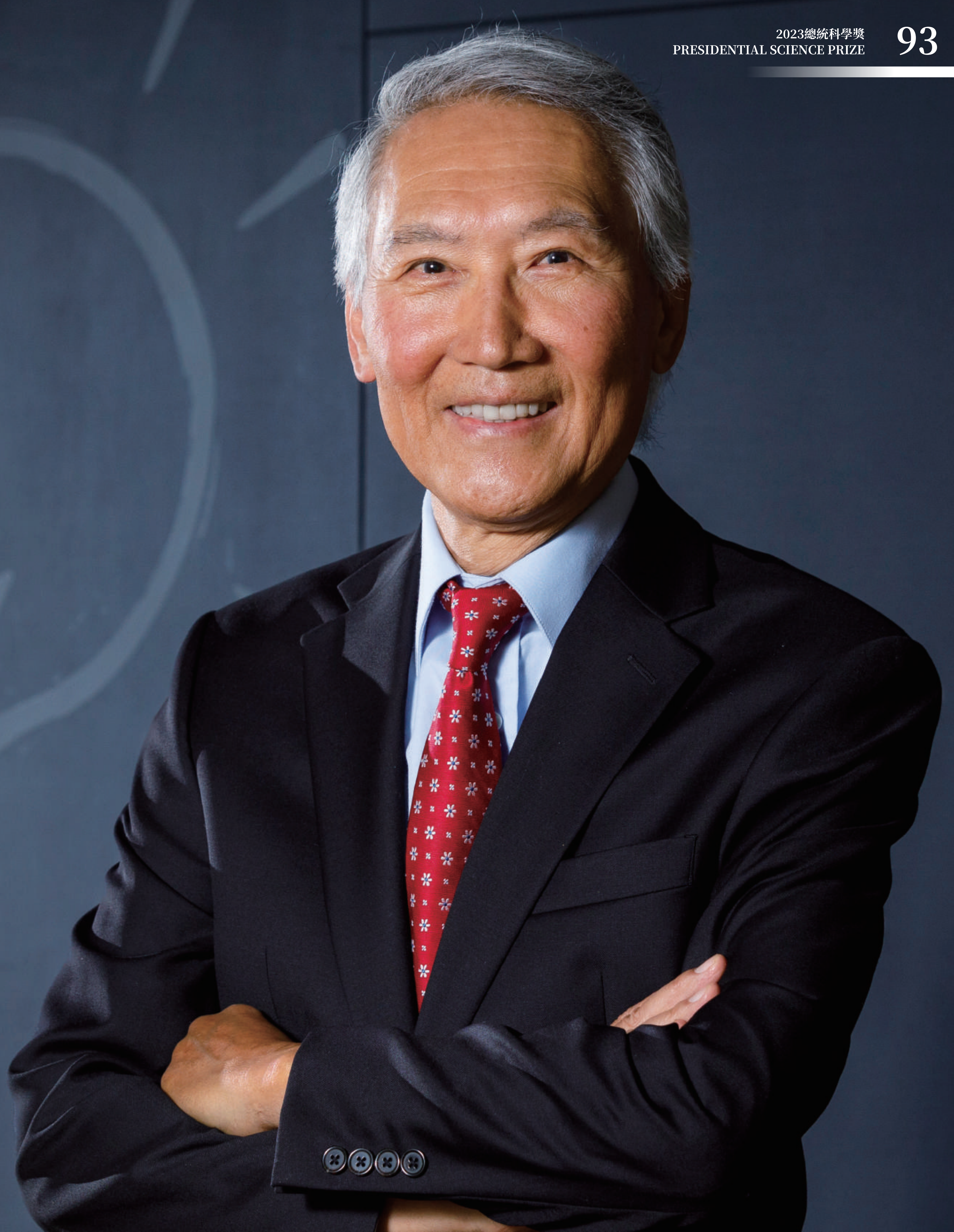
Academician Hu's scientific research achievements have made a profound impact on Taiwan's academic and industrial sectors. What is even more commendable is that, after retiring from the University of California, he assumed the role of Chair Professor at National Yang Ming Chiao Tung University in 2017. He continued to dedicate his lifetime of knowledge to giving back to his homeland and strengthening the nation's industrial capabilities.

Inventor of FinFET – Overcoming the Limits Of Semiconductors

Advancing Cutting-Edge Technology Research and Assisting Taiwan's Semiconductor Industry

Academician Hu, who grew up and was educated in Taiwan, came into contact with semiconductors in his senior year in college, and turned it into his lifelong passion. He invented the "FinFET" transistor, which successfully addressed the challenges of chip overheating and miniaturization, enabling the production of smaller and more efficient chips. Today's smartphones, the internet, artificial intelligence, etc. all use FinFET chips, which have a huge impact on human life.

Despite his long tenure as a professor at the University of California, Berkeley, Hu remained connected to his homeland. In 2001, he made a resolute decision to return to Taiwan and joined TSMC as its first Chief Technology Officer. During this period, he led his team to publish numerous advanced FinFET prototypes and patents, establishing TSMC's leading position in the international semiconductor industry. He is not only a leading figure in technology research but also an essential member of the academic community. He collaborated closely with Taiwan's industry and academia to enhance the country's research capabilities and international academic standing. He also participated in various national programs, and was a driving force behind Taiwan's semiconductor industry's innovative development.



胡正明院士後排右邊第二，
站在椅子上

Hu was born in Beijing in 1947. He relocated to Taiwan with his family during the war. In 1968, he graduated from National Taiwan University with a degree in electrical engineering. Subsequently, he pursued further studies in the United States, specializing in semiconductor technology.

Hu mentioned that his initial choice to enter the semiconductor field was somewhat serendipitous. During his senior year in college, the school invited Dr. Fang Fu, who was working at IBM in the United States and conducting research in semiconductor physics and devices, to serve as a visiting professor for a semester, during which he taught an introductory semiconductor course. Prior to this, there was no semiconductor course on campus. "I remember a professor lamenting that it took him decades to finally understand the 'vacuum tube,' and now there is something called a 'transistor' that seems even harder to figure out." said Hu with a smile.

Hu's curiosity and good performance in the course drew encouragement and praise from Dr. Fang. Consequently, when applying for scholarships to American universities, he decided to focus on the field of semiconductors. In 1970 and 1973, Hu earned his master's and doctoral degrees in electrical and computer engineering from the University of California, Berkeley. After graduating, he became an assistant professor at the Massachusetts Institute of Technology (MIT) and later returned to his alma mater, the University of California, Berkeley, in 1976, where he served until his retirement in 2010. He cultivated countless outstanding talents during this period and won the "Berkeley Distinguished Teaching Award" from the University of California, Berkeley for his exceptional teaching methods.

Forty Years of Teaching at Berkeley, Abundant Achievements in Research Papers and Patents

Throughout his four-decade career, Academician Hu authored five semiconductor textbooks, published over 1,000 research papers, and secured 150 U. S. patents. His dedication to education earned him prestigious awards such as the IEEE Education Award, the SRC Aristotle Award, and the Berkeley Distinguished Teaching Award. His contributions to the industry were equally profound. Notably, the transistor computer model series he developed, known as the BSIM series, was selected as the international standard in 1996, serves as a communication tool between the manufacturing sector and the computer-based chip design sector of the semiconductor industry.

He generously made his software models, and continues to release new versions annually. This contribution has been used to design integrated circuits with over a trillion dollars in value for the semiconductor chip industry.

Among his extensive research achievements, his successful development of the "FinFET transistor" in 1999 garnered the most attention. Hu shared his original motivation for undertaking the research, saying, "I am a person who enjoys problem-solving. Conducting research is all about addressing real-world problems, and I take great pleasure in tackling these difficult challenges."

At the time, the biggest challenge faced by the semiconductor industry was excessive energy consumption that led to high chip temperatures. Intel's Chief Technology Officer issued a public warning, stating that "in the near future, the heat generated per unit area by semiconductor chips may surpass that of a nuclear reactor core." The reason was that transistor miniaturization had reached its physical limits, causing industry-wide panic with no apparent solutions. This prompted Hu to boldly venture in this direction.

Research funding is an essential component that enables scientific research to proceed. Academician Hu's research project obtained research funding from the "Defense Advanced Research Projects Agency (DARPA)" of the United States. At the same time, IBM and the United States Air Force Research Laboratory also received research funding. DARPA is an agency under the jurisdiction of the U. S. Department of Defense, responsible for developing advanced technologies. They have a long history of funding disruptive technology breakthroughs, including projects such as computer networks (Internet) and NLS (the first hypertext system).

Be bold in trying to solve difficult problems addressing real needs

In 1999, Hu and his research team developed the FinFET, which received a U. S. patent in 2000. He would go on to transform the traditional planar transistors, used for 50 years, into a three-dimensional structure, overcoming the physical limits of semiconductors. This innovation allowed for increased transistor density while raising speed and lowering power consumption. Hu candidly expressed, "The time spent in acquiring knowledge and skills far exceeded the time dedicated to actual problem-solving. It took less than three years from receiving the funding to complete our research. The success can be attributed to having the right skills and opportunity and the collective effort of our team."

Academician Hu shared two factors that enabled him to perceive innovative directions that had escaped others' attention. "Firstly, it involves putting in hard work and thoroughly understand the subject matter. Sometimes, we need to provide alternative explanations or ask alternative questions instead of just following the herd. This allows us to generate fresh ideas while exploring all possible solutions in our minds. Secondly, it requires self-confidence, which allows us to take on challenges that even large corporations couldn't tackle."

"Confidence is accumulated over time." Hu believed that accumulating confidence is best achieved through small successes. Small achievements, recognitions and praises build self-confidence, allowing individuals to tackle more significant challenges and accumulate more confidence.

Academician Hu strongly encourages young people to venture into problem-solving and to refrain from self-doubt before trying. "Many students believe their math skills are lacking, leading them to assume they cannot become good engineers or scientists. However, the reality is that as long as you possess curiosity and a willingness to learn, you can contribute to science and engineering and contribute to addressing global challenges. The key is recognizing your passion for problem-solving, being open to acquiring scientific and engineering knowledge, and cultivating confidence, as these are the pivotal elements in becoming a problem solver."

Academician Hu recounted, "My math skills were just average, yet I have always harbored a curiosity for unraveling the mysteries of things. For instance, when my father told me that the alarm clock rang because little people lived inside it, I remained skeptical. I opened up the alarm clock and figured out its inner workings." Academician Hu used his own experiences to illustrate that true ingenuity emerges from a blend of knowledge and a thirst for exploration.

He emphasized the importance of self-confidence and advised young individuals that while external praise is welcome, self-affirmation becomes crucial in the absence of such validation, as it provides the necessary motivation to progress.

Changing the Paradigm: From Planar to 3D

After the publication of the "FinFET" paper in December 1999, it immediately garnered significant attention from the semiconductor industry. Many companies, including Intel, invited Academician Hu to speak on the topic.

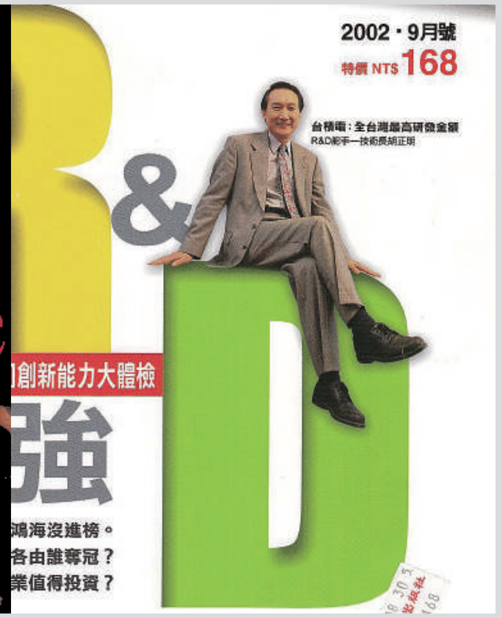
So, what is the "FinFET" (Fin Field-Effect Transistor)? In simple terms, it transformed the original 2D transistor structure into a 3D structure, resembling fish fins, hence the name "FinFET." Academician Hu and his team achieved this feat, earning him the title of the "Father of 3D Transistors."

The difference between horizontal and vertical can be likened to building houses in a city. Initially, you build flat houses (horizontal). However, as the city develops, you can't keep building flat houses; you need to construct tall buildings (vertical). Similarly, FinFET technology used an upward stacking approach to overcome the physical limits of semiconductors, allowing for increased transistor density.

The design of FinFET also addressed other limitations of traditional planar transistors. The fin-like structure improved current control, reducing leakage current and solving the problem of excessive chip power consumption and high temperatures. These advantages enabled semiconductor miniaturization, extending Moore's Law. It's worth noting that the FinFET 3D architecture also became the foundation for subsequent developments such as Gate-All-Around (GAA) nanowire transistors and nanosheet transistors, significantly impacting the semiconductor industry's long-term future.

Speaking of Moore's Law, Academician Hu mentioned contemplating similar questions during elementary school. "When a piece of paper is cut in half repeatedly, how small can it get? There must be a point where it can't be cut further." Perhaps, it was this curiosity that led him into the field of scientific research and ultimately to the development of microchip technology, overcoming the bottleneck of semiconductor technology.

The advent of FinFET brought significant changes to human society. Modern smartphones, regardless of the brand, use FinFET chips. Technologies like network communications, artificial intelligence (AI), and all advanced electronics require FinFET. Transistors are the fundamental building blocks of semiconductor technology, and the more transistors a chip has, the more tasks it can perform. Today, there are tens of billions of FinFET transistors in a single chip, enabling breakthroughs in AI and other fields that were once considered impossible.



TSMC's First Chief Technology Officer: Advancing Taiwan's Semiconductor Industry

Although FinFET gained international attention after its publication, it initially didn't draw the attention of the Taiwanese government or Taiwanese industries. Academician Hu, who grew up and received his education in Taiwan, made a resolute decision to return and contribute to his homeland. In the spring of 2001, after returning to Taiwan, he visited TSMC's Chairman, Dr. Morris Chang. He volunteered his services and expressed his willingness to work in Taiwan for a period of time. He mentioned, "Morris called the executives in Hsinchu to arrange an interview with me. After our discussion, the details were settled on the same day – they even created a new position for me called the 'Chief Technology Officer' of TSMC."

At that time, Taiwan's academic community was actively seeking the involvement of Academician Hu. However, he believed that while education was undoubtedly important, its effect is felt over a long term. The most pressing concern was helping Taiwan industry to take the lead. Failing to do so would make it even more challenging for Taiwan's semiconductor industry to thrive in the future. Consequently, he made the decision to enter the industry.

Academician Hu specified that Chairman Chang entrusted him with two critical tasks. Firstly, he was charged with extending the time horizon of technological development. His mandate was not merely to catch up with foreign technologies but to surpass them. The FinFET technology emerged as a remarkable opportunity in this context. Under his guidance, TSMC's research team consistently unveiled pioneering FinFET prototypes, including 25nm (2002), 10nm (2003), and 5nm (2004). The second task was to optimize the patent portfolio. He recognized that the problem lies not in the quantity of patents but in their quality. To address this, he initiated internal educational programs, delivered lectures, and bolstered the patent acumen of the research team. Moreover, he established a patent management department entirely staffed by engineers.

Academician Hu underscored that patents should not only stand the test of legality but should also exhibit high utility. He emphasized, "FinFET patents are not restricted to singular applications. Because FinFET is versatile, one can contemplate its integration with other technologies. This synergy is indispensable, and as long as the integration represents a non-trivial innovation, it qualifies as a valuable patent."

In over three years at TSMC, Academician Hu played a crucial role in the early adoption of FinFET technology and patents, laying a foundation for competition with top international semiconductor companies. He also helped establish a career advancement system for technical personnel at TSMC, one of the foundations for TSMC's long-term development. In 2011, Intel became the first to employ 22nm FinFET technology, hailing it as "the most radical change in semiconductor technology in 50 years." Subsequently, TSMC introduced 16nm and 14nm FinFET technology and maintained global leadership with 12nm, 10nm, 7nm, 5nm, and 3nm FinFET technologies.

In 2004, Academician Hu was elected the first Academician of Academia Sinica who works at the Hsinchu Science Park. Following the successful completion of his assignment at TSMC, he returned to the University of California, Berkeley, to continue his teaching career.

Even back in the United States, Academician Hu remained connected to Taiwan. He continued to collaborate closely with Taiwan's academic, industry, and research sectors, co-publishing dozens of academic papers, and working tirelessly to enhance Taiwan's semiconductor research capabilities and international academic standing.

Industry-Academia Collaboration: Industry Poses Questions, Academia Provides Answers

Academician Hu stated that his experience at TSMC was a significant learning process for someone from the academic world. He said, "Teaching and application go hand in hand. Industry experience benefited my teaching. Teachers who collaborate with the industry are usually the best teachers in students' eyes because students want to learn practical knowledge and do useful things. When teachers bring industry insights and experience to students, it significantly enhances their learning interest and motivation."

Regarding industry-academia collaboration, Academician Hu acknowledged that most innovation occurs in the industry. He explained, "Because the industry knows where the problems are, but they often lack the manpower to solve problems that will only become pressing three to five years later. Through industry-academia collaboration, students can access the industry knowledge about problems needing solutions, while the industry gains talent for mid to long term research."

Academician Hu believes that the best approach to industry-academia collaboration is for "the industry to pose questions, the government to provide funding, and academia to search for solutions." The process of problem-solving also serves the government's goal of supporting education and nurturing talent. "Nurturing talent is not just about studying; it's also about learning how to solve problems, and industry-academic collaboration is the best training ground."

"Industry and academia are interdependent. People often say that the reason why the San Francisco Bay Area's electronics and information technology industry developed well was because of prestigious schools like Stanford and Berkeley. In fact, it might be the other way around. Why are Stanford and Berkeley top universities? Because there is a good industry presence there." Hu went on to point out that the University of Washington was not initially a top-ranking school, but due to the presence of the headquarters of Microsoft and Amazon in Seattle, the University of Washington's computer science department rose to the top four in the United States. Similarly, the University of California, San Diego, gained global recognition in high-frequency electronics because Qualcomm was located in the city. Taiwan's engineering universities can certainly become world-class, by focusing on closer collaboration with local industries. The government should also recognize that education directly influences future economic development, and should seize the favorable opportunities rather than insisting on uniform development across different departments or even taking resources from strength to prop up the weak.

Market demand to determine the cultivation of industry use of education resource

Academician Hu, who has long resided in Silicon Valley, consistently provided service to Taiwan. This includes serving as the inaugural Executive Yuan National Chair Professor in 1985, where he taught advanced semiconductor courses at the Industrial Technology Research Institute. In 1992, he served as a steering committee member of the National Submicron Project, playing a role in establishing Taiwan's first 8-inch wafer experimental factory. From 2009 to 2014, he conducted monthly remote conferences with researchers at the National Nano Device Laboratories (NDL, now named TSRI), offering guidance and mentoring to researchers to facilitate their achievements.

In 2011, Hu collaborated with National Yang Ming Chiao Tung University to jointly execute a five-year projet supported by the Ministry of Science and Technology for an international top-notch R&D center, integrating researchers from the University of California, Berkeley, and the Chiao Tung University research team. After retiring from the University of California, Hu began serving as a tenured TSMC Chair Professor at National Yang Ming Chiao Tung University in 2017. The subsequent year, he personally oversaw the Ministry of Education and National Science and Technology Council-supported research center project, known as the Center for Semiconductor Technology Research. Under Academician Hu's leadership, the National Yang Ming Chiao Tung University team has dedicated itself to advanced semiconductor technology research and development, achieving numerous world-class results while nurturing many exceptional research talents.

Regarding the shortage of semiconductor industry talent, Academician Hu believes that the semiconductor industry requires a skilled workforce. He contends that the government should refrain from disproportionately allocating limited educational resources to createing new industries. Instead, he argues that industries are forged by the private sector, not the government. The government's primary responsibility should be to provide human resources to support thriving industries capable of creating jobs, foreign exchange, and economic growth.

"The U. S. government provides research universities with a lot of funding, not necessarily for breakthrough research results but to cultivate good talent for the country and industry. Everything in

American schools is determined by market supply and demand. Schools can increase the number of students because of the manpower need of a particular industry," he pointed out. As an example, he cited the University of California, Berkeley, where he taught. From 2009 to 2019, the number of students taking computer science courses increased from 3,000 per year to 10,000 per year, more than tripling. Not only did the engineering students take such courses, but students from humanity and other colleges also eagerly enrolled in computer courses. The government and schools not only did not restrict this but also assisted professors in increasing the number of students in their classes several times or even tenfold.

Academician Hu also mentioned that during his tenure as Chief Technology Officer at TSMC, many in the government considered all "manufacturing" to be low-tech, and underestimated the value of the semiconductor and technology outsourcing industry. However, TSMC is a semiconductor foundry, and is TSMC not high-tech enough? Or not innovative enough? "Sometimes the government may be misled by a few terms. In fact, as long as an industry can create added value, provide high-paying job opportunities, and comply with the law to protect the environment, it is worth the government's support."

He suggests that the Taiwanese government and government research organizations need to rethink their strategies. Taiwan already possesses large, internationally competitive private enterprises. Consequently, government strategies should evolve beyond the traditional methods of doing research for industries and should concentrate on educating talent to meet the needs of current industry requirements. The responsibility for technological innovation and research development should be delegated to the industry. At the same time, large govenment research organizations should adopt a new approach. Rather than competing for talent with the industry and universities, they should focus on releasing talent into the industry. In doing so, they will infuse renewed vigor into the national economy.

"The semiconductor industry will continue to be a mainstream industry in the future. If young people are interested, they should not worry about their career prospects." Academician Hu pointed out that in the digital age, the world relies on semiconductors and electronics. Whether it's the internet, artificial intelligence, or other fields, all of them require digital processing, which depends on semiconductors.

He also advised young people to have confidence in themselves, cultivate curiosity, be eager to learn new things, and be willing to work hard. "One of the challenges faced by the American semiconductor industry is that young people often perceive technology as difficult or believe that they are unsuitable for careers in technology due to their lack of mathematical prowess. In reality, as long as they are willing to work hard, and enjoy problem-solving, they can contribute to the technology industry and society and have satisfying careers."

Nanomanufacturing is a Key Semiconductor Core Strength

In 2016, former U. S. President Barack Obama awarded the 'National Medal of Technology and Innovation' to Academician Hu at the White House, recognizing his outstanding contributions to the world through technological innovation. That same year, he also received the title of Academician from the Industrial Technology Research Institute. In 2020, the Institute of Electrical and Electronics Engineers (IEEE) awarded him its highest honor, the "IEEE Medal of Honor," hailing him as a "semiconductor visionary."

Throughout his life, Academician Hu dedicated himself to research in electronic science. He acknowledged that every material has its limits, and Moore's Law (which states that the number of transistors on a chip doubles approximately every two years) would eventually reach its conclusion. Both academia and industry have been attempting to alter transistor structural designs, materials, and physical principles to prolong Moore's Law as much as possible.

"The innovation in 3D FinFET lies in the fact that whether we make the transistor thinner or stack it higher, there is still room for advancement. I firmly believe that the future of the semiconductor industry will continue to progress in these two directions," emphasized Academician Hu. He stressed that technological development is continually evolving, and semiconductor materials will evolve over time, possibly incorporating more non-semiconductor materials onto chips. However, regardless of the materials used, it has many intricate and complex structures. Therefore, nanomanufacturing is the core technology of the semiconductor industry, and this is one of Taiwan's strengths. Taiwan Semiconductor Manufacturing Company (TSMC) will not only continue to perform well but will also explore new stages to perform on.

Passion for Research and Life, Commitment to Giving Back to Society

Throughout his journey, Academician Hu not only benefited humanity through scientific research but also made significant contributions in other ways. For example, Dr. Chenming Hu and his wife, Margaret Hu, donated money to establish the 'Dr. Chenming and Margaret Hu Medical Center' in the Asian Health Services (AHS) in Oakland's Chinatown. This building was renovated from the original AHS administration building and is now equipped with state-of-the-art pediatric and family care facilities. Asian Health Services was established in 1974 as a volunteer-run clinic. Over the past few decades, the center's patient population has grown to tens of thousands, with 95% being low-income children and families. The expansion of medical facilities will enable better healthcare services for more patients.

Dr. Chenming Hu's philanthropic spirit comes from a long-standing family tradition. His father had established scholarships in China. His two sons, Raymond Hu and Jason Hu, continue this tradition. Raymond has contributed many beautiful paintings to the medical center, while Jason has engaged in philanthropic AIDS prevention work in Ghana, West Africa. It is worth mentioning that the City of Oakland, in appreciation of the contributions of Dr. Chenming Hu and Margaret Hu to the community, designated August 31, 2018, as 'Dr. Chenming and Margaret Hu Day. '

Academician Hu not only engages in academic research, he also has diverse interests and leads a vibrant life.

He utilizes his spare time to explore activities such as sailing and scuba diving, and often shares these special moments with his sons. He even treked to the Mount Everest base camp. Hu's sister, Hu Haiyan, mentioned in a media interview, "My brother is not only a science expert, is multi-talented. Since childhood, he wrote speeches for his siblings when they participated in competitions. He likes poetry, music, and painting." She further recalled how her brother patiently taught and creatively explained complex problems whenever they encountered academic difficulties in their youth. "No matter how complex the problem, after his explanation, it would become simple and clear." The talent for mentoring was evident in Academician Hu from a young age.

With numerous accolades, Academician Hu looks back on his journey with deep gratitude. Every step of the way, from Dr. Fang Fu leading him into the semiconductor field, to the education he received at National Taiwan University and the University of California, and the teamwork of his students and colleagues, to his entry into the industry at TSMC, has led him to fulfill his dream of giving back to society. He is grateful for his parents' education, which included encouragement and praise, and how it helped him to build self-confidence. The support and companionship of his family allowed him to fully engage in research and innovation.

Academician Hu particularly emphasized the importance of "self-confidence" in his life, stating, "The foremost task for young people is to build self-confidence. When someone genuinely appreciates you, accept it willingly. Even if you feel that someone's praise is reserved, try to believe it. In any case, seize any opportunity to boost your self-confidence. Even if no one praises you, encourage yourself." Hu has emphasized the importance of self-affirmation on many occasions. He says, "Believe in yourself, so that you have the strength to solve more difficult challenges."

Academician Hu, who has achieved numerous world-class accomplishments, passionately stated, "Take from society and give back to society. As long as there is an opportunity, I will continue to contribute to industry and academia."

List of Selected Publications

1. Sub 50-nm finfet: Pmos X Huang et al., International Electron Devices Meeting 1999. Technical Digest
2. 25 nm CMOS omega FETs FL Yang et al. (TSMC), International Electron Devices Meeting Digest, 255-258, 2002
3. Scaling of CMOS FinFETs towards 10 nm HY Chen et al. (TSMC), International Symposium on VLSI-TSA 2003
4. 5nm-gate nanowire FinFET FL Yang et al. (TSMC), Symposium on VLSI Technology, 2004
5. MOSFET modeling & BSIM3 user's guide Y Cheng, C Hu,Springer Science 1999
6. BSIM model for circuit design using advanced technologies C Hu, Symposium on VLSI Circuits, 2001
7. Modern semiconductor devices for integrated circuits C Hu, Prentice Hall, 2010
8. MoS2 transistors with 1-nanometer gate lengths SB Desai et al., Science 354 (6308), 99-102, 2016
9. Deep learning-based BSIM-CMG parameter extraction for 10-nm FinFET MY Kao et al. IEEE Transactions on Electron Devices 69 (8), 2022
10. van der Waals epitaxy of 2D h-AlN on TMDs by atomic layer deposition at 250° C SJ Chang et al. (NYCU), Applied Physics Letters 120 (16), 2022

Mathematics and Physical Sciences Category ——**Wing-Huen Ip**

Pioneering a New Era in Taiwanese Planetary Research

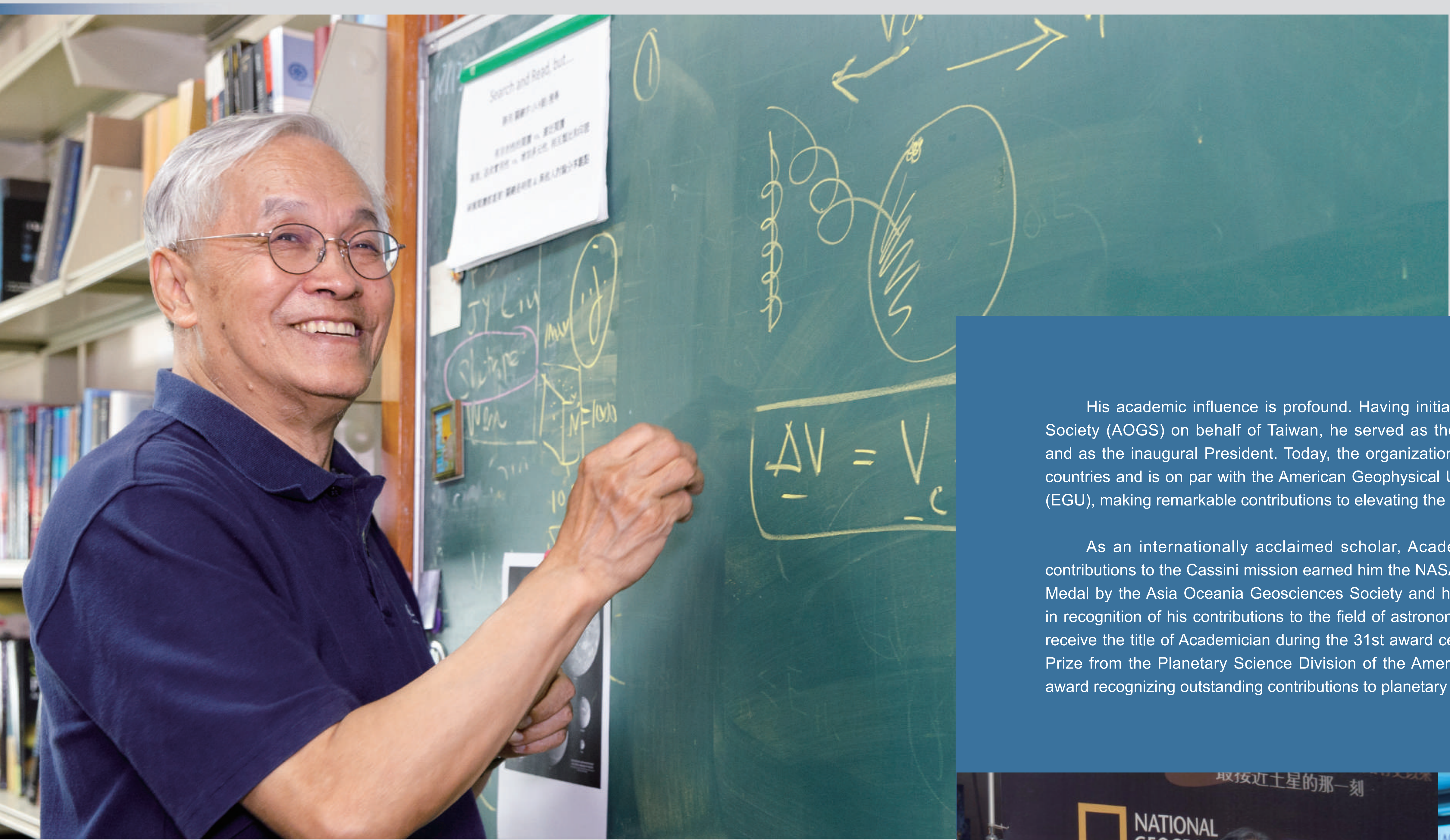
Over 60 Top-Notch Papers Published, Remarkable International Academic Reputation

Academician Wing-Huen Ip has dedicated himself to the fields of cometary physics, planetary dynamics, and the interaction between satellites and magnetospheres. His contributions have been exceptionally prolific, with a cumulative publication of over 500 journal papers, including more than 60 published in top international journals such as "Nature" and "Science." His foundational research on the interaction between cometary atmospheres and solar winds holds indispensable value in understanding the formation of the solar system and the origin of planets. He is also one of the three main proposers of the collaborative "Cassini-Huygens Mission" between the European Space Agency (ESA) and National Aeronautics and Space Administration (NASA).He introduced atmospheric models of Saturn's rings and the role of charged particles in magnetospheric dynamics, leading the research team at National Central University to discover abundant water vapor in Saturn's satellites' plumes. These pioneering contributions have furthered our understanding of the Saturnian system, exploration of extraterrestrial habitable environments, and the origins of life.

Academician Ip was born in Nanjing in 1947. His family came to Taiwan for a short time before moving to Portuguese Macau. His years of study at the Sheng Kung Hui Choi Kou School Macau and New Asia College of the Chinese University of Hong Kong inspired his curiosity and passion for knowledge. Subsequently, he pursued further studies in the United States, earning a Master's degree in Physics from the University of Pittsburgh in 1970 and a Ph.D. in Applied Physics and Information Science from the University of California, San Diego in 1974, where he continued his postdoctoral research. In 1978, the Max Planck Institute for Aeronomy (renamed "Max Planck Institute for Solar System Research" in 2004) in Germany appointed Academician Ip as a researcher, where he served for 20 years.

Between 1991 and 1992, he accepted an invitation from the National Science and Technology Council of Taiwan to serve as the Chief Scientist of the National Space Laboratory Provisional Office of the Executive Yuan (renamed "National Space Organization" in 2005). He played a vital role in defining the mission of Taiwan's first scientific satellite, and the design and selection of scientific payloads, laying a solid foundation for Taiwan's space technology development. In 1998, he decided to settle in Taiwan and accepted an invitation from National Central University to serve as the Dean of the College of Science. During his six-year tenure, he effectively utilized his interdisciplinary expertise and planning skills to establish the Institute of Cognitive Neuroscience, Institute of Biophysics, and Institute of Bioinformatics. He also founded the Solar System Laboratory within the Institute of Astronomy, ushering in a new era of planetary science research in Taiwan.

Academician Ip played a key role in establishing the Lulin Observatory at National Central University, transforming it into a national-level facility and advancing research in the field



of time-domain astronomy. Lulin Observatory became a prominent platform for international collaborations and a highlight of solar system research. The domestic team he led successfully participated in a number of international space missions, including the Cassini Saturn mission jointly conducted by ESA and NASA, ESA's Rosetta comet mission, Mars Express, and the BepiColombo Mercury mission jointly conducted by the Japan Aerospace Exploration Agency (JAXA) and ESA. In 2020, he founded the Taiwan Space Union (TSU) and served as its chairman, promoting close collaboration between academia, industry, and government to further integrate Taiwan's expertise in space technology. He also raised funds from industry partners and collaborated with the Delta Electronics Foundation to establish the "Young Astronomer Lecture Series," aiming to attract outstanding young scholars from abroad to promote astronomy education in Taiwan. Academician Ip is dedicated to nurturing scientific talent, successfully mentoring numerous high-caliber educators and contributing to K-12 science education by identifying and cultivating exceptional individuals.

His academic influence is profound. Having initiated and organized the Asia Oceania Geosciences Society (AOGS) on behalf of Taiwan, he served as the Chairman of the Organizing Committee in 2002 and as the inaugural President. Today, the organization boasts over 11,000 members from more than 54 countries and is on par with the American Geophysical Union (AGU) and the European Geosciences Union (EGU), making remarkable contributions to elevating the academic status of the Asia-Pacific region.

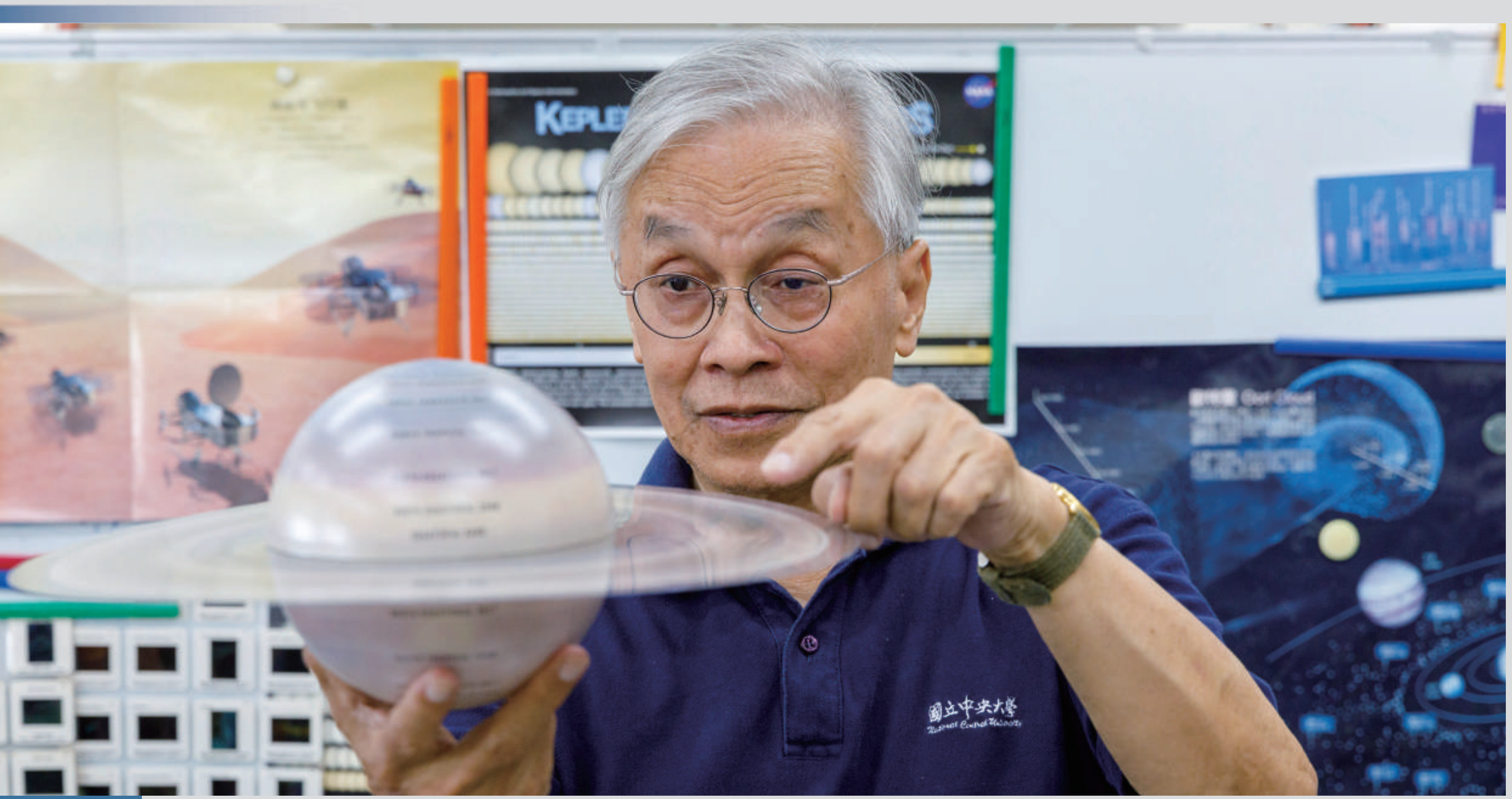
As an internationally acclaimed scholar, Academician Ip has received numerous awards. His contributions to the Cassini mission earned him the NASA Public Service Medal. He was awarded the Axford Medal by the Asia Oceania Geosciences Society and had an asteroid, 18730 Wingip, named in his honor in recognition of his contributions to the field of astronomy. In 2016, Ip was selected by Academia Sinica to receive the title of Academician during the 31st award ceremony. In 2020, he received the Gerard P. Kuiper Prize from the Planetary Science Division of the American Astronomical Society, a lifetime achievement award recognizing outstanding contributions to planetary science.

Research on Saturn and Comets - Exploring the Solar System and the Origins of Life

Participating in Multiple International Space Missions – Advancing Planetary Science in Taiwan

Academician Ip, born in 1947 in Nanjing, spent his childhood in Macau. He studied physics at the Chinese University of Hong Kong during his undergraduate years and pursued further studies in the United States, earning a master's degree in physics from the University of Pittsburgh and a Ph.D. from the University of California, San Diego. In 1978, he joined the Max Planck Institute for Aeronomy in Germany as a research fellow, where he served for 20 years. Academician Ip's research covers comets, planets, and the solar system, and he played a leading role in international space missions. Throughout his academic career, he has authored and co-authored over 500 academic papers.

In 1998, after returning to Taiwan, he initiated a number of research institutes and the Solar System Laboratory at National Central University, dedicated to promoting planetary research in Taiwan and the nation's space technology. His significant impact on the academic world led to the establishment of the Asia-Oceania Geosciences Society (AOGS), where he served as its founding president. He played a pivotal role in the development of the Lulin Observatory at National Central University, promoted the development of time-domain astronomy, and founded the Taiwan Space Union (TSU) in 2020 to facilitate collaboration between industry, government, and academia. He is also dedicated to advancing scientific education and nurturing talent.



In August and September 1977, NASA launched the Voyager 2 and Voyager 1 spacecraft, which flew by the Saturnian system, providing the first high-resolution images of Saturn and its moons. The young scientist Wing-Huen Ip, then only 30 years old, was profoundly impressed by this achievement. He expressed his excitement at the time, saying, "Galileo first observed Saturn's rings with a telescope in 1610. Four hundred years later, humanity could finally see Saturn up close!"

This initial encounter with Saturn ignited a greater desire for exploration. Academician Ip recalled his thoughts at the time: "Back then, the two spacecraft merely passed by quickly. If we wanted to truly understand the Saturnian system, especially Titan (Saturn's moon), we needed a more in-depth exploration project." Titan is the solar system's first moon discovered to possess a thick atmosphere, leading scientists to speculate on the presence of life on it. It is believed that investigating Titan could help us understand the early conditions on Earth and unravel the mystery of the origin of life.

A"Bold Proposal" for the Cassini Mission

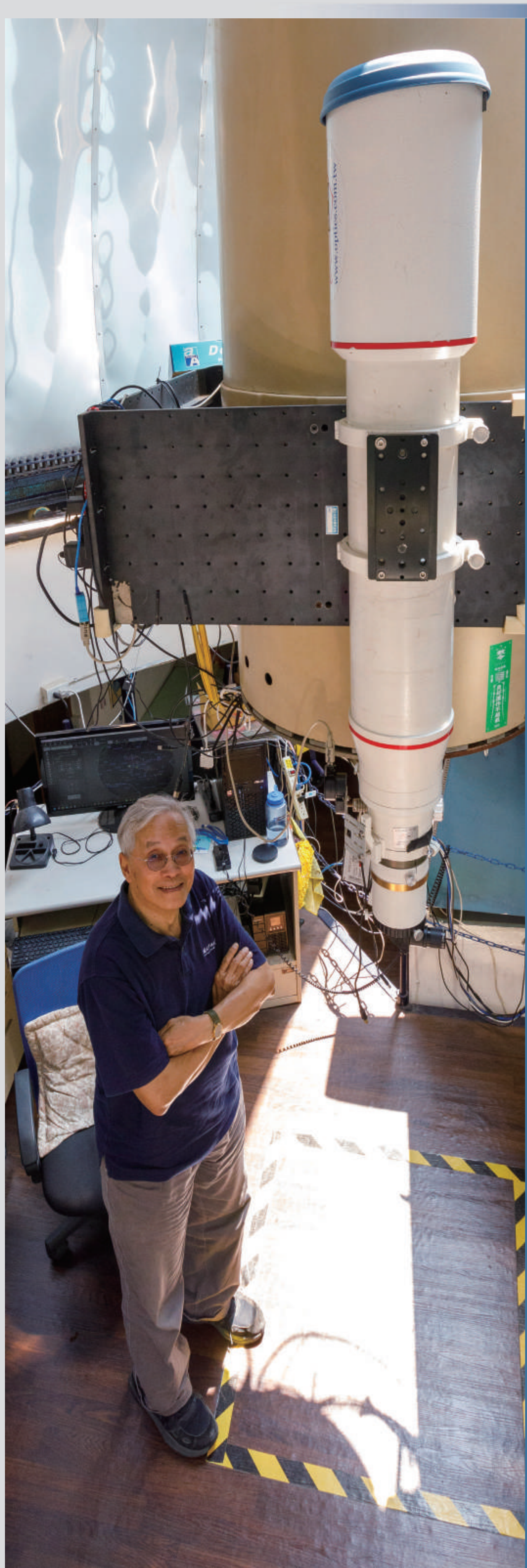
A passion for exploration fueled a "bold proposal." At the time, Academician Ip had only been a research scientist at the Max Planck Institute for Aeronomy for four years when he, together with French scientist Daniel Gautier, proposed the "Cassini Saturn Probe Mission" to the European Space Agency (ESA) in 1982. Ip once shared an interesting anecdote about convincing his French colleague, "He was an atmospheric expert on Titan and was initially reluctant to support a young scientist like me. So, I decided to name the project ‘Cassini,’ after Giovanni Cassini, a renowned figure in French astronomy who first discovered the gap between Saturn's rings (Cassini Division) in 1675. When I shared this idea with Daniel, he accepted the proposal after thinking it over for a moment." At the time, most people had little faith in the project's approval, given that Ip was a young scholar. Some even bet against him, promising to send him a large crate of champagne if the project got the green light.

As it turned out, Ip won the bet. With the joint efforts of Ip, Gautier, and American astronomer Toby Owen, the project received support from the European Space Agency (ESA) and NASA, costing $3.4 billion, involving 256 scientists from 18 countries. In 2009, NASA awarded Academician Ip and his two colleagues the "NASA Exceptional Public Service Medal" for their contributions.

In October 1997, the Cassini-Huygens mission successfully set out for Saturn. The Cassini spacecraft carried various instruments for studying Saturn, while the Huygens probe had a parachute system that allowed it to land on Titan for exploration. After a long flight, Cassini-Huygens entered Saturn's orbit in 2004, and the Huygens probe successfully landed on Titan in 2005, marking the first-ever landing on a celestial body in the outer solar system. Using Cassini as a relay, the Huygens probe transmitted valuable data back to Earth. The mission's scientific achievements exceeded expectations, leading NASA to extend it until 2017.

This 13-year-long exploration mission provided scientists with a deeper understanding of Saturn's atmosphere, Saturn's rings, and its moons. One of the most surprising discoveries was that Titan had lakes and mountains, while another moon, Enceladus, showed signs of potential life. During this time, Academician Ip led a research team from National Central University to participate in a very important discovery related to the water vapor emitted from a geyser on Saturn's moon, Enceladus. He also proposed atmospheric models for Saturn's ring atmosphere and ionosphere and conducted research on the dynamics of charged particles in the magnetosphere, making crucial contributions to the study of Saturn's ring structure and origin.

The achievements of the Cassini mission advanced human exploration of the solar system and the origin of life, placing it alongside projects like Apollo, Voyager, and the Hubble Space Telescope in the history of space research.



Commitment to Comet Research, Exploring the Mystery of Solar System Formation

"How did the solar system form?" "How did life originate?" Many of Academician Ip's research efforts have revolved around these two profound questions, with comet research being one of them. Ip has been dedicated to cutting-edge comet research since participating in the space exploration of Halley's Comet in 1988.He led a team from National Central University in participating in the European Space Agency's Rosetta mission, bringing humanity closer to the truth. Academician Ip emphasized the importance of this research: "Comets may hold the key to understanding the solar system and even the origin of life." Comets are considered ancient objects left over from the formation of the solar system. Their relatively unchanged nature within the solar system allows scientists to gain a deeper understanding of the early solar system environment and reveals important information about the formation of the solar system.

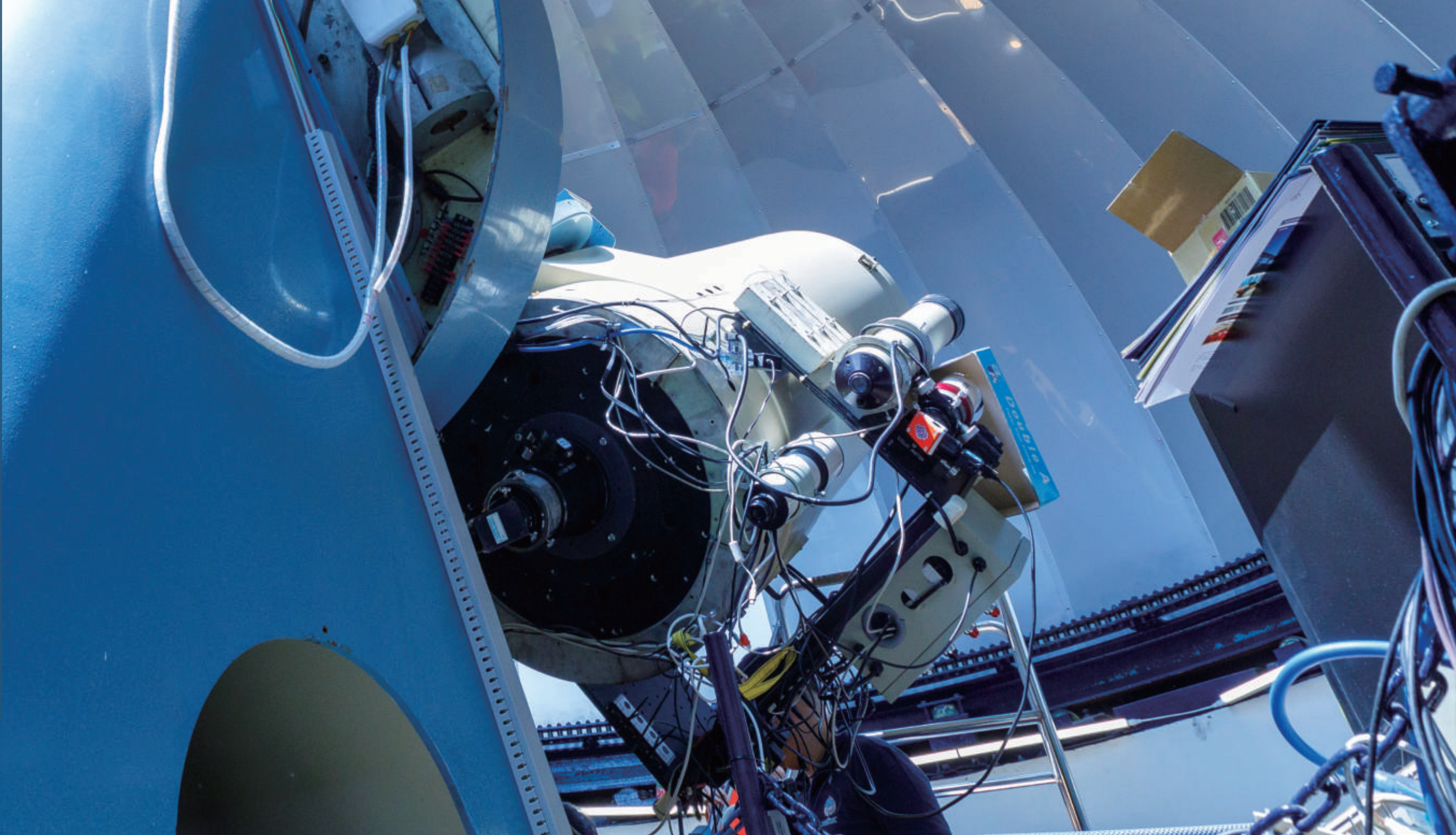
In 2004, the European Space Agency launched the Rosetta spacecraft, which, after a ten-year journey, reached Comet 67P/Churyumov-Gerasimenko (67P/C-G). In addition to orbiting the comet, the spacecraft also deployed the Philae lander onto the surface of 67P/C-G. This historic event marked the first successful landing on the surface of a comet and provided invaluable data about the comet's structure. From his time at the Max Planck Institute to his return to Taiwan to teach at National Central University, Academician Ip has always been committed to analyzing observational data of solar system small bodies and related theoretical research.

The entire journey, from proposing collaborative plans to the actual transmission of data, spanned a total of 30 years. "Many may feel that this period of time is very long, but in the context of human history, it's just in a blink of an eye." As an astronomer, Academician Ip pondered the vastness of the cosmos and the infinite river of time. "Human life is finite, and it is only through the relay of generations of scientists, the accumulation of data point by point, and the discoveries from experiment to experiment, that we can gradually unveil the mysteries of the universe and life."

Planetary exploration often spans decades, and the blossoming results of related research may not always be reaped by the initiators of the projects. Therefore, Academician Ip admitted that in his nearly four decades of astronomical research, there hasn't been a dramatic "Eureka" moment, which is a sudden flash of insight. He explained, "The only moments of excitement I've had were when some space projects were approved, because I knew there were resources available to continue exploring the unknown!"

Academician Ip once described the development of scientific research as "Planting trees for future generations to enjoy the shade." He said, "Scientific achievements are not the result of a few individuals but the collective efforts of many. You might be someone else's big tree, or you might be the person sitting in the shade somewhere." He provided an example: In the past, scientists believed that the planetary orbits in our solar system would remain relatively stable as the planets grew in size, somewhat akin to the saying "As you are at three, so you will be at eighty." However, a theoretical model he constructed in 1984 in collaboration with a young Uruguayan scientist, Julio Angel Fernandez, challenged this belief. "According to this model, we believed that the exchange of angular momentum resulting from the accretion and ejection of small celestial bodies by planets would cause some planets, like Jupiter and Saturn, to move slightly closer to the Sun, while Uranus and Neptune would move significantly farther away." This theory did not receive much attention or acknowledgment at the time of its proposal. However, years later, an American scientist used this theory to explain the peculiar orbital resonance phenomenon of Pluto with Neptune, attracting significant attention. "I still remember that the scientist mentioned our paper from years ago in her interview, stating that it was very helpful to her research."

Academician Ip believes that the joy of exploring the unknown is the greatest reward in scientific research. However, he didn't always aspire to be a scientist. "I just went with the flow and followed the tide!" Academician Ip casually mentioned as he looked back upon his journey.



Growing up in an environment of free exploration – Cultivating a lifelong curiosity

From Nanjing to Taiwan, then to Macau and Hong Kong, and later to the United States and Europe, and now back in Taiwan, Academician Ip's life journey spans "two sides of the strait" (referring to mainland China and Taiwan), Macau, the United States, and Germany. His story is like a microcosm of the larger historical era. In 1947, Academician Ip was born in Nanjing, and in 1948, his family decided to move to Taichung, Taiwan. Just a year later, in 1949, the Republic of China government, led by the Kuomintang, retreated from mainland China to Taiwan.

While they settled in Taiwan, the elder members of the Ip family didn't consider it the ideal place to settle. "Many of my family's elders were military professionals who had experienced eight years of war and the Chinese Civil War. They didn't want to be dragged into more conflicts, so they chose to leave Taiwan and establish themselves in Macau, which was then still under Portuguese administration and maintained a policy of neutrality." Academician Ip proceeded to recount his journey of growth.

When his family relocated to Macau, the young Wing-Huen Ip enrolled at the Sheng Kung Hui Choi Kou School Macau. Reflecting on his time in high school, he underscored the importance of "free exploration" and "active learning." He believed that this attitude towards learning, coupled with the altruistic values instilled by the church school, played a crucial role in leading him into the field of scientific research. "At that time, there was no unified college entrance exam system in Macau, and there were no universities. Many students felt that completing high school was sufficient. So, I progressed to the second year of high school without ever thinking about going to college. We were studying various subjects without the pressure of pursuing higher education, and it was a very carefree time." His spirit of exploration was nurtured decades ago, during his high school years.

Fueled by a curiosity for knowledge, when he learned about the existence of "universities," Ip began preparing for college during his senior year at high school, with both Hong Kong and Taiwan universities as options. "At the time, I wasn't sure which field I liked the most, so I applied for 10 different areas of study, such as physics, chemistry, medicine, and hydraulics," Academician Ip recalled about the application process. He mentioned this because the experience taught him an important lesson, "When it came to college, my father had only one requirement: I couldn't study hydraulic engineering because he said Macau had no rivers, and there was no demand for hydraulics. At the time, I thought it made sense, but little did I know that due to climate change, floods would become prevalent everywhere, and hydraulic engineering would become significant, even in Macau. This experience taught me that knowledge is never useless; it always comes in handy, so we should strive to seek knowledge and learn as much as possible."

Later, Academician Ip was admitted to the National Defense Medical Center in Taiwan. However, there was a twist in his plans. "I was all set to go to Taiwan for my studies. My bags were packed, but my mother couldn't bear the thought of me being too far away from home. So, on the eve of my departure, she made the decision for me to study at the Chinese University of Hong Kong instead." This decision would shape Ip's future career choices. Nevertheless, his connection with Taiwan wasn't over, as he later settled in Taiwan as a son-in-law and made significant contributions to the field of astronomy in Taiwan.

Entering the Department of Physics at the Chinese University of Hong Kong, Academician Ip greatly appreciated the holistic education provided by the New Asia College. New Asia College was founded in 1949 by Mr. Ch'ien Mu and a group of scholars from mainland China in extremely challenging circumstances. "Among the teachers at the college were philosophers, historians, and literary scholars, and together they established the New Confucianism school of thought. Their unwavering dedication to the country and its people in difficult times deeply impressed me, and I feel that my values have been profoundly influenced by the teachings and actions of these teachers." Experiencing setbacks in an academic career is normal, and the examples set by his predecessors reminded Ip to persevere even in difficult times. Another source of strength that helped him overcome challenges was his Hakka heritage. "I am Hakka, and we have a natural ‘hard-headed’ spirit that enables us to persist and persevere," said Ip.

During his days at New Asia College, Ip immersed himself in an education that balanced the humanities and sciences. However, he didn’t study hard for the sake of grades but because he genuinely loved acquiring knowledge. "It wasn’t until my third year that I learned about the option of pursuing graduate studies after college. My teachers also encouraged me to further my education abroad." Subsequently, Ip earned a Master’s degree in Physics from the University of Pittsburgh in the United States and a Ph.D. in Applied Physics and Information Science from the University of California, San Diego.

Transitioning from Pittsburgh to San Diego, Academician Ip still vividly remembers the awe-inspiring feeling of seeing the local scenery upon arrival. "I grew up in Macau and Hong Kong and had never seen the swaying palm trees before. I instinctively felt that I had come to a good place." At school, someone approached him and said, "Prof. Soo Lin-kwan from the Chinese University of Hong Kong had high praises for you, as if you were a rare talent sent from the heavens!" It was at this point that Ip realized that Prof. Soo’s praise had greatly helped him. "I didn’t actually think I was that good; I received a lot of help along the way. I believe I was fortunate, and I’m very grateful to Prof. Soo. He changed my life." Academician Ip also wanted to use this opportunity to remind young people that, "When you do your best, there will always be someone quietly watching and willing to give you opportunities when necessary, such as extending a helping hand." This is what is often referred to as, "God helps those who help themselves."

Under the Guidance of a Nobel Laureate – Embarking on the Journey of Space Physics

Graduation Party at the Alfvéns in La Jolla in December 1973. From left: Diana and Wing-Huen Ip, Bibhas and Gopa De.
(Hannes Alfvén would joke to Asoka Mendis: "Between the two of my graduate students, I have a grand total of four letters in the last names!")
[*Photo: Kerstin Alfvén*]

His introduction into the field of space physics is a different story. While pursuing his Ph.D., Ip was in urgent need of financial support, and his sole criterion was to go wherever he could secure a research assistantship. A fellow student suggested that he prioritize searching for opportunities in the field of space physics. "Around 1970, especially after the Apollo moon landing missions, space physics gained attention in the United States, and funding was relatively abundant," he explained. After some twists and turns, Ip approached Nobel Prize-winning physicist Hannes Alfvén. Alfvén was a Swedish plasma physicist and astronomer known for his research in the field of magnetohydrodynamics. "After I explained my intention to him, Alfvén handed me a lecture note and told me to read it thoroughly before making a decision," Academician Ip recalled with a smile. "I flipped through a few pages of the lecture note, didn't quite understand it, and when I went back to him, I simply said I wanted to join his research group." From then on, Ip immersed himself in the field of space physics.

"Being a student of a Nobel laureate was quite challenging," he said. He also mentioned another dilemma, "Alfvén liked challenging authority and often engaged in debates with renowned scholars. This influenced his students, often pulling them into these arguments." Nevertheless, Ip was certain that this teacher had indeed taught his students to maintain their critical thinking abilities and not trust authority blindly. "However, you couldn't question his authority; you had to follow his instructions to a 'T.' " Academician Ip humorously described Alfvén's academic style.

Starting from the 1980s, Ip delved into the study of asteroids and comets, a topic that wasn't receiving much attention at the time. "Many people didn't understand why I chose to focus on this, but I was very clear about it," he further explained. "The organic materials needed on Earth could potentially be brought by these small celestial objects. Researching asteroids and comets helps us understand the origins of life." Between 1978 and 1986, alongside his theoretical work, he also participated in the Giotto Project to Halley's Comet.

After completing his Ph.D. and spending three years as a postdoctoral researcher at the University of California, San Diego, Ip began looking for his next job. Only two institutions responded to his applications: The Department of Atmospheric Sciences at National Central University in Taiwan and an observatory in Venezuela. "I still remember that the letter I received from National Central University was written with a calligraphy brush, which left a deep impression on me." After much consideration, he decided to go to Venezuela. However, "Life's circumstances are really unpredictable. I didn't end up going to Venezuela but came to National Central University over 20 years later, and I'm still here today."

His journey to Venezuela was abruptly interrupted due to a surprising turn of events. The reason for this change was that the Max Planck Institute for Aeronomy (now Max Planck Institute for Solar System Research) sought to recruit him. This was because at that time, the institute's director, Professor W. Ian Axford, who was a professor at UCSD was in the process of establishing a space research program. So, instead of Venezuela, Ip headed to Germany, where he would spend a remarkable 20 years. During this period, Ip participated in missions such as Cassini, Giotto, Deep Impact, and Rosetta, accumulating numerous research achievements. From being a young scholar urgently seeking employment, he evolved into a distinguished scientist in the field of planetary science. In 1998, Ip relocated from Europe to Taiwan.

Returning to Taiwan to Teach at National Central University – Advancing Space Technology and Planetary Science

Academician Ip's connection with Taiwan began in the mid-20th century when he was still an infant. Shortly before welcoming the 21st century, at the age of fifty, he made the decision to come to Taiwan. "I had been working and studying in Europe and the United States, but my relationship with Taiwan was deep because my wife is Taiwanese." Discussing the reasons behind his decision to return to Taiwan, Ip explained, "I got to know Academician Liu Chao-Han in Germany. He was actively promoting space programs in Taiwan and invited me to join. So, I continued my research in Germany while providing my assistance." Between 1991 and 1992, at the invitation of the National Science and Technology Council, he served as the Chief Scientist of the National Space Laboratory Provisional Office of the Executive Yuan (renamed "National Space Organization" in 2005), focusing on mission definition and the design and selection of scientific payloads for Taiwan's first scientific satellite, ROCSAT1. This laid the foundation for the development of Taiwan's space technology.

Academician Ip played a pivotal role in establishing and organizing the Asia-Oceania Geosciences Society (AOGS) in the name of Taiwan. He served as the chairman of the preparatory committee in 2002 and as the founding president from 2004 to 2006.Currently, AOGS boasts over 11,000 members from more than 54 countries globally. Standing alongside prominent organizations like the American Geophysical Union (AGU) and the European Geosciences Union (EGU), AOGS has significantly influenced the elevation of the academic status of the Asian region.

"After Liu Chao-Han became the president of National Central University, he invited me to teach at the school and continue to assist in space projects. Also, my wife missed Taiwan a lot, so when our two daughters finished high school, we came back to Taiwan." In 1998, after settling in Taiwan, Ip was invited to become the Dean of the College of Science at National Central University. During his six-year tenure, he leveraged his interdisciplinary knowledge and management skills to establish the Institute of Cognitive Neuroscience, the Institute of Biophysics, and the Institute of Bioinformatics. Additionally, he initiated the Solar System Laboratory at the Institute of Astronomy, pioneering planetary science research in Taiwan. From being the Dean of the College of Science to later serving as the Vice President of National Central

University and the Vice President of the University System of Taiwan, and currently as the Li Kuo-Ting Chair Professor of Astronomy and Space Science, thanks to Academician Ip's outstanding international academic reputation, Taiwan and National Central University have seen a continuous rise in international visibility in the fields of space and astronomy. This has led to numerous international collaboration opportunities.

For example, as the U.S. government heightened its concerns about the risk of asteroid impact on Earth, the University of Hawaii launched the Pan-STARRS Project in 2005. During one of his visits to the University of Hawaii, Ip had an in-depth discussion with the head of the local Institute for Astronomy, which led to National Central University's involvement in this international research project. The Pan-STARRS Project first built a complete telescope system (PS1) on Maui Island, Hawaii, in collaboration with universities and research institutions from the United States, Germany, the United Kingdom, and Taiwan. Ip mentioned, "Taiwan's unique geographical location on the western side of the Pacific Ocean, relative to Hawaii, gave us special observation opportunities." Consequently, Ip actively promoted the installation of a two-meter diameter telescope at the Lulin Observatory of National Central University. Furthermore, regarding the famous European Space Agency's Rosetta mission, National Central University is the only Asian institution involved. There are countless examples of such international research collaborations, and through these efforts, Academician Ip has not only advanced planetary science research but also nurtured many young Taiwanese planetary scientists.

Awakening Students' Passion for Learning and Inspiring the Motivation to Explore Knowledge

In terms of educational advocacy, Ip has always spared no effort. He especially aims to share his youthful "intrinsic love for knowledge" with the young generation in Taiwan.

For over twenty years since returning to Taiwan, Academician Ip, who has held positions from the Dean of the College of Science at National Central University to his current position as the Li Kuo-Ting Chair Professor in Astronomy and Space Science, has consistently focused on cultivating scientific education for Taiwanese students. Not only did he raise funds from the industry, successfully establishing the "Young Astronomer Lectureship" in collaboration with the Delta Electronics Foundation, he also actively contributes at the grassroots level to promote K-12 science education. K-12 education covers the learning stages from kindergarten to high school, aiming to develop students' comprehensive abilities and help them grow from children to adults. This educational model originated in the late 19th century in the United States and has been adopted by many countries worldwide. In 2018, Taiwan began implementing a 12-year compulsory education program to provide more comprehensive education for students. K-12 education is not only about personal growth but it is also a key factor in a nation's progress. Therefore, strengthening K-12 education is an important issue for many governments worldwide.

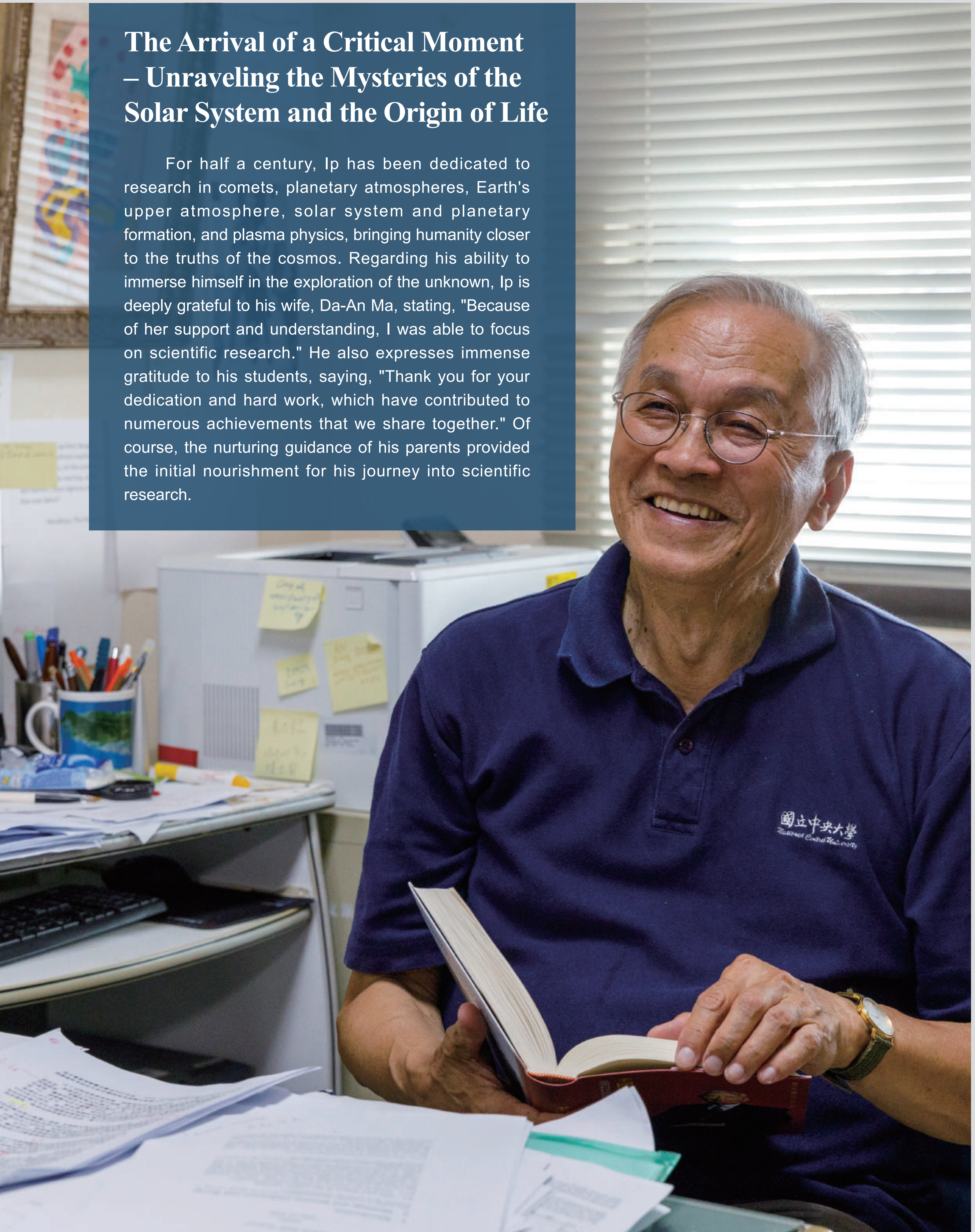
Academician Ip openly expressed his concern about the current state of education in Taiwan: "Taiwanese students face tremendous exam pressure, which turns them from seekers of knowledge driven by their inner curiosity into mere exam prepping machines." He is surprised to hear that some education professionals consider the Taiwanese students' ability to mimic as a significant advantage. "From my perspective, in this rapidly changing era, mere imitation may not be enough to adapt to the future. So, it can hardly be called an advantage!"

Academician Ip straightforwardly states, "The repetitive learning model is the problem in Taiwan's education system. We need to start from the grassroots and find ways to nurture students' interests and awaken their motivation to learn." What methods are there? "In museums, we always see the sparkling eyes of young children, filled with curiosity about knowledge. If we can sustain such experiences, they will become an endless source of learning motivation for them. So, we hope to create rich opportunities for scientific experiences through a series of activities, allowing students to remain curious and passionate about science," Ip said earnestly. "Young people without dreams cannot make the world a better place." Furthermore, many students who have sailed smoothly through their academic tests often struggle to cope with life's setbacks down the road. However, scientific research achievements are actually accumulated through numerous setbacks. Therefore, he emphasizes that Taiwan's education system must focus on developing students' ability to face and deal with setbacks.

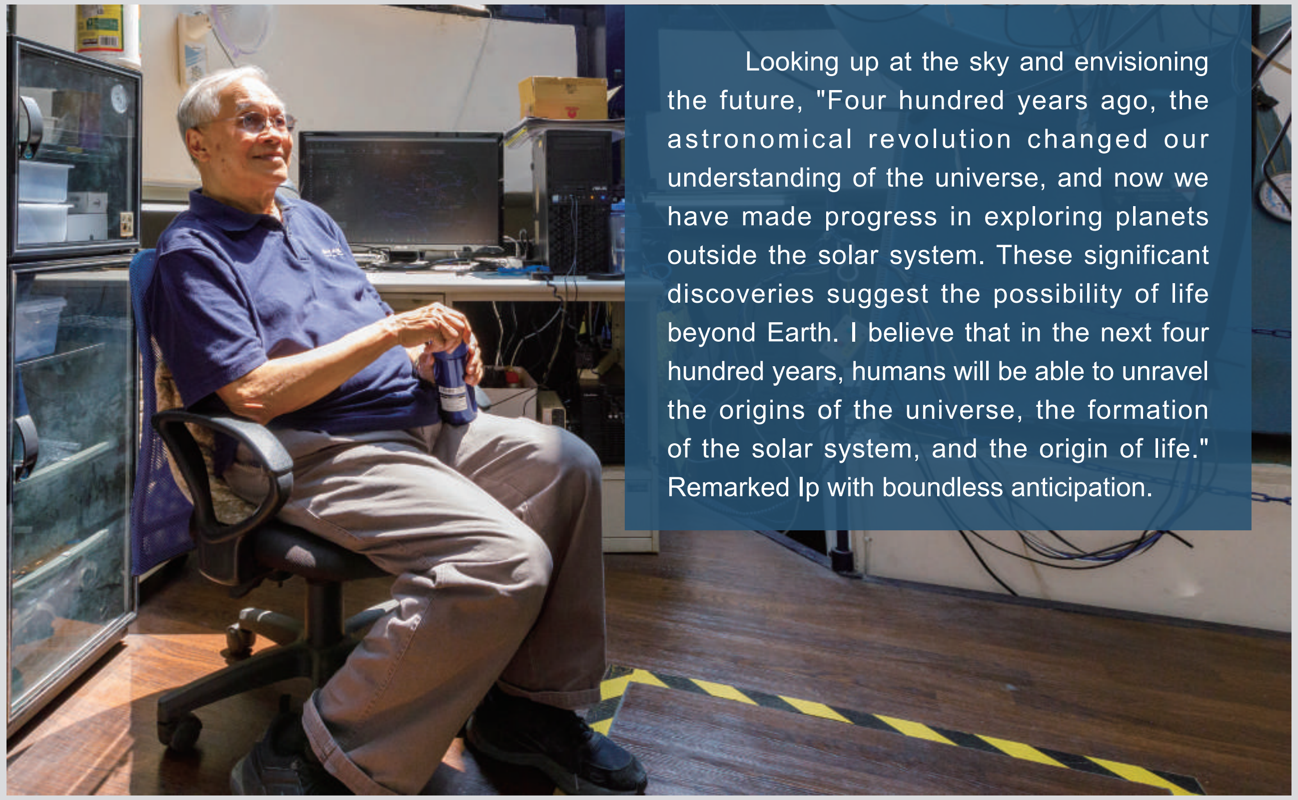
He also urges the educational sector in Taiwan to emphasize the true spirit of literacy education: "Literacy is not just the accumulation of knowledge but, more importantly, the cultivation of the ability to think and solve problems. This applies to both science and other fields of knowledge." He also astutely points out the existing misconception, "Cultivating students with literacy should not aim solely to get them into good universities but to help them find a clear life goal, pursue excellence, and have the courage to change the world."

The Arrival of a Critical Moment – Unraveling the Mysteries of the Solar System and the Origin of Life

For half a century, Ip has been dedicated to research in comets, planetary atmospheres, Earth's upper atmosphere, solar system and planetary formation, and plasma physics, bringing humanity closer to the truths of the cosmos. Regarding his ability to immerse himself in the exploration of the unknown, Ip is deeply grateful to his wife, Da-An Ma, stating, "Because of her support and understanding, I was able to focus on scientific research." He also expresses immense gratitude to his students, saying, "Thank you for your dedication and hard work, which have contributed to numerous achievements that we share together." Of course, the nurturing guidance of his parents provided the initial nourishment for his journey into scientific research.



Scientific research is often a lonely and challenging path, but the next research challenge has aways filled Ip with excitement. Whether as a young scientist just starting out or the esteemed elder of the scientific community today, his curiosity and passion for knowledge have never waned. "Regarding the development of planetary and astronomical science, we are at a critical moment," Ip further explains. Planetary science investigates the origins of planets, while astronomy studies phenomena like black holes and gravitational waves. These two fields had fewer connections with Earth sciences in the past. "However, with advancements in human space exploration, and the possibility of establishing human bases on Mars or other planets, the intersections between planetary science, astronomy, and Earth sciences are increasing because we need to understand elements like the biosphere, atmosphere, oceans, and volcanoes. These are all part of Earth sciences." Ip enthusiastically states, "In the next 20 years, we will witness extensive exploration of the solar system, further searching for signs of oceans and life."



Looking up at the sky and envisioning the future, "Four hundred years ago, the astronomical revolution changed our understanding of the universe, and now we have made progress in exploring planets outside the solar system. These significant discoveries suggest the possibility of life beyond Earth. I believe that in the next four hundred years, humans will be able to unravel the origins of the universe, the formation of the solar system, and the origin of life." Remarked Ip with boundless anticipation.

List of Selected Publications

1. "An interpretation of the dawn-dusk asymmetry of UV emission from the Io plasma torus," W.-H. Ip and C.K. Goertz, Nature, 302, 232-233 (1983)

2. "Some dynamical aspects of the accretion of Uranus and Neptune: The exchange of orbital angular momentum with planetesimals," J.A. Fernandez and W.-H. Ip, Icarus, 58, 109-120, (1984)

3. The formation of a magnetic field-free cavity at comet Halley," W.H. Ip and W.I. Axford, Nature, 325, 418-419 (1987)

4. "The atomic sodium exosphere/coma of the Moon," W.-H. Ip, Geophysical Research Letters, 18(11), 2093-2098 (1991)

5. "Ion sputtering and surface erosion at Europa," W.-H. Ip, D.J. Williams, R.W. McEntire, B.H. Mauk, Geophysical Research Letters, 25(6), 829-832 (1998)

6. "On a ring origin of the equatorial ridge of Iapetus," W.-H. Ip, Geophysical Research Letters, 33, L16203 (2006)

7. "Cassini Ion and Neutral Mass Spectrometer: Enceladus plume composition and structure," J.H. Waite, M.R. Combi, W.-H. Ip, T.E. Cravens, R.L. McNutt, W. Kasprzak, R. Yelle, J. Luhman, H. Niemann, D. Gell, B. Magee, G. Fletcher, J. Lunnie, W.-L. Tseng, Science, 311, 1419-1422 (2006)

8. "The structure and time variability of the ring atmosphere and ionosphere," W.-L. Tseng, W.-H. Ip, R.E. Johnson, T.A. Cassidy, M.K. Elrod, Icarus, 206, 382-389 (2010)

9. "Transport and electrodynamical coupling of nano-grains ejected from the Saturnian rings and their possible ionospheric signatures," W.-H. Ip, C-M. Liu, and K.-C. Pan, Icarus, 276, 163-169 (2016)

10. "Gas outflow and dust transport of comet 67P/Churyumov-Gerasimenko," I.L. Lai, W.-H. Ip, C.C Su, J.S. Wu, J.C. Lee, Z.Y. Lin, Y. Liao, N. Thomas, H. Sierks, et al. Monthly Notices of the Royal Astronomical Society, 462 (Supl_1) S533-S546 (2016).

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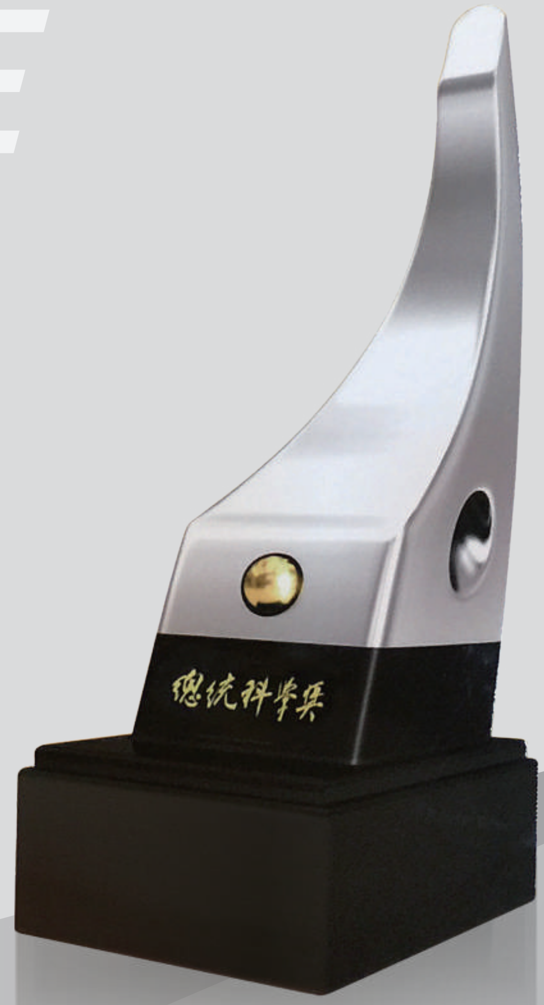

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