Frontiers in Education Technology
Vol. 6, No.1, 2023
www.scholink.org/ojs/index.php/fet
ISSN 2576-1846 (Print) ISSN 2576-1854 (Online)

Original Paper

Classic Experiments in Education Technology

Steven B. Oppenheimer[1]

[1] Department of Biology and Center for Cancer and Developmental Biology, California State University, Northridge, Northridge, CA 91330-8303, USA

Received: February 18, 2023 Accepted: March 3, 2023 Online Published: March 11, 2023

doi:10.22158/fet.v6n1p26 URL: http://dx.doi.org/10.22158/fet.v6n1p26

Abstract

Classic experiments in Biomedicine are presented that inspire students to enthusiastically continue in this field, written by a U.S. Presidential Award winning, American Association for the Advancement of Science Fellow. Four experiments are selected: the structure of DNA, the structure of the cell membrane, sugars in cell adhesion, and unconventional dealing with a deadly cancer problem. Papers, written mostly by students, from the author's lab are also included that support the concept that students will enter a science research field if they are introduced to it by easy to read, enjoyable, papers. Some of the author's papers strongly support one of the Classics presented, the role of sugars in cell adhesion. Using these Classics to teach students at all levels is presented, as the author has used them for decades, helping him win a US Presidential Award for Mentoring and supporting his election as Fellow, American Association for the Advancement of Science (AAAS) (Note 1). This approach helps students to understand the personalities involved in great discoveries, making them unforgettable.

1. Introduction

The author has decades of experience in the 4 selected classics and is therefore qualified to show how they are used and can be used by many folks to excite and inspire students in today's classrooms, pre-college and college.

2. The Structure of DNA

"What Mad Pursuit" is the title of a short book (Note 2, Note 3) written by the late Francis Crick, co-discoverer of the molecular structure of DNA, that won a Nobel Prize in 1962, and has been cited as the greatest advance in life science of the 20th Century.

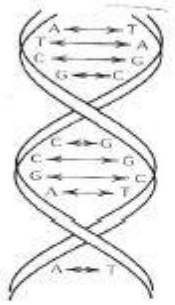
Francis Crick was honorary chair of a program led by me, Steve Oppenheimer, at California State University, Northridge. He visited the university for about 10 years, working with students, colleagues

and staff. He signed autographs and spent hours taking photos with the hundreds of individuals in attendance. What an inspiration!

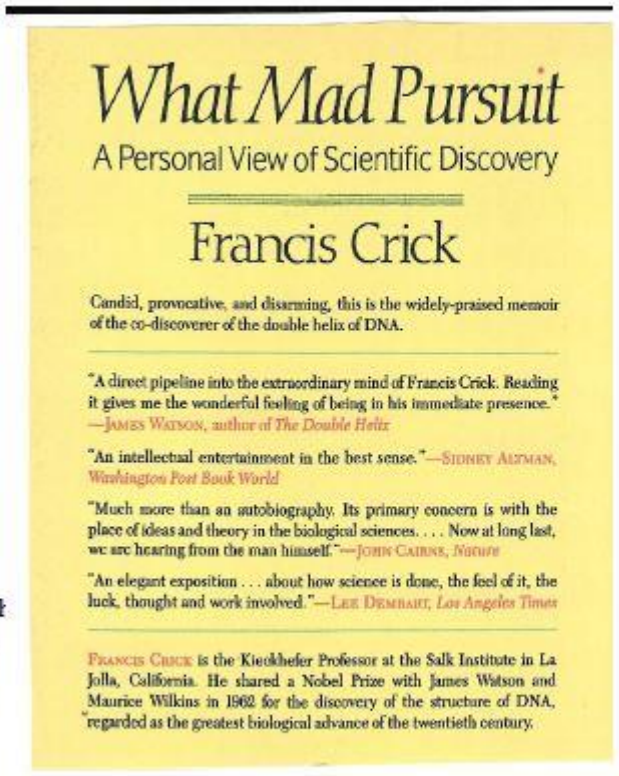
In one of his visits Francis Crick showed the movie Race for the Double Helix (Note 2) before presenting his personal insights into this great discovery. I suggest that everyone see this film. It is the most inspiring movie that I've seen in 50 years. It can be shown in two 50 min parts. It was developed for BBC. It was released initially by Studio Hamburg Enterprises and stars, among others, Jeff Goldblum. What is so important about this movie is that gives us a glimpse of the personalities of the scientists involved. It shows that the structure of DNA was developed by Crick and Watson with the help of others such as Rosalind Franklin. The interplay of Watson and Franklin, for example, is fantastic and unforgettable. There is little doubt that Franklin would have shared the Nobel Prize if she did not pass away before it was awarded. Her x-ray crystallography pattern of DNA was key evidence that led to the concept of DNA as a double helix, an idea developed by Crick before Franklin's x-ray crystallography provided solid evidence.

As for the base pairing, a key clue was provided by Edwin Chargaff, when he told Watson and Crick, that his studies indicated that there was a rough equivalence of the bases A and T and also C and G in cells. This suggested to Watson and Crick that A and T might pair and C and G might pair. The chemical structures of A, T, C and G were drawn and modeled leading to the discovery of how the bases actually paired. The video is a masterpiece but reading Crick's memoir, What Mad Pursuit, only 182 pages long, gives even more detail, What Mad Pursuit was originally published by Basic Books, a Division of Harper Collins Publishers and the Alfred P. Sloan Foundation (ISBN 0-465-09137-7, cloth, ISBN 0-465-09138, paper, sells for $10) (Note 3)

By seeing the film and/or reading the book, students will never forget how the DNA double helix model was developed. Without the film or book, the flavor of the discovery will be hard to understand. Drawings of the double helix DNA model showing base pairing will help. But, of course great teachers can make the DNA story come alive. A purpose of this section is to entice educators to try to get a hold of the movie/and or book. I've used the video in my classes for decades.



DNA double helix showing base pairing A with T and C with G. From Nobel Prize discovery by Crick, Watson and Wilkins. From Oppenheimer, S., Introduction to Embryonic Development, Allyn and Bacon 1980, Boston, p. 296.

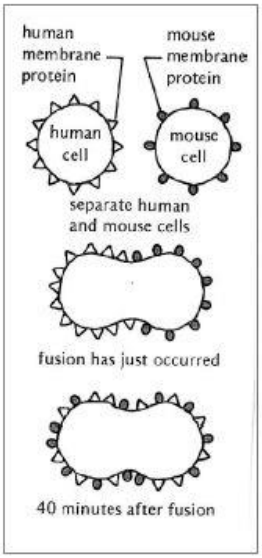


3. The Structure of the Cell Membrane

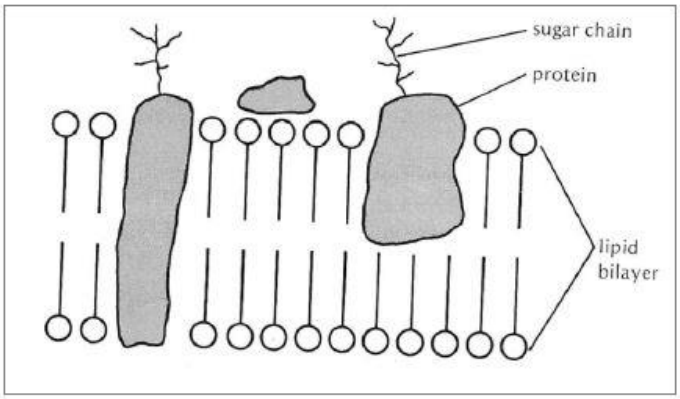
The cell membrane was thought to consist of a lipid bilayer with a protein coating on its outside and inside. The exciting story of the discovery of the modern version of cell membrane structure is another exciting Classic. The story begins with experiments by Larry Frye and Mike Edidin at Johns Hopkins that started around 1970. This was Larry's Ph.D. thesis project. They used mouse cells and human cells and antibodies that bound to membrane proteins in each cell type. Then they used green and red fluorescent dyes to visualize the proteins that were embedded in the cell membranes of each cell type. They then fused the mouse and human cells with Sendai virus (or no virus in some experiments). Right after applying the antibodies and fluorescent stains, the mouse cells were of one color and the human cells fused with the mouse cells were of the other color. But by 40 minutes after fusion the protein antigens of both cell types intermixed (Note 4).

S.J. Singer's and Garth Nicolson's analysis of this intermixing indicated that intermixing of the proteins in the cell surfaces was consistent with lateral diffusion of the proteins in a sea of lipid They presented this analysis in their paper appearing in Science titled the Fluid Mosaic Model of the Structure of the Cell Membrane (Note 5).

These sets of simple experiments are Classics. This is easy to teach. Have the students draw the fluid-mosaic model of the cell membrane and the Frye and Edidin fusion experiment as shown below.



Frye and Edidin Experiment (4) From Oppenheimer,Introduction to Embryonic Development, Allyn and Bacon, 1980, p. 257



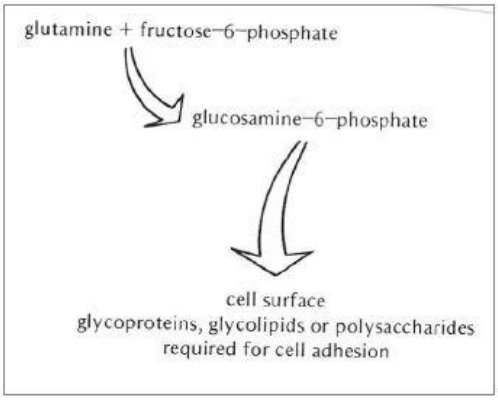
Fluid Mosaic Model of Cell Membrane. Based on Singer and Nicolson(5). From Oppenheimer, Introduction to Embryonic Development, Allyn and Bacon, 1980, p. 38.

4. Sugars in Cell Adhesion

When Larry Frye was doing the human/mouse fusion experiments at Johns Hopkins, Steve Oppenheimer, also at Johns Hopkins, was doing his Ph.D. thesis project with Saul Roseman, Mike Edidin and Charlie Orr that became arguably the first solid evidence for a role of sugars in cell adhesion. This was also a set of Classic experiments of importance in many areas such as cancer spread. Steve found that a group of cells (mouse ascites teratoma cells) adhered to each other when L-glutamine was added to the culture medium, while no other medium component including other amino acids, sugars, vitamins and co-factors caused the cells to adhere (Note 6). Other cell types also responded by adhering with L-glutamine (Note 7). As glutamine is an amino acid, did glutamine act in the formation of adhesive proteins? No. A complex series of experiments showed that L-glutamine donated its amino group to fructose-6-phosphate, forming glucoasamine-6-phosphate. Glucosamine-6-phosphate was the key intermediate in the formation of cell surface sugars in polysaccharides, glycolipids and glycoproteins. This work was published in the Proceedings of the National Academy of Sciences (PNAS) (Note 6). This Classic finding provides an important target in cancer cells, that often possess altered cell adhesion. Experiments from the author's lab are very simple

and will excite students' interest in research science (Notes 1-91). And many experiments from the author's lab support the role of sugars in cell adhesion and cell surface behavioral properties (Notes 5, 6, 7,8, 9,10,11,12,13,14,15,16 16,18 19, 20, 21, 22, 23,24,25, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37 38, 40,41, 42, 43, 44,47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 67, 69, 71, 73, 74, 75, 77, 79, 81, 83, 85, 86, 87, 88, 89).

See the PNAS paper for details of the biochemistry involved in the glutamine reaction (Note 6). Teaching this Classic can be at different levels from simply showing that L-glutamine causes cells to adhere, to the complex biochemistry, using specific inhibitors, that show how glutamine is acting.



Pathway of L-glutamine's role in cell adhesion. Based on Oppenheimer et al.(6). From Oppenheimer, Introduction to Embryonic Development, Allyn and Bacon, 1980, p.367

5. Classic Approach to a Cancer Problem

I've used the Nova video, The Cancer Detectives of Lin Xian, October 7, 1980 (Note 90) for decades in my classes. It, like the Race for the Double Helix, described in part 1 of this paper, is a true Classic but almost nobody knows about the cancer detectives video. This video showcases what was done in China to deal with a cancer that affected the people in Lin Xian in epidemic proportions. The Chinese approached esophageal cancer in a way so different than done in Western nations. This video can inspire new generations of students to tackle big problems, not only by spending billions of dollars on molecular biology, but by a focus on prevention that worked well.

First, the health workers carefully examined the food and drink of the people. They found high levels of nitrite, nitrate, nitrosamines and mold, as well as too low levels of vitamin C in the food that the people ate. They improved food storage and increased vitamin C in food and broadcast the new information to the people. They checked the temperature of the drink and found it was no hotter than what was consumed by people in neighboring regions without high rates of esophageal cancer. The chickens owned by people with high rates of esophageal cancer also had tumors in their gullets. It was believed that the table scraps fed to the chickens might be a cause of the cancer. It will take years to see if any of these dietary improvements lower the rate of esophageal cancer, so the health workers and scientists did not stop at the dietary improvements.

They developed an abrasive balloon that was swallowed by the people and pulled up gently scraping the esophagus. They wiped the balloon on slides that were examined by technicians to see if the scrapings contained cells that were pre-cancerous or cancerous. Medicines were given to people who had pre-cancerous cells to reduce the advance of the cancer. Such people were examined regularly. Those with advanced cancer were offered standard operations with standard anesthesia. In such operations, the cancer in the esophagus was removed and the ends of the esophagus were sewn together. Today, in the West, smoking and heavy alcohol consumption have been added as causes of this cancer. But in the West, little attention is given to early detection strategies, unlike what is done for breast cancer, where frequent checks are made.

China has been doing relatively well in dealing with esophageal cancer. One hospital in China reports an 82.4% decrease in mortality from this cancer from the 1970s to 2018, Five year survival is reported at 92.7%. This report was published by Science/AAAS Custom Publishing Office and presented on page 1 in the December 10, 2021 issue of Science (374, 6573) (Note 91).

This Nova program is as relevant today as it was decades ago. It is a Classic teaching tool. While smoking and heavy alcohol consumption, particularly smoking, have been reduced in the West, nothing like the Chinese multi-factor approach that focuses on prevention has been implemented for esophageal cancer in Western societies. Very few people have seen the Nova video, which is a model for cancer prevention. While billions of dollars spent by the West on molecular biology of cancer, has improved the cancer picture, more effort should be focused on cancer prevention strategies. The Cancer Detectives of Lin Xian is a Classic that should be viewed by all.

6. Conclusions

This paper gives students a depth of understanding of fundamental biology experiments that can not be obtained from standard textbooks or from the usual classroom presentations.

The 4 Classic sets of experiments presented have been used in my classes for up to 50 years and have helped me win a U.S. Presidential Award for Mentoring and election as Fellow of the American Association for the Advancement of Science (AAAS). The election as Fellow of the AAAS recognized my contributions to the Sugars in Cell Adhesion Classic that began with the PNAS paper (Note 6). The video Race for the Double Helix (Note 2) and the book What Mad Pursuit (Note 3) present the personal insights into the Nobel Prize winning discovery of the double helix/base pairing structure of DNA. Students will find that these personal insights give life to the monumental discovery. They will learn that this great discovery included the work of others in addition to Crick and Watson and that the contributions of the scientists involved were instrumental in this major breakthrough. With this approach using Classics students will never forget what went into this major discovery. The discovery of the fluid-mosaic model of the cell membrane was also a collaboration of more than one group and illustrates how a great new model was developed. The Nova program, the Cancer Detectives of Lin Xian (Note 90) is a seminal journey into unconventional approaches to a deadly cancer. Finally, the

scores of mostly student co-authored papers cited here, from the author's lab, make for readings that could inspire new generations of students to enter science research fields. This paper provides new thoughts about areas of study that can be inspirational to students in science and technology. Many of the cited papers deal with the Classic finding of a role of sugars in cell interactions, an area that has not been thought of as a Classic in the past. I believe that election as Fellow AAAS supports the notion that this indeed is a Classic. Hundreds of students took part in the experiments cited here and this contributed to the U.S. Presidential Award for mentoring received by Steve in addition to the AAAS Fellow designation.

Acknowledgements

Thanks to Carolyn Oppenheimer for expert insertion of the figures into this manuscript. My colleagues, the Dean, Chair, Associate Chair, Provost and President provided over 50 years of great support.

Notes

Note 1. Oppenheimer, S, A Model for Enhancing the Science Workforce, Frontiers in Education Technology, Vol. 5, No 1, pp. 29-60 (2022).

Note 2. Studio Hamburg Enterprises, BBC Video, Race for the Double Helix, April 27, 1987.

Note 3. Crick, F., What Mad Pursuit, Basic Books, 1988, 182 pages.

Note 4. Frye, L.D., M. Edidin, The Rapid Intermixing of Cell Surface Antigens After Formation of Mouse-Human Heterokaryons, J. Cell Sci 7, pp. 319-335 (1970).

Note 5. Singer, S.J., G.L. Nicolson, The Fluid Mosaic Model of the Structure of the Cell Membrane, Science 175, pp. 720-731 (1972).

Note 6. Oppenheimer, S. B., M. Edidin, C.W. Orr, and S. Roseman, An L-Glutamine Requirement for Intercellular Adhesion, Proc, Nat. Acad. Sci. U.S., 63: pp. 1395-1402 (1969).

Note 7. Oppenheimer, S. Utilization of L-Glutamine in Intercellular Adhesion: Ascites Tumor and Embryonic Cells, Exp. Cell Res. 77, pp. 175-182 (1983).

Note 8. Smith, T., Oppenheimer, S.B., Involvement of L-rhamnose in Sea Urchin Gastrulation: A Live Embryo Assay, Zygote, doi:10.1017/S0967199413000452 (2013)

Note 9. Singh, S., Karabidian, E., Kandel, A., Metzenberg, S., Carroll, Jr.E., Oppenheimer, S.B., A Role for Polyglucans in a Model Sea Urchin Embryo Cellular Interaction, Zygote doi:10.1017/S0967199413000038 (2013)

Note 10. Ghazarian, H, B.Idoni, S.Oppenheimer. . A Glycobiology Review: Carbohydrates, Lectins, and Implications in Cancer Therapeutics). Acta Histochemica, vol. 113, pages 236-247 (2011) PMCID PMC3027850. On the order of 10,000 downloads. One of the most of all time.

Note 11. Dreyfuss, J. and S. Oppenheimer. Cyclodextrins and cellular interactions in E. Bilensoy, ed., Cyclodextrins in Pharmaceutics, Cosmetics, and Biomedicine, Current and Future Industrial Applications, John Wiley and Sons, Hoboken, N.J., Chapter 15, pp. 287-295. (2010)

Note 12. Idoni, B. H.Ghazarian, S.Metzenberg, V.Hutchins-Carroll, S.Oppenheimer, and E.Carroll Jr. Use of Specific Glycosidases to Probe Cellular Interactions in the Sea Urchin Embryo. Experimental Cell Research, vol. 316, pp. 2204-2211 (2010) PMCID PMC2921930

Note 13. Alvarez, M., Nnoli, J., Carroll, E.J., Jr., Hutchins-Carroll, V., Razinia, Z., Oppenheimer, S.B., Exogenous Hyalin and Sea Urchin Gastrulation, Part II: Hyalin, An Interspecies Cell Adhesion Molecule, Zygote 16: 73-78 (2008). PMCID PMC2557437

Note 14. Carroll, E.J., Jr., Hutchins-Carroll, V., Coyle-Thompson, C., Oppenheimer, S.B., Hyalin is a Cell Adhesion Molecule Involved in Mediating Archenteron-Blastocoel Roof Attachment, Acta Histochemica 110: 265-275 (2008). PMID 18262230

Note 15. Contreras, A., Vitale, J., Hutchins-Carroll, V., Carroll, E.J., Oppenheimer, S.B., Exogenous Hyalin and Sea Urchin Gastrulation. Part III: Biological Activity of Hyalin Isolated from Lytechinus pictus embryos, Zygote 16: 355-361 (2008). PMCID PMC2586997

Note 16. Oppenheimer,S.B., Alvarez, M., Nnoli, J.,Carbohydrate-Based Experimental Therapeutics for Cancer, HIV/AIDS and Other Diseases, Acta Histochemica 110: 6-13 (2008). PMCID PMC2278011

Note 17. Oppenheimer, S.B., Cellular Basis of Cancer Metastasis: A Review of Fundamentals and New Advances, Acta Histochemica, 108: 327-334 (2007). This paper garnered the most downloads of all papers in this Elsevier journal, August 06-March 07 (813 downloads). PMID16730054

Note 18. Petrossian, K., Banner, L., Oppenheimer, S.B., Lectin Binding and Lectin Effects on Human Cancer and Non-Cancer Cell Lines: Examination of Issues of Interest in Drug Design Strategies, Acta Histochemica 109: 491-500 (2007).

Note 19. Razinia, Z., Carroll, Jr., E.J., Oppenheimer, S.B., Microplate Assay for Quantifying Developmental Morphologies: Effects of Exogenous Hyalin on Sea Urchin Gastrulation, Zygote 15: 1-6 (2007).

Note 20. Sajadi, S., Rojas, P., Oppenheimer, S.B., Cyclodextrin, A Probe for Studying Adhesive Interactions, Acta Histochemica 109: 338-342 (2007). PMCID PMC 1988679

Note 21. Zem, G.C., Badali, O., Gaytan, M. Hekmatjou, H., Alvarez, M., Nnoli, J., Katus, E., Oppenheimer, S.B., Microbead Analysis of Cell Binding to Immobilized Lectin: An Alternative to Microarrays in the Development of Carbohydrate Drugs and Diagnostic Tests, Acta Histochemica 108: 311-317 (2006).

Note 22. Ghazarian, H.,Coyle-Thompson, C., Dalrymple, W., Hutchins-Carroll, V., Metzenberg, S., Razinia, Z., Carroll, Jr., E.J., Oppenheimer, S.B., Exogenous Hyalin and Sea Urchin Gastrulation, Part IV: a Direct Adhesion Assay- Progress in Identifying Hyalin's Active Sites, Zygote 18: 17-26 (2010). PMCID PMC2817981

Note 23. Oppenheimer, S. & Meyer, J. (1982). Carbohydrate specificity of sea urchin blastula adhesion component, Experimental Cell Research, 139, 451-456.

Note 24. Idoni, B., Ghazarian, H., Metzenberg, S., Hutchins-Carroll, V, Carroll, Jr., E., & Oppenheimer, S. (2010). Use of specific glycosidases to probe cellular interactions in the sea urchin embryo. Experimental Cell Research, 316, 2204-2211.

Note 25. Liang, J., Aleksanyan, H., Metzenberg, S., & Oppenheimer, S. (2016). Involvement of L-rhamnose in sea urchin gastrulation. Part II: alpha rhamnosidase, Zygote 24, 37-377.

Note 26. K. Crocker, J. Deleon, L. Telliyan, K.Aprelian, A. Rosenberg, N. Pouri, G. Beltran, V. Ramirez, D. Kaufman, A. Petrosyan, D. Nazarian, M. Magistrado, S. Matinian, D. Hanna, S. Eskandari, F. Atanante, A. Nerses, G. Zem, S. Oppenheimer, A Kinetic Assay for Drug Discovery: Part 2, Sodium Sulfate American Journal of Applied Scientific Research 2020; 6(2): 39-42 http://www.sciencepublishinggroup.com/j/ajasr doi: 10.11648/j.ajasr.20200602.12 ISSN: 2471-9722 (Print); ISSN: 2471-9730 (Online)

Note 27. V. Nahapetyan, S. Delos Santos, K. Crocker, D.Tobar, D.Nazarian, H. Chirishyan, G.Beltran, R. Dubin, L. Reque, P. Singh, B. Cardona, G. Royce Bachinela, L. Sarkisyan, G. Zem, S. Oppenheimer, A manual kinetic assay in a fixed yeast model for drug discovery American Journal of Applied Scientific Research 5, No1: 28-35. Doi 10.11648/j.ajasr.20190501.15 (2019).

Note 28. Aleksanyan, H., Liang, J., Metzenberg, S., Oppenheimer, S. B., Terminal alpha-D-mannosides are critical during sea urchin gastrulation, Zygote doi: 10.1017/SO967199416000113 (2016).

Note 29. A. Ghazarian, Oppenheimer, S, Microbead analysis of cell binding to immobilized lectin. Part II: quantitative kinetic profile assay for possible identification of anti-infectivity and anti-cancer reagents http://dx.doi.org/10.1016/j.acthis.2014.07.015, Acta Histochemica 116 (2014) 1514-1518.

Note 30. Singh, E. Karabidian, A. Kandel, S. Metzenberg, E. Carroll, Jr,. S. Oppenheimer, A role for polyglucans in a model sea urchin embryo cellular interaction, Zygote (Cambridge University Press), (2013), doi.10.1017/S096719943000038 (2013).

Note 31. H. Ghazarian, C. Coyle-Thompson, Dalrymple, V. Hutchins-Carroll, S. Metzenberg, Z. Razinia, E. Carroll, Jr., S. Oppenheimer, Exogenous Hyalin and Sea Urchin Gastrulation, Part IV: a Direct Adhesion Assay – Progress in Identifying Hyalin's Active Sites Zygote 18: 17-26 (2010).

Note 32. A. Contreras, Vitale, V. Hutchins-Carroll, E. Carroll, Jr, S. Oppenheimer, Exogenous Hyalin and Sea Urchin Gastrulation, Part III: Biological Activity of Hyalin Extracted from Lytechinus pictus embryos Zygote, vol. 16, pp. 355-361 (2008).

Note 33. E. Carroll, Jr., V. Hutchins-Carroll, C.Coyle Thompson, S. Oppenheimer, Hyalin is a Cell Adhesion Molecule Involved in Mediating Archenteron Blastocoel Roof Attachment, Acta Histochemica, vol. 110, pp. 265-275 (2008).

Note 34. M. Alvarez, J. Nnoli, E. Carroll, Jr., V. Hutchins-Carroll, Z. Razinia, S. Oppenheimer, Exogenous Hyalin and Sea Urchin Gastrulation, Part II: Hyalin, An Interspecies Cell Adhesion Molecule, Zygote, vol. 16, pp. 73-78 (2008).

Note 35. M. Alvarez, J. Nnoli, S. Oppenheimer, Carbohydrate-Based Experimental Therapeutics for Cancer, HIV/AIDS and Other Diseases, Acta Histochemica, vol. 110, pp. 6-13 (2008).

Note 36. K. Petrossian, L.Banner, S.Oppenheimer, Lectin Binding and Effects in Culture on Human Cancer and Non-Cancer Cell Lines: Examination of Issues of Interest in Drug Design Strategies, Acta Histochemica, vol 109, pp. 491-500 (2007).

Note 37. Z. Razinia, E. Carroll, Jr, S. Oppenheimer, Microplate Assay for Quantifying Developmental Morphologies: Effects of Exogenous Hyalin on Sea Urchin Gastrulation, Zygote, vol 15, pp. 1-6 (2007).

Note 38. S. Sajadi, Rojas, S. Oppenheimer Cyclodextrin, A Probe for Studying Adhesive Interactions, Acta Histochemica, vol. 109, pp. 338-342 (2007).

Note 39. S. Oppenheimer, Cellular Basis of Cancer Metastasis: A Review of Fundamentals and New Advances Acta Histochemica, vol. 108, pp. 327-334 (2006).

Note 40. G. Zem, O. Badali, Gaytan, Hekmatjou, M. Alvarez, J. Nnoli, Katus, S. Oppenheimer, Microbead Analysis of Cell Binding to Immobilized Lectin: An Alternative to Microarrays in the Development of Carbohydrate Drugs and Diagnostic Tests, Acta Histochemica, vol. 108, pp. 311-317 (2006).

Note 41. L. Welty, E. Heinrich, C. Garcia, L. Banner, M. Summers, L. Baresi, S. Metzenberg, C Coyle-Thompson, S. Oppenheimer, Analysis of Unconventional Approaches for the Rapid Detection of Surface Lectin Binding Ligands on Human Cell Lines Acta Histochemica, vol. 107, pp. 411-420 (2006).

Note 42. C. Coyle-Thompson, S. Oppenheimer, A Novel Approach to Study Adhesion Mechanisms by Isolation of the Interacting System, Acta Histochemica, vol. 107, pp. 243-251 (2005).

Note 43. E.Heinrich, L. Welty, L. Banner, S. Oppenheimer, Direct Targeting of Cancer Cells: A Multiparameter Approach, Acta Histochemica, vol. 107, pp. 335-344 (2005).

Note 44. M. Khurrum, Hernandez, Eskalaei, O. Badali, C. Coyle-Thompson, S. Oppenheimer, Carbohydrate Involvement in Sea Urchin Gastrula Cellular Interactions Acta Histochemica, vol. 106, pp. 97-106 (2004).

Note 45. M.Maldonado, G. Weerasinghe, F.Ambroise, Yamoah, M. Londono, J. Pelayo, Grigorian, S. Oppenheimer, The Charged Milieu: A Major Player in Fertilization Reactions, Acta Histochemica, vol. 106, pp. 3-10 (2004).

Note 46. L. Ngo, M. Barajas, G. Weerasinghe, G. Zem, S. Oppenheimer, A New Histochemical Approach for Studying Sperm Cell Surfaces, Acta Histochemica, vol. 105, pp. 21-28 (2003).

Note 47. M. Khurrum, G. Weerasinghe, E. Soriano, R. Riman, O. Badali, S. Gipson, Medina, Alfaro, V. Navarro, C. Harieg, L. Ngo, T. Sakhakorn, L. Kirszenbaum, Khatibi, Abedi, M. Barajas, G. Zem, A. Kirszenbaum, Razi, S. Oppenheimer, Analysis of Surface Properties of Human Cancer Cells Using Derivatized Beads, Acta Histochemica, vol. 104, pp. 217-223 (2002).

Note 48. V. Navarro, S. Walker, O. Badali, Abundis L. Ngo, G. Weerasinghe, M. Barajas, G. Zem, S. Oppenheimer, Analysis of Surface Properties of Fixed and Live Cells Using Derivatized Agarose Beads, Acta Histochemica, vol. 104, pp. 99-106 (2002).

Note 49. B. Salbilla, H. Vaghefi, Chhabra, Hall, Bworn, Sadoughi, E.Francisco, L. Attas, S. Walker, Nguyen, S. Oppenheimer, Analysis of Cell Surface Properties Using Derivatized Agarose Beads Acta histochemica, Vol. 101, pp. 271-279 (1999).

Note 50. V. Latham, S. Oppenheimer A Simple Image Analysis Method for Evaluating Cell Binding to Derivatized Beads Acta histochemica, Vol. 101, pp. 263-270 (1999).

Note 51. V. Latham, M. Tully, S. Oppenheimer A Putative Role for Carbohydrates in Sea Urchin Gastrulation Acta histochemica, Vol. 101, pp. 293-303 (1999).

Note 52. V.Latham, L. Latham, S. Oppenheimer, Desktop Computer-Based Image Analysis of Cell Surface Fluorescence Patterning from a Photographic Source Acta histochemica, vol. 98, pp. 295-300 (1996).

Note 53. J. Philip, Rodriguez, R.Bada, F. Ambroise and Hernandez, S. Oppenheimer, Charge Interactions in Sperm-Egg Recognition , Acta histochemica, Vol. 99, pp. 401-410 (1997).

Note 54. Ghoneum, Vojdani, A. Banionis, Lagos and Gill, S. Oppenheimer, The Effects of Carcinogenic Methylcholanthrene on Carbohydrate Residues of NK cells Toxicology and Industrial Health, Vol. 13, No. 6, pp. 727-741, 1997.

Note 55. V. Latham, Martinez, L. Cazares, Hamburger M. Tully, S. Oppenheimer, Accessing the Embryo Interior Without Microinjection, Acta histochemica, Vol. 100, pp. 193-200 (1998).

Note 56. R. Roque, S. Herrera,Yeh,. J. Philip,T. Borisavljevic,L. Brunick, Miles, Haritunians, C. Addy, R. Bada, H. Vaghfi, S. Matsumoto, G. Picionelli and Rodriquez, S. Oppenheimer, Cell Adhesion Mechanisms: Modeling Using Derivatized Beads and Sea Urchin Cell Systems, Acta histochemica, Vol. 98, pp. 441-451 (1996).

Note 57. M. Daily,V. Latham,C. Garcia, C. Hockman, H. Chun, M. Oppenheimer, S. West, K. Rostamiani, R.Chao, E. Pollock, S. Oppenheimer, Producing Exposed Coat-Free Embryos, Zygote, Vol. 2, pp. 221-225 (1994).

Note 58. M. Spiegler, S. Oppenheimer, Extending the Viability of Sea Urchin Gametes, Cryobiology, Vol. 32, pp. 168-174 (1995).

Note 59. V. Latham, J. Ducut, K. Rostamiani, H. Chun, Lopez, S. Herrera, S. Oppenheimer, A Rapid Lectin Receptor Binding Assay: Comparative Evaluation of Sea Urchin Embryo Cell Surface Lectin Receptors, Acta histochemica, Vol. 97, p. 89-97 (1995).

Note 60.V. Latham, S. Herrera, K. Rostamiani, H. Chun, S. Oppenheimer, Rapid Identification of Lectin Receptors and Their Possible Function in Sea Urchin Cell Systems, Acta histochemica, Vol.97, pp. 373-382 (1995).

Note 61. M. Ghoneum, A. Banionis, Gill and Romero, S. Oppenheimer, Demonstration of Involvement of Mannose Residues on NK Cell Cytotoxicity using Lectin - Coupled Beads, Natural Immunity and Cell Growth Regulation, 10:132(1991).

Note 62. S. Oppenheimer, Biology and Cultivation of Teratoma Cells, in Tests of Teratogenicity in Vitro, North Holland, Amsterdam, pp. 261-274.

Note 63. S. Oppenheimer, Human Made Carcinogens vs. Natural Food Carcinogens: Which Post the Greatest Cancer Risk? American Clinical Products Review, Vol. 4, No. 2, pp. 16-19, February 1985.

Note 64. S. Oppenheimer, Cancer and Stress, Longevity Letter, 2(6): 3, 1984.

Note 65. S. Oppenheimer, Carcinogens in Food and Water, Longevity Letter, 2(9): 2-3, 1984.

Note 66. S. Oppenheimer Carcinogens in the Home, Longevity Letter, 3(5), 2-4, May 1985.

Note 67. S. Oppenheimer, Preventing Cancer, American Longevity 1 (no.1), pp. 1-5, 1983.

Note 68. Meyer, P. Thompson, R. Behringer, R. Steiner, Saxton, S. Oppenheimer, Protease Activity Associated with Loss of Adhesiveness in Mouse Teratocarcinoma Exp. Cell Res., 143, pp. 63-70, 1983.

Note 69. Meyer, S. Oppenheimer, Carbohydrate Specificity of Sea Urchin Blastula Adhesion Component, Exp. Cell. Res., 139, pp. 451-456. 1982.

Note 70. S. Oppenheimer Causes of Cancer: Gene Alteration Versus Gene Activation, Amer. Lab., pp. 40-46, November 1982.

Note 71. J. Meyer, S. Oppenheimer Isolation of Species-specific and Stage-specific Adhesion Promoting Component by Disaggregation of Intact Sea Urchin Embryo Cells, Exp. Cell Res., 137, pp. 471-476, 1982.

Note 72. C. Capelle, J. Meyer, S. Sorensen, S. Oppenheimer Isolation of Aggregation Inhibitory Factor from Non-Adhesive Mouse Teratoma Cells, Exp. Cell Res., 131, pp. 470-476, 1981.

Note 73. W. Childress, Freedman, C. Koprowski, Doolittle and P. Sheeler, S. Oppenheiimer, Surface Characteristics of Separated Subpopulations of Mouse Teratocarcinoma Cells, Exp. Cell Res., 122, pp. 39-45, 1979.

Note 74. M. Grodin, Nystrom, J. Scordato, M. Cantor, S. Oppenheimer, Relationship of Adhesiveness of Cells in Culture with Specific Enzyme Activity, Exp. Cell Res., 122, pp. 149-157, 1979.

Note 75. M. Asao, S. Oppenheimer, Inhibitor of Cell Aggregation by Specific Carbohydrates, Exp. Cell. Res., 120, pp. 149-157, 1979.

Note 76. S. Oppenheimer Introduction to the Symposium and Studies on the Surfaces of Separated and Synchronized Tumor and Embryonic Cell Populations. American Zoologist, 19, pp. 801-808, 1979.

Note 77. S. Oppenheimer, Cell Surface Carbohydrates in Adhesion and Migration. American Zoologist, 18, pp. 12-23, 1978.

Note 78. B. Bales, Brenneman, L. Knapp, Lesin, A.Neri , E.Pollock, S. Oppenheimer, Modulation of Agglutinability by Alteration of the Surface Topography in Mouse Ascites Tumor Cells Exp. Cell Res., 105, pp. 291-300, 1977.

Note 79. B. Bales, Lesin, S. Oppenheimer On Cell Membrane Lipid Fluidity and Plant Lectin Agglutinability: A Spin Label Study of Mouse Ascites Tumor Cells, Biochemica et Biophysica Acta, 465, pp. 400-407, 1977.

Note 80. J. Meyer, S. Oppenheimer, The Multicomponent Nature of Teratoma Cell Adhesion Factor, Exp. Cell Res., 102, pp. 359-364, 1976.

Note 81. A. Neri, M. Roberson, D. Connolly, S. Oppenheimer Quantitative Evaluation of Concanavalin A Receptor Site Distributions on the Surfaces of Specific Populations of Embryonic Cells, Nature, 258, pp. 342-344, 1975.

Note 82. R. Potter M. Barber, S. Oppenheimer Alteration of Sea Urchin Embryo Cell Surface Properties by Mycostatin, a Sterol Binding Antibiotic, Developmental Biology, 33, pp. 218-223.

Note 83. S. Oppenheimer J. Odencrantz, A Quantitative Assay for Measuring Cell Agglutination: Agglutination of Sea Urchin Embryo and Mouse Teratoma Cells by Concanavalin A, Exp. Cell Res., 73, pp. 475-480, 1972.

Note 84. S. Oppenheimer, T.Humphreys Isolation of Specific Macromolecules Required for Adhesion of Mouse Tumor Cells, Nature, 232, pp. 125-127, 1971.

Note 85. D. Connolly, S. Oppenheimer, Cell Density-Dependent Stimulation of Glutamine Synthetase Activity in Cultured Mouse Teratoma Cells, Exp. Cell Res., 94, pp. 459-464, 1975.

Note 86. M. Roberson, A.Neri, S. Oppenheimer), Distribution of Concanavalin A Receptor Sites on Specific Populations of Embryonic Cells, Science, 189, pp. 639-640, 1975.

Note 87. S. Oppenheimer Functional Involvement of Specific Carbohydrates in Teratoma Cell Adhesion Factor, Exp. Cell Res., 92, pp. 122-126, 1975.

Note 88. M. Roberson, S. Oppenheimer Quantitative Agglutination of Specific Populations of Sea Urchin Embryo Cells with Concanavalin A Exp. Cell Res. 91, pp. 263-268, 1975.

Note 89. K. Krach, A. Green G. Nicolson, S. Oppenheimer, Cell Surface Changes Occurring During Sea Urchin Embryonic Development Monitored by Quantitative Agglutination with Plant Lectins, Exp. Cell Res., 84, pp. 191-198, 1974.

Note 90. Nova, The Cancer Detectives of Lin Xian, October 7, 1980.

Note 91. Fourth Hospital of Hebei Medical University 2021, Esophageal Cancer Report, Science/AAAS Custom Publishing Office, Science 374 (6573), Dec 10, 2021, p. 1.