[illegible]

[illegible]2021[illegible]6[illegible]

[illegible]

■[illegible]

- [illegible]HTML[illegible]PDF[illegible]

■[illegible]

- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]
- [illegible]HTML[illegible]PDF[illegible]

■[illegible]

- [illegible]HTML[illegible]PDF[illegible]

■[illegible]

- [illegible]—[illegible]HTML[illegible]PDF[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]IUPAC[illegible]

[illegible]

[illegible]NARST[illegible]

mhchiu@gapps.ntnu.edu.tw

[illegible]2003[illegible]SARS[illegible]2019[illegible]5[illegible]15[illegible]5[illegible]19[illegible]5[illegible]17[illegible]5[illegible]28[illegible]5[illegible]18[illegible]6[illegible]7[illegible]6[illegible]28[illegible]7[illegible]2[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

hueiying.ho@gmail.com

n [illegible]

[illegible]1760~1840[illegible]1769[illegible]1870~1914[illegible]1831[illegible]1920~[illegible]1939~1945[illegible]1945[illegible]

[illegible]…[illegible]1959[illegible]12[illegible]Richard Feynman[illegible]There’s Plenty of Room at the Bottom[illegible]

n [illegible]K-12[illegible]

2000[illegible]12[illegible]2001[illegible]1[illegible]2003[illegible]2003[illegible]2009[illegible]2009[illegible]2015[illegible]K-12[illegible]K-12 [illegible]K-12[illegible]photonic crystal[illegible]lotus effect[illegible]gecko effect[illegible]self-assembly[illegible]

n [illegible]

[illegible]2015[illegible]2015[illegible]

[illegible]—[illegible]K-12[illegible]

[illegible]POE[illegible]POE[illegible]

[illegible]K-12[illegible]108[illegible]—[illegible]—[illegible]—[illegible]K-12[illegible]—[illegible]K-12[illegible]—[illegible]2014a, b, c, d[illegible]2016a, b, c, d[illegible]K-12[illegible]K-12[illegible]2014a, b, c, d[illegible]2016a, b, c, d[illegible]—[illegible]Lotus effect[illegible]—[illegible]

n [illegible]

[illegible]2014a[illegible]**K-2**[illegible]K-12[illegible](ISBN[illegible]978-986-04-1575-9)

[illegible]2014b[illegible]**K-2**[illegible]K-12[illegible](ISBN[illegible]978-986-04-1576-6)

[illegible]2014c[illegible]K-12[illegible](ISBN[illegible]978-986-04-1582-7)

[illegible]2014d[illegible]K-12[illegible](ISBN[illegible]978-986-04-1581-0)

[illegible]2016a[illegible]K-12[illegible](ISBN[illegible]978-986-04-5288-4)

[illegible]2016b[illegible]K-12[illegible](ISBN[illegible]978-986-04-5287-7)

[illegible]2016c[illegible]K-12[illegible](ISBN[illegible]978-986-04-5286-0)

[illegible]2016d[illegible]K-12[illegible]

[illegible](ISBN[illegible]978-986-04-5285-3)

[illegible]2014a[illegible]K-12[illegible](ISBN[illegible]978-986-04-1577-3)

[illegible]2014b[illegible]K-12[illegible](ISBN[illegible]978-986-04-1578-0)

[illegible]2014c[illegible]K-12[illegible](ISBN[illegible]978-986-04-1580-3)

[illegible]2014d[illegible]K-12[illegible](ISBN[illegible]978-986-04-1579-7)

[illegible]2016a[illegible]**K-2**[illegible]K-12[illegible](ISBN[illegible]978-986-04-5282-2)

[illegible]2016b[illegible]**K-2**[illegible]K-12[illegible](ISBN[illegible]978-986-04-5280-8)

[illegible]2016c[illegible]K-12[illegible](ISBN[illegible]978-986-04-5284-6)

[illegible]2016d[illegible]K-12[illegible](ISBN[illegible]978-986-04-5283-9)

[illegible] [illegible]

[illegible]

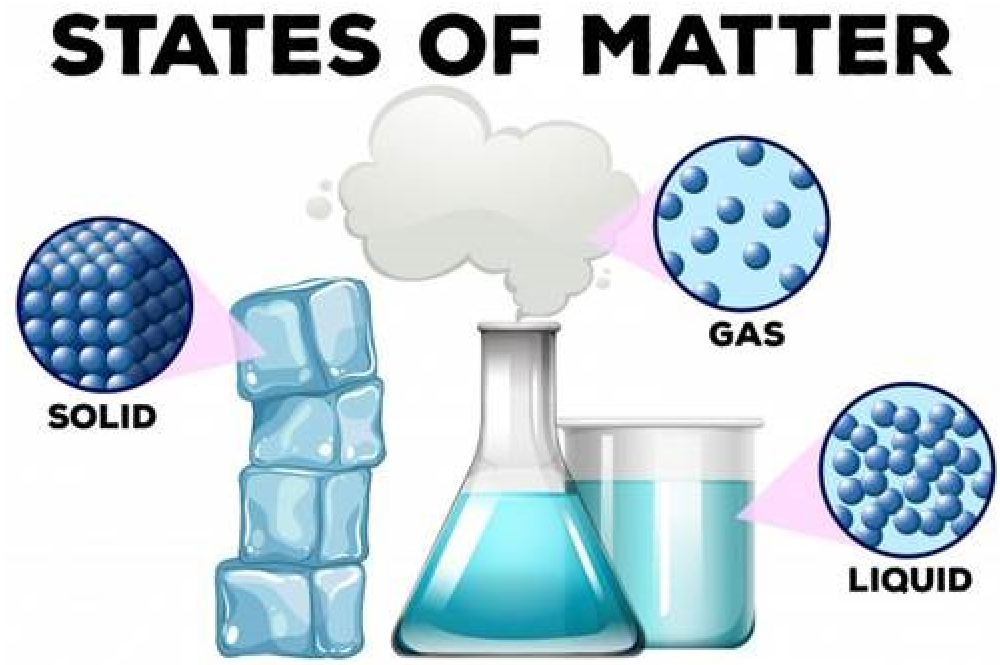
[illegible]

[illegible] [illegible] [illegible]

huiyuchen@nchu.edu.tw

[illegible]100[illegible]0[illegible]

[illegible]([illegible])[illegible]1[illegible]



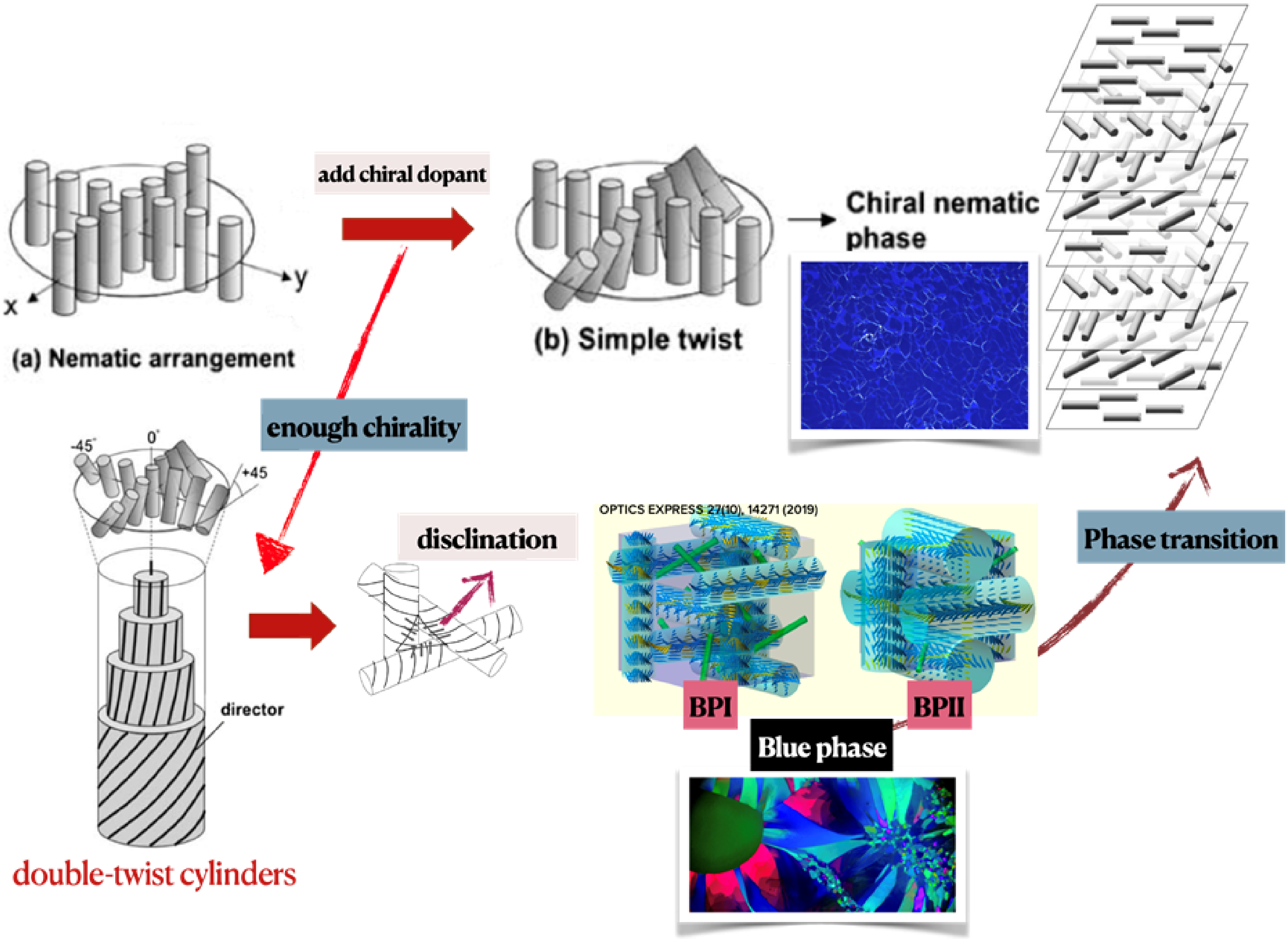
[illegible]1 [illegible] [illegible]Solid: [illegible]Liquid: [illegible]Gas: [illegible])[illegible]
[illegible]freepik[illegible]

[illegible]—[illegible]Liquid Crystal[illegible]1[illegible]YouTube: What are liquid crystals? https://youtu.be/MuWDwVHVLio[illegible]

[illegible](nematic phase)[illegible](cholesteric

liquid crystal)□□□
□□
□□□(blue phase)□□2007□□

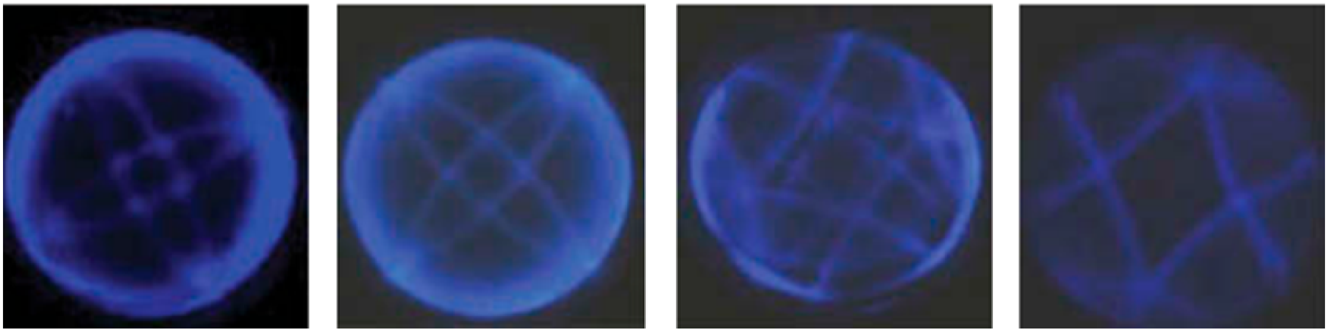
□□□□□□□□□□□□□□□□□□□□□□(double-twist cylinder, DTC)□□DTC□□±45□□2□□



□2 (a) □□□□□□□□□□——□□□□□(Nematic LC)□□□(b) □□□□□□□□chiral matter□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□chiral nematic LC□□(double-twist cylinder)□□□

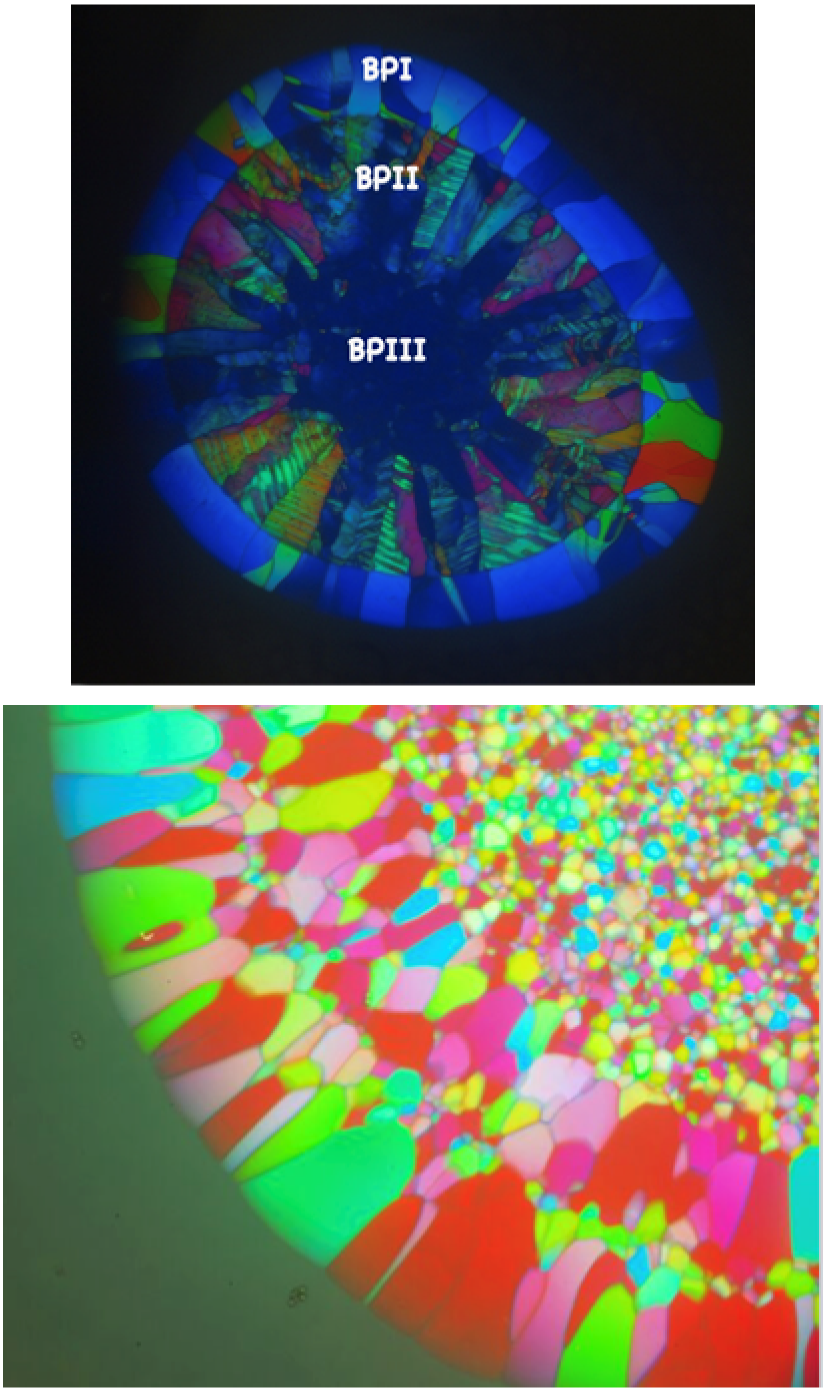
□□
□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

□□□□□□□□□□□□□□□□□□□□□□□□2π□□□□□□□(pitch)□□□□□500nm□□phase transition□□□BP III□BP II□BP I□□□□BP I□BP II□□□□□□□□□□□□□□□□□□□□□□□□□□□□□BP I □□□□□□□(body-centered cubic)□BP II□□□□□□□(simple cubic) □□□□□□□□□□□BPIII□□□□□□□□□□□□□□□□□□□□□(□□□□□□□□~0.1°C)□□□□□□□□□□□□□□□□□□□□□□□□□□BPIII□□□□□□□□□□□□□(foggy blue)□□3□□

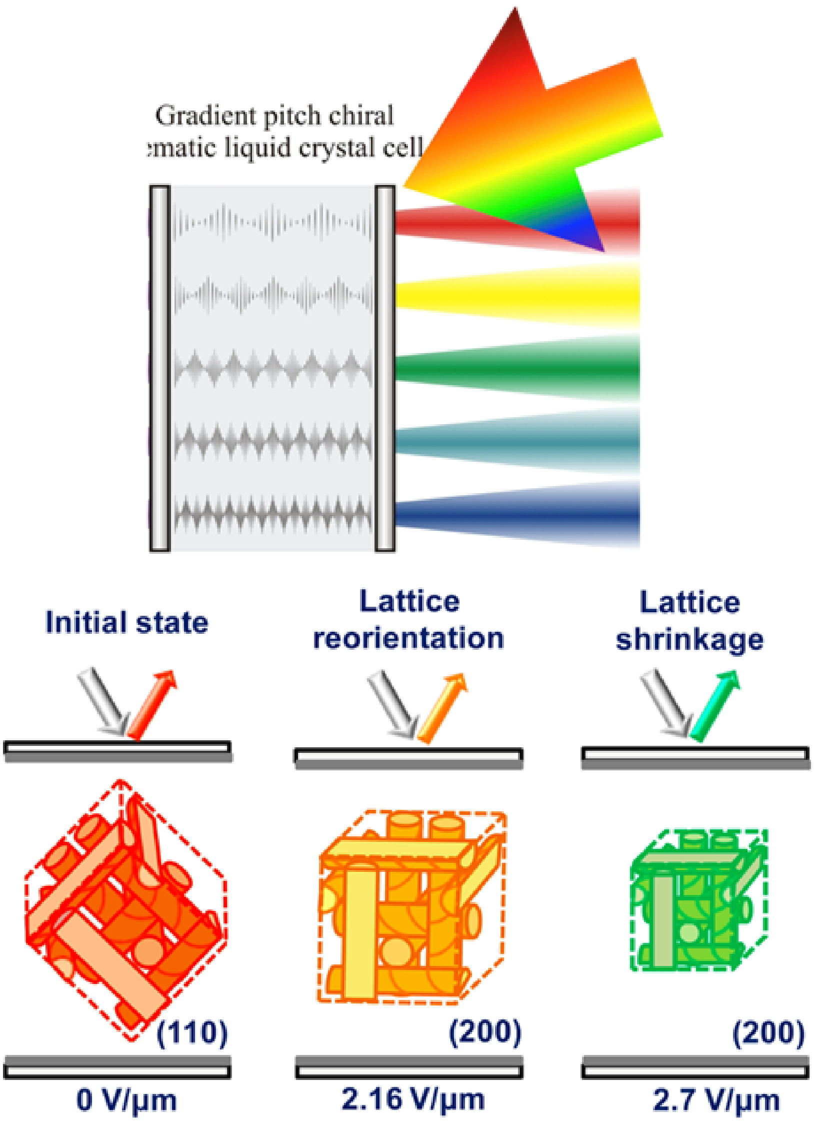


□3 □□

□□□nm□□4□5□□□



[illegible]4 [illegible]

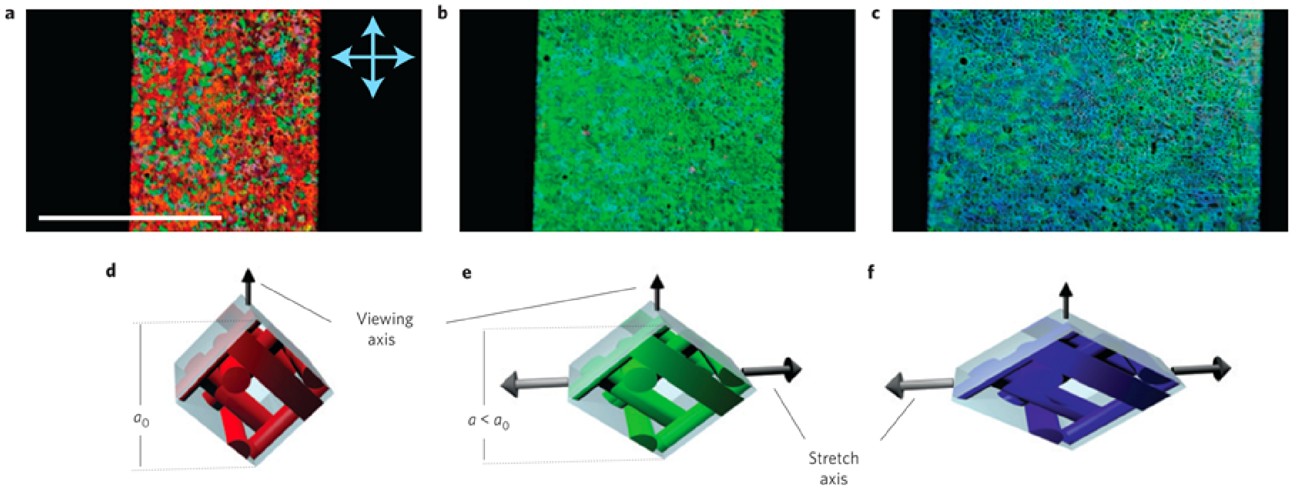


(a)

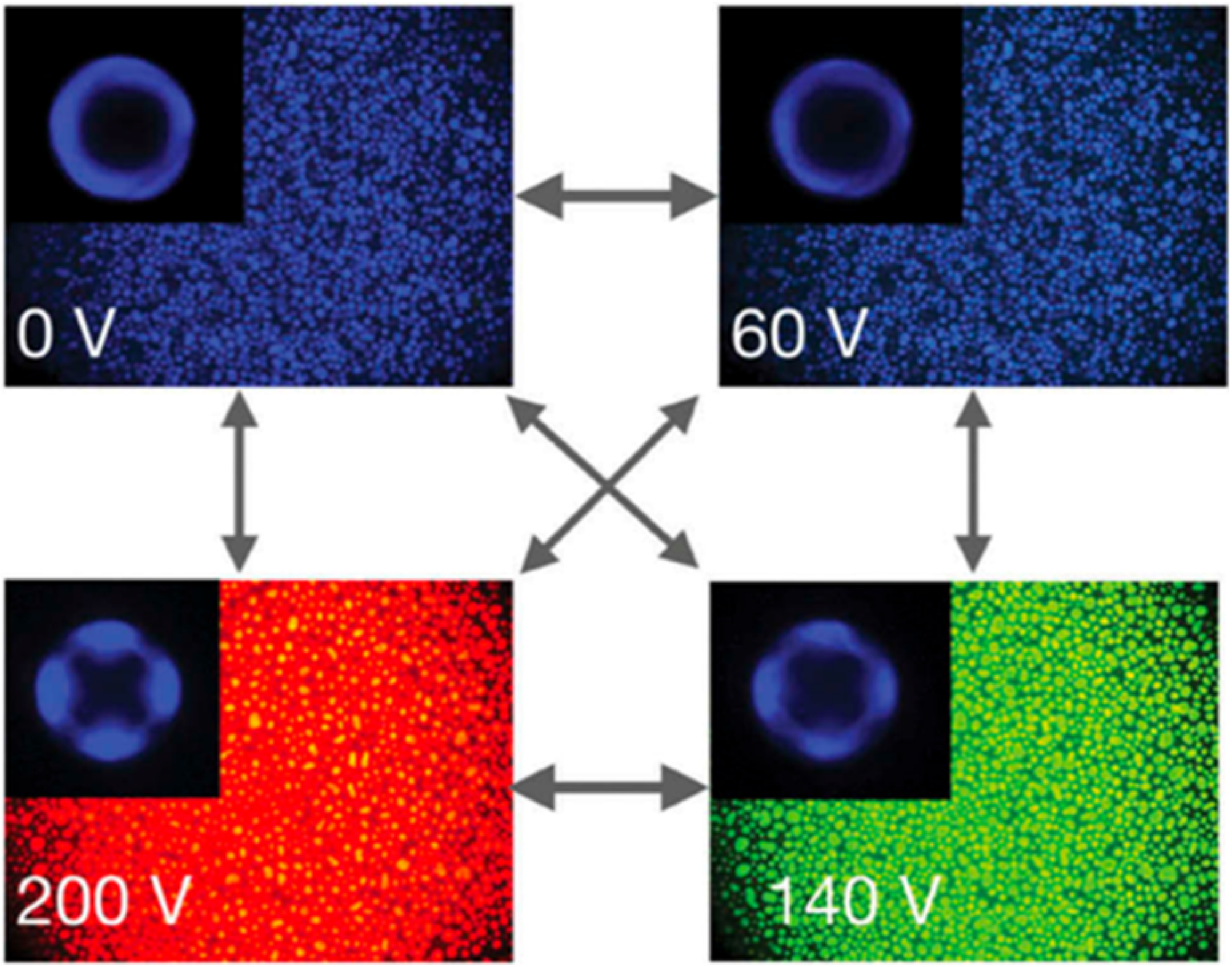
(b)

[illegible]5 (a) [illegible] [illegible]Photo credit: University of Cambridge[illegible]b[illegible]Photo from: ACS Appl. Mater. Interfaces 2017, 9, 39569-39575[illegible]

[illegible]6[illegible]7[illegible]



□6 □□
□□□
□□□□Photo from: NATURE MATERIALS, 13, 817 (2014)□



□7 □□(1, 0, 0)□□□□□□□□□□□□□□□□□□□□□□□□□
□□□

[illegible]

n [illegible]

[illegible]

[illegible]

[illegible]

[illegible] [illegible]*

[illegible]

kclee@tea.ntue.edu.tw

■[illegible]

[illegible]carbon nanotubes[illegible]Graphene Oxide[illegible]Graphene Quantum Dots[illegible]

■[illegible]

[illegible]LaVan et al.,2003[illegible]Kostarelos et.al., 2009; Wang et. al., 2011[illegible](carbon nanotubes)[illegible](Graphene Oxide)[illegible](Graphene Quantum Dots)[illegible]Aillon et al., 2009; Lee et al., 2019[illegible](SWCNT)[illegible](MWCNT)[illegible](C_{60})[illegible](GQD)[illegible]Aillon et al., 2009; Lacerda et al., 2006; Lee et al., 2019; Wu et al., 2013[illegible]Huang et al., 2019; Lo et al., 2020; Liu et al., 2018[illegible]

[illegible]Iijima[illegible]1991[illegible]Iijima, 1991[illegible]Bianco & Prato, 2003; Davis et al., 2003[illegible]SWCNT[illegible]DWCNT[illegible]MWCNT[illegible]

[illegible]GQD[illegible]100 nm[illegible]Jiang et al., 2013; Lo et al., 2020; Shen et al., 2012[illegible]Lo et al., 2020; Iannazzo et al., 2019; Zhang et al., 2012[illegible]Zhu et al., 2011[illegible]Lo et al., 2020[illegible]

■[illegible]

[illegible]

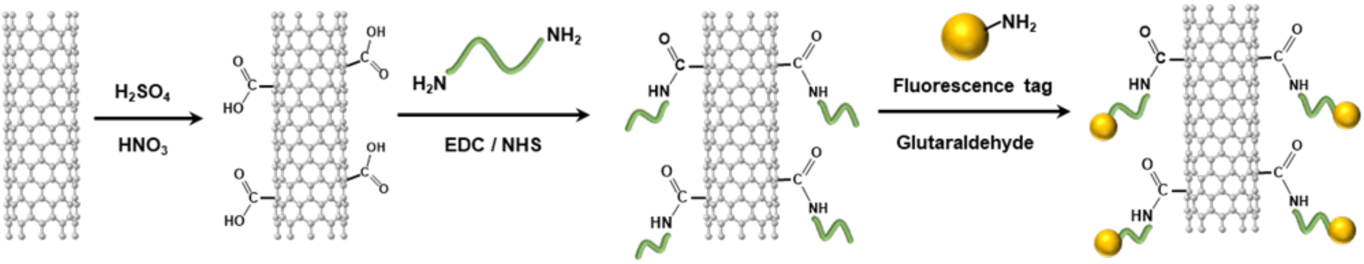
[illegible]

[illegible]a[illegible]π[illegible]

[illegible]b[illegible]

[illegible]

[illegible](□□1)[illegible]Zhao et al., 2004[illegible]Hamon et al., 1999[illegible]Chattopadhyay et al., 2003[illegible]

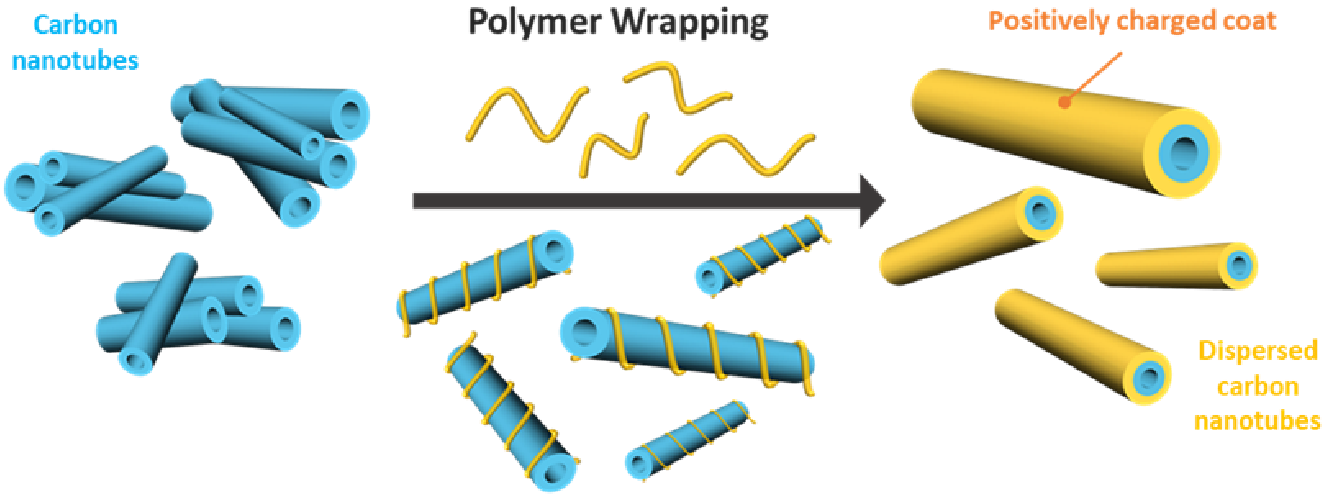


□1 [illegible]

[illegible]

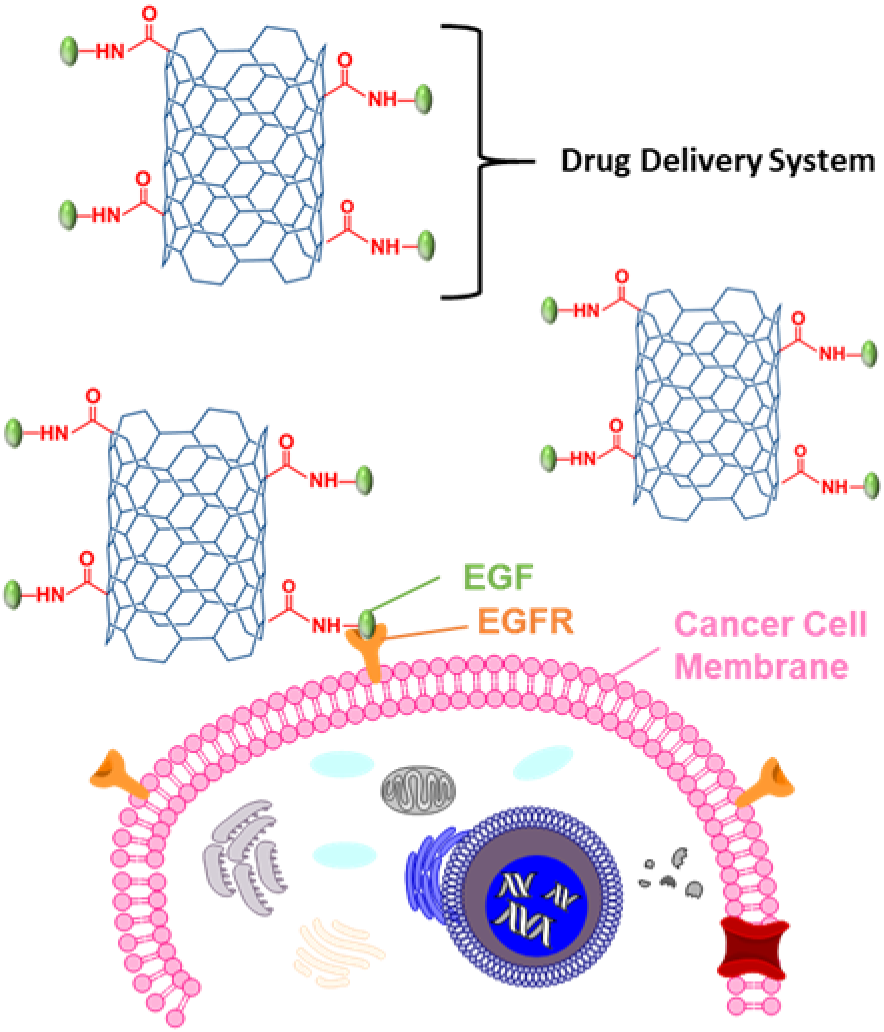
[illegible](□□2)[illegible]π[illegible]

□□π-π□□□□□□□□□□□□□□□□□□□□□□□□□Mickelson et al., 1998; Pekker et al., 2001□□□Chen et al., 1998□□□□□□Kamaras et al., 2003□□□□□□□□□□□□□□□□□□□□



□2 □□□□□□□□□□□□□□□(□□□□□)

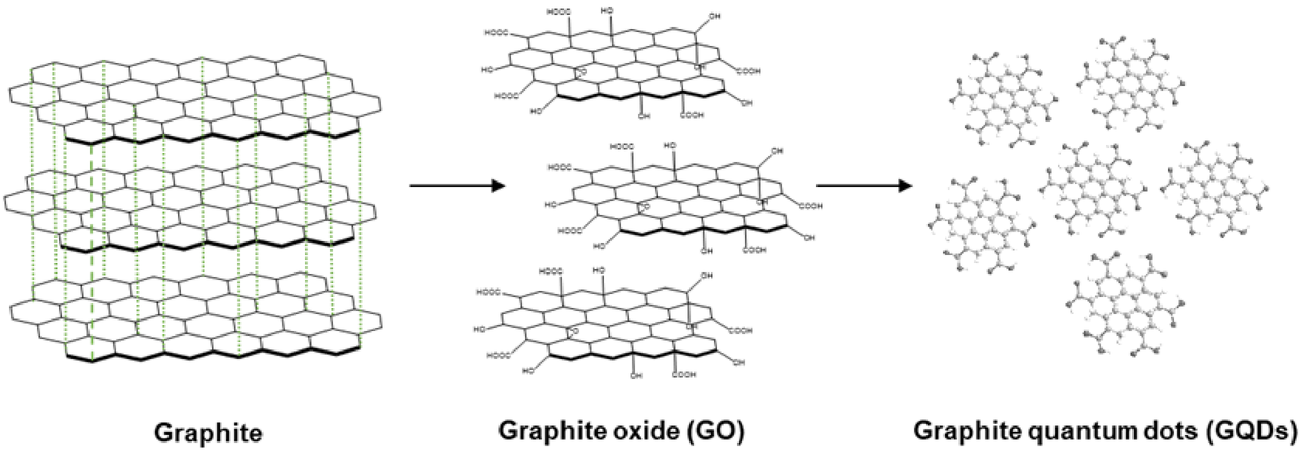
□□□3□□Chen et al., 2005; Lo et al., 2020□□Sun□□□□□□□□□□□□□□□□□□□□□□□□□□□—□□□Mickelson et al., 1998; Pekker et al., 2001□□□-L-□□□□□□□□□□-L-□□□□□□□□□□□□□□□□□Elkin et al., 2005; Huang et al., 2002□□□



□3 □□□□□□□□□□□□□□□□□□□

□□□□□□□□□□□□□

□□(□□□)□□(Cdots)□Luo et al., 2013□□□□□□□□□□□□□□(GQD)□Peng et al., 2012□□(□□□□□□□□□□)□Shen et al., 2012□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□



□4 □□□□□□□□□□□

□□pi-pi□□(□□□□□)□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

■□□□□□□□□□□□□□□

□□□Lo et al., 2020□□□DNA□□

■□□

□□□—□□

■□□□□

1. LaVan, D. A., McGuire, T.,& Langer, R. (2003). Small-scale systems for in vivo drug delivery. *Nature Biotechnology*,*21*(10), 1184-1191.

2. Wang, Y., Li, Z., Wang, J., Li, J., Lin, Y. (2011). Graphene and graphene oxide:biofunctionalization and applications in biotechnology. *Trends in Biotechnology*, *29* (5), 205-212.

3. Kostarelos, K., Bianco, A., & Prato, M. (2009). Promises, facts and challenges for carbon nanotubes in imaging and therapeutics. *Nature Nanotechnology*, *4*(10), 627-633.

4. Aillon, K. L., Xie, Y., El-Gendy, N., Berkland, C. J., & Forrest, M. L. (2009). Effects of nanomaterial physicochemical properties on in vivo toxicity. *Advanced Drug Delivery Reviews*, *61* (6), 457-466.

5. Lee, K.-C., Lo, P.-Y., Lee, G.-Y., Zheng, J.-H., & Cho, E.-C. (2019). Carboxylated carbon nanomaterials in cell cycle and apoptotic cell death regulation. *Journal of Biotechnology*, *296*(20), 14-21.

6. Lacerda, L., Bianco, A., Prato, M., & Kostarelos, K. (2006). Carbon nanotubes as nanomedicines: from toxicology to pharmacology.

Advanced Drug Delivery Reviews, 58 (14),1460-70.

7. Wu, C., Wang, C., Han, T., Zhou, X., Guo, S., & Zhang, J. (2013). Insight into the Cellular Internalization and Cytotoxicity of Graphene Quantum Dots. *Advanced Healthcare Materials, 2* (12), 1613-1619.

8. Lo, P.-Y., Lee, G.-Y., Zheng, J.-H., Huang, J.-H., Cho, E.-C., Lee, K.-C. (2020). GFP Plasmid and Chemoreagent Conjugated with Graphene Quantum Dots as a Novel Gene Delivery Platform for Colon Cancer Inhibition In Vitro and In Vivo. *ACS Applied Bio Materials, 3*(9), 5948-5956.

9. Huang, D., Zhou, H., Wu, Y., Wang, T., Sun, L., Gao, P., Sun, Y., Huang, H., Zhou, G., Hu, J. (2019).Bottom-up synthesis and structural design strategy for graphene quantum dots with tunable emission to the near infrared region. *Carbon, 142*, 673-684.

10. Liu, J., Dong, J., Zhang, T., Peng, Q. (2018). Graphene-based nanomaterials and their potentials in advanced drug delivery and cancer therapy. *Journal of Controlled Release, 286*(28), 64-73.

11. Iijima, S.(1991). Helical microtubules of graphitic carbon. *Nature, 354* (6348), 56-58.

12. Bianco, A., & Prato, M. (2003). Can carbon nanotubes be considered useful tools for biological applications? *Advanced. Materials*, *15*(20), 1765-1768.

13. Davis, J. J., Coleman, K. S., Azamian, B. R., Bagshaw, C. B., & Green, M. L. H. (2003). Chemical and biochemical sensing with modified single walled carbon nanotubes. *Chemistry-A European Journal*, *9*(16), 3732-3739.

14. Shen, J., Zhu, Y., Yang, X.,& Li, C. (2012). Graphene quantum dots: emergent nanolights for bioimaging, sensors, catalysis and photovoltaic devices. *Chemical Communications, 48* (31), 3686-3699.

15. Jiang, F., Chen, D., Li, R., Wang, Y., Zhang, G., Li, S., Zheng, J., Huang, N., Gu, Y., Wang, C., & Shu, C. (2013). Eco-friendly synthesis of size-controllable amine-functionalized graphene quantum dots with antimycoplasma properties. *Nanoscale*, *5*, 1137-1142.

16. Zhang, M., Bai, L., Shang, W., Xie, W., Ma, H., Fu, Y., Fang, D., Sun, H., Fan, L., Han, M., Liu, C., & Yang, S. (2012). Facile synthesis of water-soluble, highly fluorescent graphene quantum dots as a robust biological label for stem cells. *Journal of Materials*

Chemistry, 22, 7461 -7467.
17. Iannazzo, D., Pistone, A., Celesti, C., Triolo, C., Patané, S., Giofré, S. V., Romeo, R., Ziccarelli, I., Mancuso, R., Gabriele, B., Visalli, G., Facciolà, A., Di Pietro, A. (2019). A smart nanovector for cancer targeted drug delivery based on graphene quantum dots. *Nanomaterials* **2019,** *9* (2),282.
18. Zhu, S., Zhang, J., Qiao, C., Tang, S., Li, Y., Yuan, W., Li, B., Tian, L., Liu, F., Hu, R., Gao, H., Wei, H., Zhang, H., Sun, H., & Yang, B. (2011). Strongly green-photoluminescent graphene quantum dots for bioimaging applications. *Chemical Communications*, *47*, 6858 – 6860.
19. Zhao, B., Hu, H., & Haddon, R. C. (2004). Synthesis and Properties of a Water-Soluble Single-Walled Carbon Nanotube-Poly(<I>m</I>-aminobenzene sulfonic acid) Graft Copolymer. *Advanced Functional Materials*, *14* (1), 71-76.
20. Hamon, M. A., Chen, J., Hu, H., Chen, Y., Itkis, M. E., Rao, A. M., Eklund, P. C., & Haddon, R. C. (1999). Dissolution of Single-Walled Carbon Nanotubes. *Advanced Materials*, *11*(10), 834-840.
21. Chattopadhyay, D., Galeska, I.,& Papadimitrakopoulos, F. (2003). A route for bulk separation of semiconducting from metallic single-wall carbon nanotubes. *Journal of the American Chemical Society, 125*(11), 3370-3375.
22. Mickelson, E. T., Huffman, C. B., Rinzler, A. G., Smalley, R. E., Hauge, R. H., & Margrave, J. L. (1998). Fluorination of single-wall carbon nanotubes. *Chemical Physics Letters*, *296* (1-2), 188-194.
23. Pekker, S., Salvetat, J. P., Jakab, E., Bonard, J. M., & Forro, L. (2001). Hydrogenation of carbon nanotubes and graphite in liquid ammonia. *The Journal of Physical Chemistry B*, *105* (33), 7938-7943.
24. Chen, J.; Hamon, M. A.; Hu, H.; Chen, Y.; Rao, A. M.; Eklund, P. C.; Haddon, R. C., Solution Properties of Single-Walled Carbon Nanotubes. *Science* **1998,** *282* (5386), 95-98.
25. Kamaras, K., Itkis, M. E., Hu, H., Zhao, B., & Haddon, R. C. (2003). Covalent bond formation to a carbon nanotube metal. *Science, 301*(5639), 1501.
26. Chen, S., Shen, W., Wu, G., Chen, D., & Jiang, M. (2005). A new approach to the functionalization of single-walled carbon nanotubes with both alkyl and carboxyl groups. *Chemical Physics Letters*, *402* (4-6), 312-317.

27. Huang, W., Taylor, S., Fu, K., Lin, Y., Zhang, D., Hanks, T. W., Rao, A. M., & Sun, Y.-P. (2002). Attaching proteins to carbon nanotubes via diimide-activated amidation. *Nano Letters*, *2*(4), 311-314.

28. Elkin, T., Jiang, X., Taylor, S., Lin, Y., Gu, L., Yang, H., Brown, J., Collins, S., & Sun, Y.-P. (2005). Immuno-carbon nanotubes and recognition of pathogens. *Chembiochem*, *6*(4), 640-643.

29. Zhang, Y., Li, J., Shen, Y., & Wang, M. (2004). Poly-L-lysine functionalization of single-walled carbon nanotubes. *The Journal of Physical Chemistry B, 108*(39), 15343-15346.

30. Chen, W., Tzang, C. H., Tang, J.,Yang, M., & Lee, S. T. (2005). Covalently linked deoxyribonucleic acid with multiwall carbon nanotubes: Synthesis and characterization. *Applied Physics Letters, 86* (10), 103114.

31. Luo, P. G., Sahu, S., Yang, S.-T., Sonkar, S. K., Wang, J., Wang, H., LeCroy, G. E., Cao, L., & Sun, Y.-P. (2013). Carbon “quantum” dots for optical bioimaging. *Journal of Materials Chemistry B*, *1*(16),2116-2127.

32. Peng, J., Gao, W., Gupta, B. K., Liu, Z., Romero-Aburto, R., Ge, L., Song, L., Alemany, L. B., Zhan, X., Gao, G., Vithayathil, S. A., Kaipparettu, B. A., Marti, A. A., Hayashi,T., Zhu, J.-J., & Ajayan, P. M. (2012). Graphene quantum dots derived from carbon fibers. *Nano Letters*, *12*(2),844-849.

[illegible] [illegible]

[illegible]

[illegible]

[illegible]

luchowch@tea.ntue.edu.tw

[illegible]Omega-3[illegible]EPA[illegible]DHA[illegible]cytokine[illegible]

[illegible]Collagen[illegible]

■[illegible]

[illegible](Kerecis)[illegible]Kerecis[illegible]cod fish skins[illegible]Omega—3[illegible]2019[illegible]75[illegible]56[illegible]2017[illegible]Omega3[illegible]2019[illegible]

[illegible]K-12[illegible]K-12[illegible]

■[illegible]Omega-3[illegible]

[illegible]Omega-3[illegible]Omega-3[illegible]eicosapentaenoic acid, $C_{20}H_{30}O_2$, EPA[illegible]docosahexaenoic acid, $C_{22}H_{32}O_2$, DHA[illegible]Omega-3[illegible]cytokine[illegible]Goldberg & Katz, 2007;Kiecolt-Glaseret al., 2011[illegible]Omega-3[illegible]Omega-3[illegible]Omega-3[illegible]Yvonne, 2007[illegible]signal protein[illegible]Lackie, 2010[illegible]

■[illegible]

[illegible]porous biological scaffold[illegible]—[illegible]Collagen[illegible]2019[illegible]2014[illegible]polypeptide[illegible]

[illegible]cross-linking[illegible]2019[illegible]2019[illegible]

[illegible]2D[illegible]3D[illegible]2016[illegible]3D[illegible]Omega3[illegible]

■[illegible]

[illegible]10[illegible]×20[illegible]14[illegible]

[illegible]K-12[illegible]Omega-3[illegible]K-12[illegible]

■[illegible]

[illegible]2016[illegible]**3D[illegible]/[illegible]**[illegible]

[illegible]2019[illegible]7[illegible][illegible]https://agritech-foresight.atri.org.tw/article/contents/1812

[illegible]2017[illegible]7[illegible][illegible]https://today.line.me/tw/v2/article/452deb91efcc25d014dfd228beb39abf8fa1f1d4cc341a9db25afdb7b045e77a

[illegible]2019[illegible]**[illegible]12**[illegible]http://dgnet.com.tw/articleview.php?article_id=18635&issue_id=3629

[illegible]2014[illegible]6[illegible]−[illegible]https://kknews.cc/zh-tw/other/k6arxq.html

Goldberg,R. J., & Katz, J. (2007). A meta-analysis of the analgesic effects of omega-3 polyunsaturated fatty acid supplementation for inflammatory joint pain. *Pain, 129*(2), 210-223.

Kiecolt-Glaser, J. K., Belury, M. A., Andridge, R., Malarkey, W. B., & Glasera, R. (2011). Omega-3 supplementation lowers inflammation and anxiety in medical students: a randomized controlled trial. *Brain Behavior Immunity, 25*(8), 1725-1734.

Lackie, J. (2010). *Cytokine*. A Dictionary of Biomedicine. Oxford. ISBN 978-0-19-172794-8.

Yvonne, B. W. (2007). *Plant based sources of vegan & vegetarian Docosahexaenoic acid-DHA and Eicosapentaenoic acid-EPA & Essential Fats*. Retrieved from http://www.foodsforlife.co.uk/nutrition/vegetarian-DHA-EPA.html

■[illegible]

[illegible]14[illegible]9[illegible]6,000[illegible]29[illegible]3[illegible]5,000[illegible]

[illegible] / [illegible]

[illegible]

[illegible][1][illegible][2]

[illegible][1]

[illegible][2]

chen7329@gmail.com[1]

luchowch@tea.ntue.edu.tw[2]

[illegible]2010[illegible]

[illegible]76.57%[illegible]POE[illegible]61.9%[illegible]POE[illegible]

n [illegible]

[illegible]nm[illegible]2004[illegible]INf-[illegible]-3[illegible]2020[illegible]

[illegible]Lotus effect[illegible]2004[illegible]10nm ~100nm[illegible]2020[illegible]

[illegible]Wandersee et al., 1994[illegible]Palmer & Flanagan, 1997[illegible]Prediction[illegible]Observation[illegible]Explanation[illegible]POE[illegible]2000[illegible]Liew, 1995[illegible]POE[illegible]

n [illegible]

[illegible]1[illegible]

[illegible]1 [illegible]

主題	教學概念	教學活動內容
疏水性	蓮葉表面與水的接觸角大於90度，具有疏水性	將水滴在蓮葉表面上，觀察～ 1. 蓮葉上的水珠形狀如何？ 2. 蓮葉上的水是滑動的還是滾動的？
自潔作用	滾動的水珠會把灰塵帶走，達到自我潔淨的效果	在蓮葉上灑一些爽身粉，再滴水，觀察～ 1. 水流過有爽身粉的蓮葉時，會產生什麼反應？ 2. 爽身粉會在水珠的裡面還是外面？

[illegible]

[illegible]
[illegible]2[illegible]

[illegible]2 [illegible]

提問	學生的正確概念	學生的另有概念反應
蓮葉上水珠的形狀如何？	57.01%學生選擇 	22.87%學生選擇 ，20.12%學生選擇 
蓮葉上的水滴為什麼會形成一顆顆圓滾滾的水珠？	59.78%學生認為蓮葉表面有蠟質及奈米級的絨毛	24.53%學生認為蓮葉上的水滴會變成水珠是蓮葉表面有奈米微粒，15.69%學生認為是蓮葉上有細毛，細毛上有蠟。
水珠滾動後的蓮葉表面，為什麼還能保持潔淨？	23.43%學生認為有奈米級絨毛使灰塵很難附著在表面	51.24%學生認為蓮葉表面細緻光滑，當雨水流時會把灰塵帶走，25.33%學生認為蓮葉表面具有油質，灰塵無法附著於葉面上。

[illegible]72.57%[illegible]
[illegible]1.[illegible]2.[illegible]
[illegible]3.[illegible]4.[illegible]
[illegible]3[illegible]

[illegible]3[illegible]

問題內容	另有概念內容	另有概念類型
水珠滾動後的蓮葉表面，為什麼還能保持潔淨？	1.葉面細緻光滑，當雨水流過時會把灰塵帶走 2.蓮葉表面具有油質，灰塵無法附著葉面上 3.奈米結構、奈米細管滾動水珠，帶走灰塵	經驗誤用模式 推理不當模式 記憶連結錯誤模式

n **[illegible]P0E[illegible]**

[illegible]
[illegible]P0E[illegible]4[illegible]

[illegible]4[illegible]P0E[illegible]

階段	教師與學生的角色	學生應答情形
預測 （P）	教師詢問、引導學生設計實驗： 1. 將水滴在未燻黑與燻黑的紙杯底部，水滴會產生什麼情形？ 2. 在未燻黑與燻黑的紙杯底部灑上爽身粉，並各滴一滴水，水和爽身粉又會產生什麼情形？	1.水滴在燻黑的紙杯底部，會呈現圓形水滴，呈現滾動現象。 2.水珠會把爽身粉帶走，爽身粉會溶解在水中，並且在水珠裡面。
觀察 （O）	學生分別進行實驗觀察與紀錄： 1.學生觀察並紀錄實驗結果。 2.學生實驗後發現與預測不相，多次重複實驗、確認實驗結果。	1. 水滴在燻黑的紙杯底部會形成水珠，水珠經過的地方，會把碳顆粒帶走，水珠也會被碳顆粒包圍而變成黑色。 2. 碳顆粒是黏附在水珠外面，不是溶解在水珠裡面。
解釋 （E）	學生比較實驗預測與觀察間的想法，解釋現象及成因： 1.學生自我比較實驗前後的想法、修正原有的想法。 2.教師引導學生比較、說明燻黑的紙杯杯底表面和蓮葉表面間的關聯性。	1. 紙杯底部燻黑後，杯底會轉變成超疏水性，當水珠滾動便可讓碳黑黏在水珠表面，並將它帶走。 2. 碳黑表面和蓮葉表面一樣具有蓮葉效應，可以形成水珠而保持乾燥，而且水珠會帶走髒汙而保持乾淨。

[illegible]5[illegible]

[illegible]5 [illegible]P0E[illegible]

測驗之概念內容說明	教學前 (%)	教學後 (%)	進步 (%)
滴水在蓮葉表面上，蓮葉上的水分子會聚在一起，形成球狀水珠	57.14	71.43	14.29
蓮葉上的水珠形狀呈	66.67	71.43	4.76
液體能在物質上滾動，故其物質與液體的接觸面積小	71.43	73.81	2.38
蓮葉上有很多奈米級的蠟質結晶，致水珠無法潤濕葉子表面	71.43	88.10	16.67
從電子顯微鏡觀察蓮葉表面結構，發現表面佈滿微米級表面細胞和奈米級蠟質結晶	73.81	83.33	9.52
水與物質材質的接觸角愈大，疏水性愈強	47.62	64.29	16.67
“蓮葉效應”指的是蓮葉表面同時具有具疏水性與自潔性	66.67	80.95	14.29
從水珠可將燻黑碳顆粒表面上的爽身粉帶走，可知燻黑碳顆粒表面具自潔性	50.00	64.29	14.29
水珠在蓮葉上滾動時可將髒汙吸附在水珠上並帶走，以達自潔功效	35.71	64.29	28.57
水珠滑過蓮葉時，將灰塵包覆在外面並將它帶走	61.90	64.29	2.38
從水珠在燻黑的碳顆粒與蓮葉表面上移動情形相同，可推論燻黑的碳顆粒表面具超疏水性	28.57	61.90	33.33
物質的材質改變後，其親水性與疏水性的程度也會跟著改變	38.10	64.29	26.19
燻黑後的紙杯底部具有蓮葉效應，其碳顆粒層是奈米級結構，具疏水性	33.33	64.29	30.95

n □□□□□

□□□POE□□

n □□□□

[illegible]2004[illegible]**K-12**[illegible]–[illegible]

[illegible]2004[illegible]**37**[illegible]2[illegible]20-25[illegible]

[illegible]2000[illegible]**8**[illegible]1-34[illegible]

[illegible]2020[illegible]7[illegible]12[illegible]
[illegible]http://scigame.ntcu.edu.tw/chemistry/chemistry-018.html[illegible]

[illegible]2020[illegible]7[illegible]19[illegible]–[illegible]/[illegible]
[illegible]https://www.naer.edu.tw/files/15-1000-14113,c1594-1.php[illegible]

Liew, C. W. (1995). A predict-observe-explainteaching sequence for learning about students'understanding of heat and expansion of liquids. *Australian Science Teachers Journal, 41*(1), 68-71

Palmer, D. H., & Flanagan, R. B. (1997). Readiness to hange the conception that "motion-Implies-force": A comparison of 12-year-old and 16-year-old students. *Science Education, 81*(3), 317–331.

Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. Gabel (Ed.), *Handbook of research on science teaching and learning*. New York: Macmillan.

[illegible] [illegible]

[illegible]

[illegible]

[illegible]

hueiying.ho@gmail.com

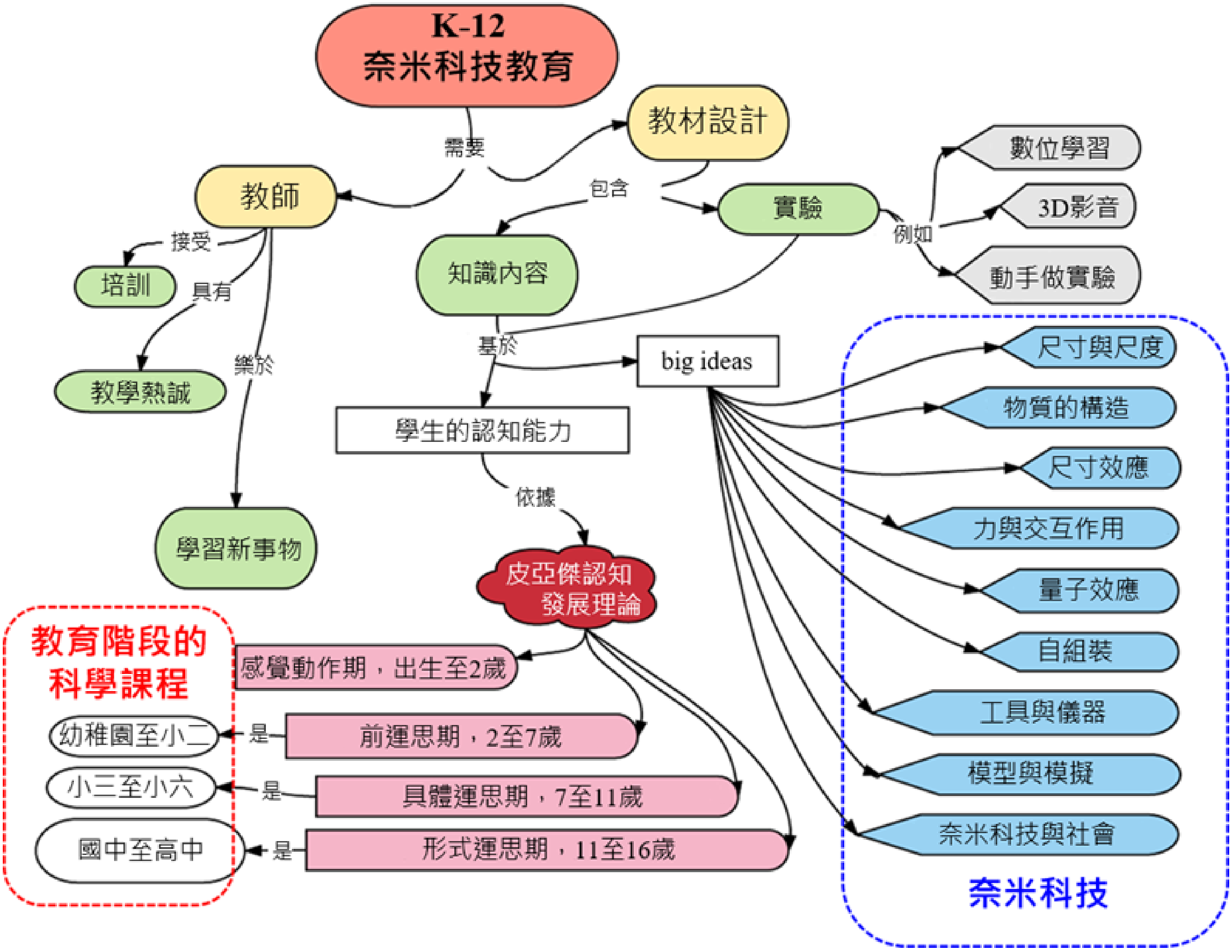
[illegible]K-12[illegible]K-12[illegible]big ideas[illegible]

n K-12[illegible]

[illegible]K-12[illegible]2003[illegible]K-12[illegible]K-12[illegible]

[illegible]2011[illegible]Stevens[illegible]2009[illegible]big ideas[illegible]2003[illegible]2008[illegible]209 [illegible]2008[illegible]K-12 [illegible]2012[illegible]3[illegible]6 [illegible]89%[illegible]3[illegible]6 [illegible]50%[illegible]big ideas[illegible]

[illegible]1[illegible]K-12[illegible]big ideas[illegible]



□1□K-12□□□□□□□□□□□□□□□□□□

n □□□□□□□Big ideas

□□□□□□□big ideas□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□(2011)□□□□□□□□□□big ideas□□□□

□□□□□□□□size & scale□

□□□□□□□□□□□□□□□□□□□□…□□□□□□□□□□□□□□□□□□□□□□□□□AU□□□□□□□□□

□□□□□ 10^{-3} m□□□□□□□ 10^{-6} m□□□□□□□□□ 10^{-9} m□□

□□□□□□□□structure of matter□

□□□
□□□□□

[illegible]（size effect）

[illegible]

[illegible]（force & interactions）

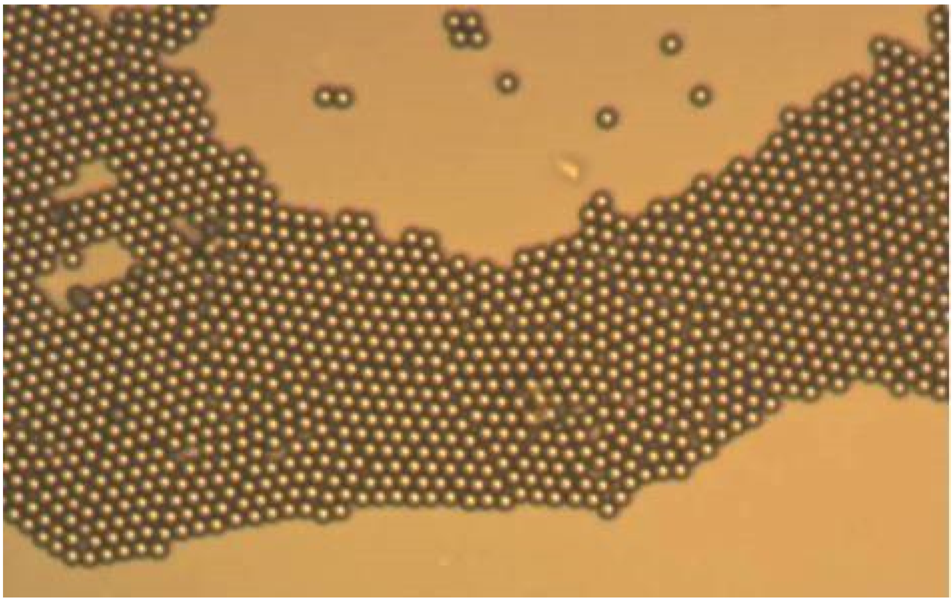
[illegible]

[illegible]（quantum effect）

[illegible]

[illegible]（self-assembly）

[illegible]DNA[illegible]2[illegible]



[illegible]2[illegible]20[illegible]2016[illegible]

[illegible]（tools & instrumentation）

[illegible]SNOM[illegible]AFM[illegible]TEM[illegible]SEM[illegible]…[illegible]

[illegible]（models & simulations）

[illegible]

[illegible]

[illegible]（**nanotechnology & society**）

[illegible]

n [illegible]K-12[illegible]

[illegible]K-12[illegible]

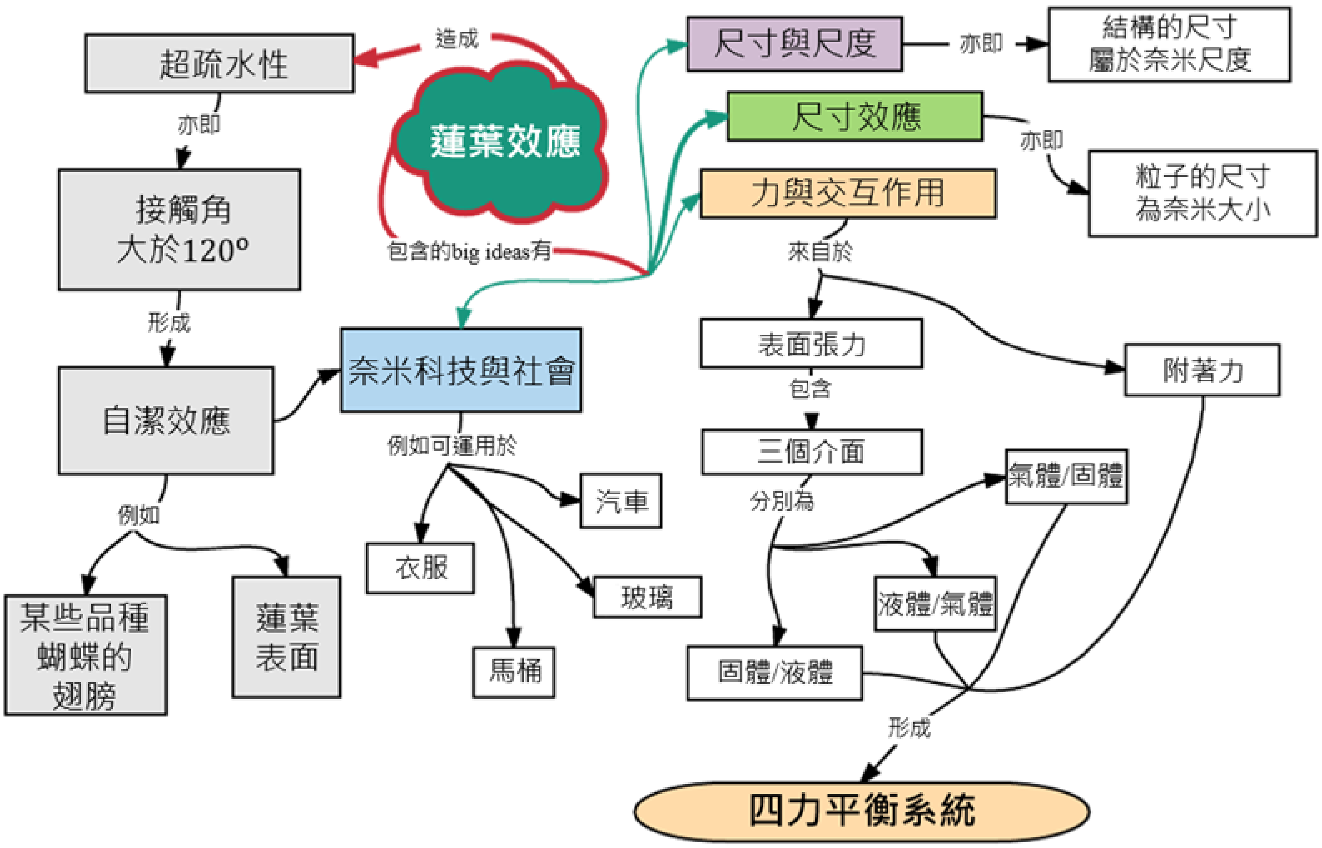
[illegible]

[illegible]K-12[illegible]

[illegible]K-12[illegible](1)[illegible](2)[illegible]big ideas[illegible]

[illegible]3[illegible]big ideas[illegible]big ideas[illegible]

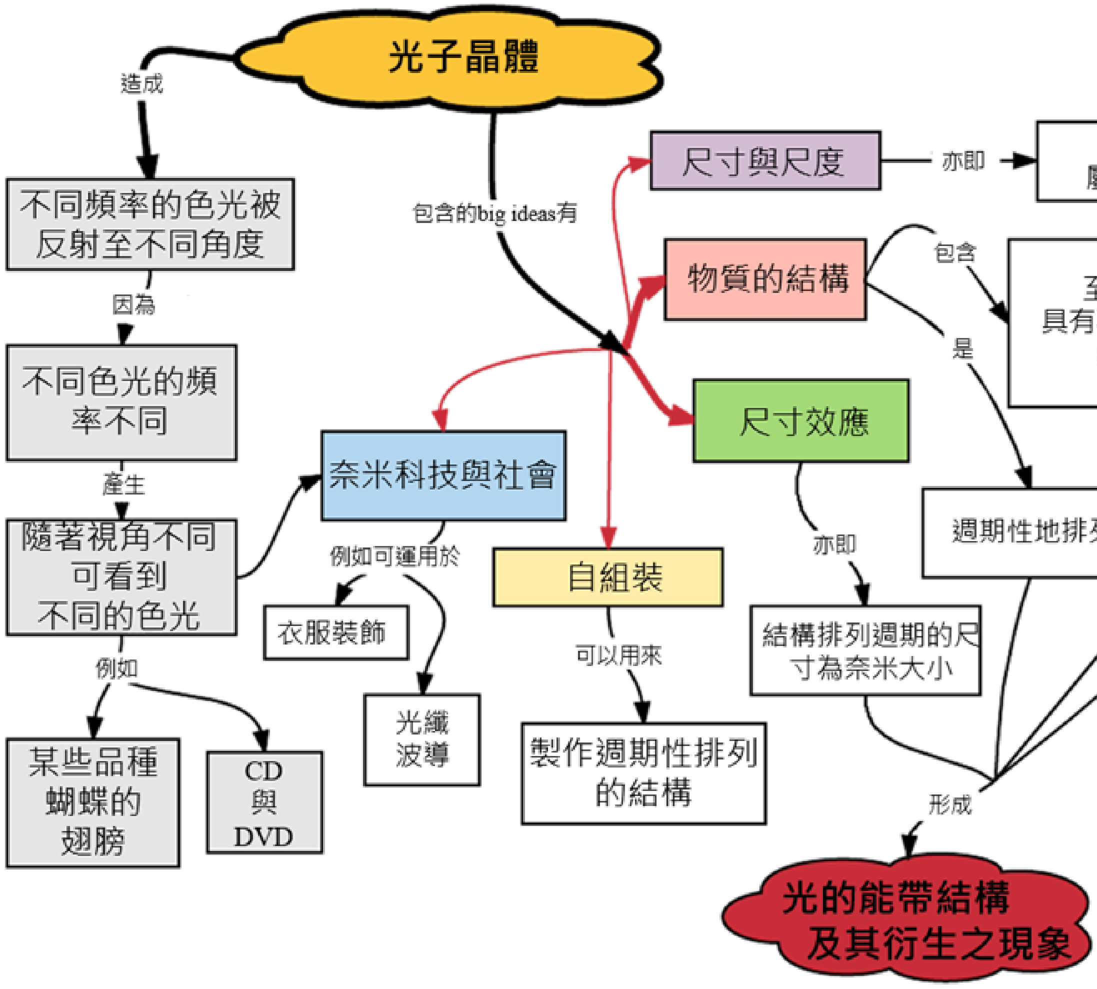
[illegible]



[illegible]3[illegible]

[illegible]4[illegible]

[illegible]big ideas[illegible]big ideas[illegible]K-12[illegible]4[illegible]



[illegible]4[illegible]

[illegible]

[illegible]

[illegible]1[illegible]

[illegible]1[illegible]

[illegible]	[illegible]	[illegible]
[illegible]		[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible]2[illegible]

[illegible]2[illegible]

	[illegible]	[illegible]
[illegible]		[illegible]
[illegible]	[illegible]…[illegible]	[illegible]([illegible])[illegible]
[illegible]	[illegible](RGB)	[illegible]

[illegible]	[illegible]	[illegible]

[illegible]

[illegible]3[illegible]4[illegible]1[illegible]2[illegible]

[illegible]

[illegible]2014[illegible]2016[illegible]

n [illegible]

[illegible]

n [illegible]

[illegible]2014[illegible]K-12[illegible](ISBN[illegible]978-986-04-1582-7)

[illegible]2016[illegible]K-12[illegible](ISBN[illegible]978-986-04-5286-0)

[illegible]2003[illegible]K-12[illegible]**25**(3)[illegible]435-443[illegible]https://www.ps-taiwan.org/bimonth2/download.php?d=1&cpid=131&did=9

[illegible]2008[illegible]**9**(1)[illegible]109-122[illegible]

[illegible]2011[illegible]**56**(4)[illegible]1-42[illegible]

[illegible]2012[illegible]3-6 [illegible]**13**(2)[illegible]77-102[illegible]

Stevens, S., Sutherland, L., & Krajcik, J. S. (2009).

The big ideas of nanoscale science and engineering: A guidebook for secondary teachers. Arlington, VA: NSTA Press.

[illegible]

[illegible]

[illegible]* [illegible]

[illegible]

hueiying.ho@gmail.com

[illegible]

n [illegible]

[illegible]400[illegible]900[illegible]Cartier[illegible]Braun[illegible]SEM[illegible]K-12[illegible]2016[illegible]

n [illegible]

[illegible]Aristotle, B. C. 384-322[illegible](Historia Animalium)[illegible]1[illegible]

[illegible]1[illegible]Editor abcdef –
Own work, Public Domain,
https://commons.wikimedia.org/w/index.php?curid=38806582[illegible]

n [illegible]

[illegible]1[illegible]

[illegible]1[illegible]Autumn & Peattie,2002[illegible]

作用機制	提出假設者	反駁者	反駁之實驗證據
分泌黏液(glue)	N/A	Wagler, 1830; Simmermacher, 1884	壁虎並沒有任何分泌的腺體，不可能分泌黏液
真空吸引(suction, 吸盤)	Simmermacher, 1884	Dellit, 1934	在高真空環境下，壁虎仍具有黏著能力
靜電吸引力 (electrostatics attraction)	Schmidt, 1904	Dellit, 1934	壁虎能在充滿電荷的環境中進行黏著，不受環境電荷的影響
摩擦力(friction)	Hora, 1923; Ruibal & Ernst, 1965	為數眾多	當力垂直於黏著的表面，摩擦力並無法發揮作用，但是壁虎卻可以倒掛在天花板行走。
微交錯作用 (microinterlocking, 俗稱爪力)	Dellit, 1934	Autumn et al., 2000	在表面極光滑的二氧化矽上，壁虎的黏附力仍不受任何影響
毛細作用 (capillary forces)	Hiller, 1968;	Autumn et al., 2002	壁虎的黏附不受吸附表面的化學性質之影響，並且也不受到環境濕度的限制。
	Huber et al., 2005	Arzt, 2006	壁虎的足底有極高疏水性，極高疏水表面之間，毛細作用中關鍵的毛細橋樑無法成形，但是壁虎卻仍可以黏附在極高疏水表面
凡得瓦力(完全因素)	Stork, 1980; Autumn et al., 2000		

Hiller[illegible]1968, 1969,1975[illegible]surface energy[illegible]Hiller[illegible]Autumn & Peattie,2002[illegible]

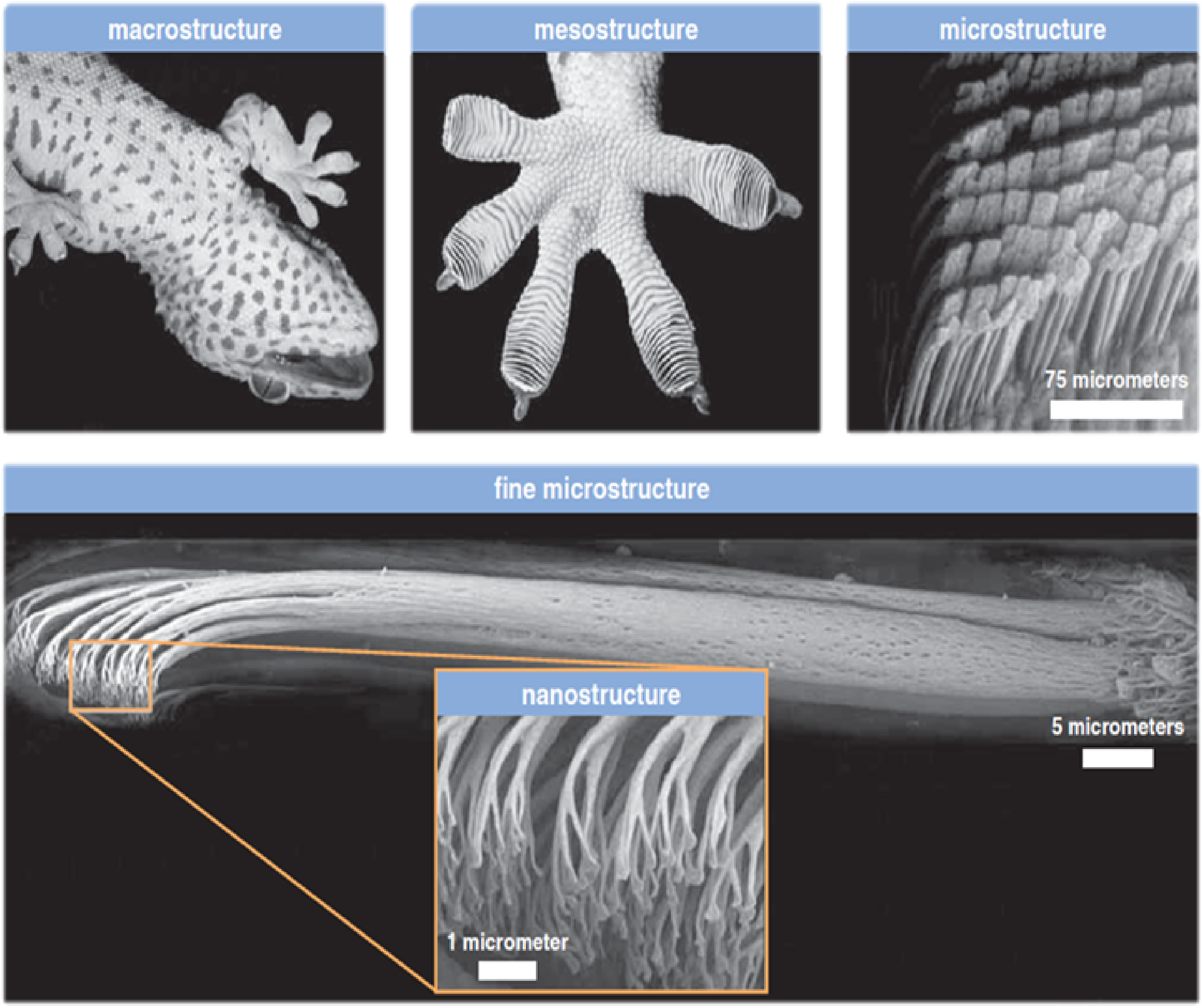
[illegible]van der Waals interaction[illegible]

□□□polarizability□□□□□□□□□□□□□□Hiller□1968□□□□□□□□□□□□□□□□□□□□□polytetrafluoroethylene,PTFE□□□□□□PTFE □□□□□□□□□□□□□□□□□□□□□□□PTFE□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□Autumn & Peattie,2002□□

1965□□□□□□□Ruibal □ Ernst□1965□□□□□□□□□□□□scanning electron microcopy, SEM□□□□□□□□□□□□□□□□□□□□setae□□□□□□□□□□□□□□□branch□□□□□□□□□□100~1000□□□□□□□□□spatulae□□□□□0.1~0.2 μm□□□□□□□□□stalk□□□□□□□□□□□□□□□□□□□□□□□□□□□200 nm□□□□0.01 μm□□□□□□□□2000□□□□□□□□□□□□□□□□□□□□Kellar Autumn□□Autumn et al., 2000□□□□□□□□□□□□□□□R□□□□□□□□□□□□□□□□□□□□□□□□D□Hamaker□□□H□□□□□□□□□□□

$$F = \frac{HR}{6D^2}$$

□□□ $H = 10^{-19}$ J□ $R = 1$ μm□ $D = 0.2$ nm□□□□□□□□□□□□□400 nN□□□□□□□□□□□□□100□1000□□□□□□□□□□□□□□40-400 μN□□□□□□□□□Autumn□□□□□□□□□□Micro Electro Mechanical Systems□MEMS□□□□□□□□□□□□□□□□□200μN□□□□□□□2002□□Autumn□□□Autumn et al., 2002□□□—□□□□□



□2□□□□□□(□□Autumn, K source: How gecko toes stick. American Scientist 94, 124-132)

n □□□□□□□□□□□□□□□□□□

□□□□□□□□□□□□□□□□□□□□□□Johnson□Kendall□Roberts□1971 □□□□JKR□□□□□□□□Cao et al.,2005□□□□□□□□□□□□□□*R*□□□□□g□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□:

$$F = \frac{3}{2}\gamma\pi R$$

□□□□□□□□□□□□□□□□□□□□□□□□□JKR□□□□□□□□□□□□□□164~196 nm□□□□□□□200 nm□□□□□□□□□□JKR□□□□□□□□□□□□□□□□□□□□□□□□□□ $F \propto R$ □□□□□□□□□□□□□□

□□□□□□□

□□□JKR□□□□□□□□□□□□Arzt et al., 2003□□□

□□□□□□□□□F□□□□R□□□□□□n□□□□□□□□□□□□□□□□□□□□□□□ $1/n$ □□□□□□□□□□□□□r□□□ $R/\sqrt{n}$ □□□JKR□□□□□□□□□□□□□□□□□□□□□□□□□□□ $F \propto R$ □□□□□□□□□□□□□□□□JKR□□□□F□□□□□□□□□□□□□f□□□□□□□□□□□□□ F' □□□□□□□□□□(□□□□□□)□□□

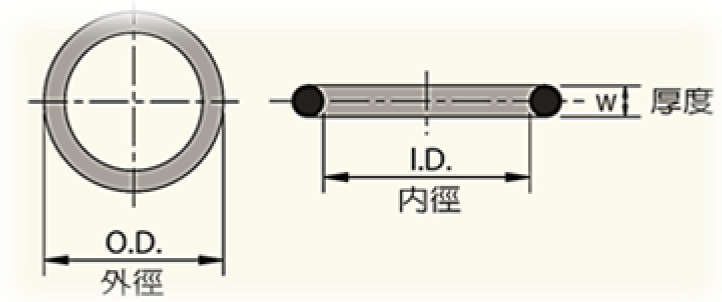
$$\left.\begin{aligned} F &= \frac{3}{2}\gamma\pi R \\ f &= \frac{3}{2}\gamma\pi r \\ r &= \frac{R}{\sqrt{n}} \end{aligned}\right\} \rightarrow F' = nf = \frac{3}{2}\gamma\pi n r = \sqrt{n}\left(\frac{3}{2}\gamma\pi R\right) = \sqrt{n}F = (\frac{R}{r})F$$

□□□□□□□□□□□□□□□□n□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ $\sqrt{n}$ □□ $F' \propto \sqrt{n} = R/r)$ □□□n□□□□□□□□□□□□□□□□□ $\sqrt{n} = R/r \rightarrow 10^9)$ □□JKR□□□□□□□□□□ $f \propto r$ □□n□□□□□□□□□ $\sqrt{n}$ □□□□□□□ $F' \propto \sqrt{n}$ □

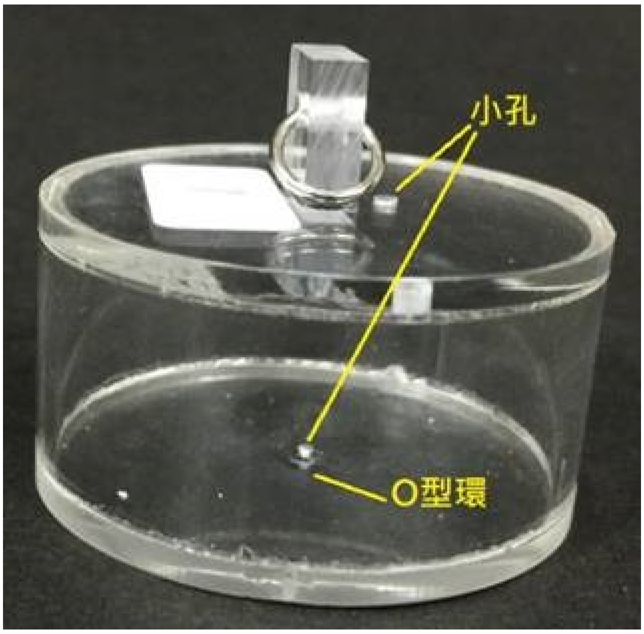
n □□□□□□□□□□□□□□□□

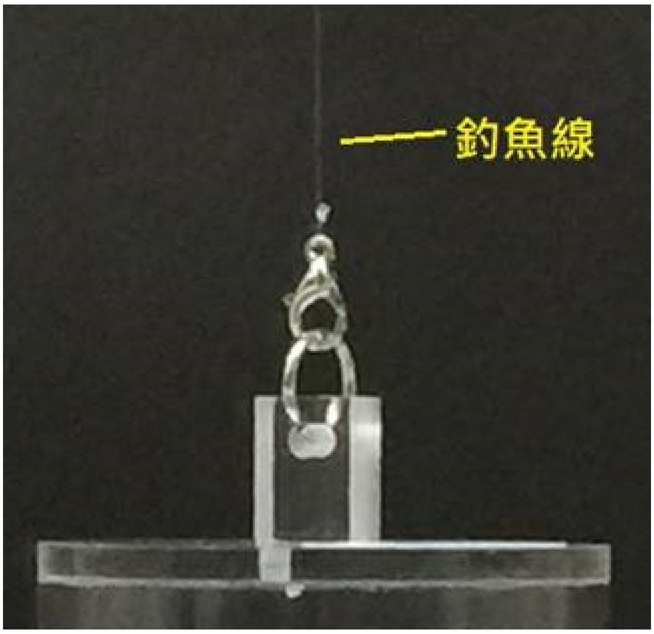
[illegible])[illegible]

[illegible]0[illegible]3[illegible]4[illegible]5[illegible]

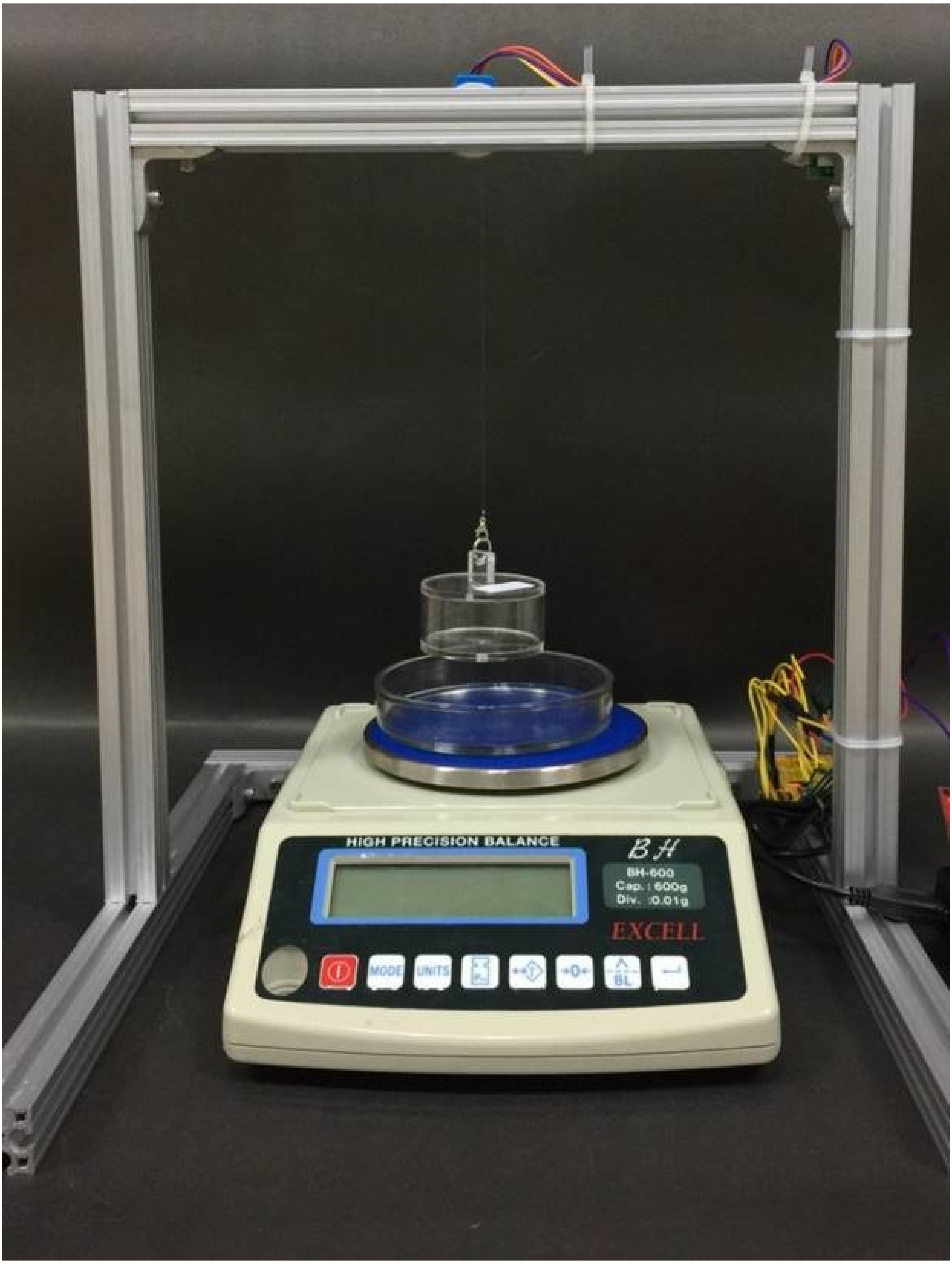


[illegible]3: 0[illegible]2017[illegible]





[illegible]4: [illegible]2017[illegible]

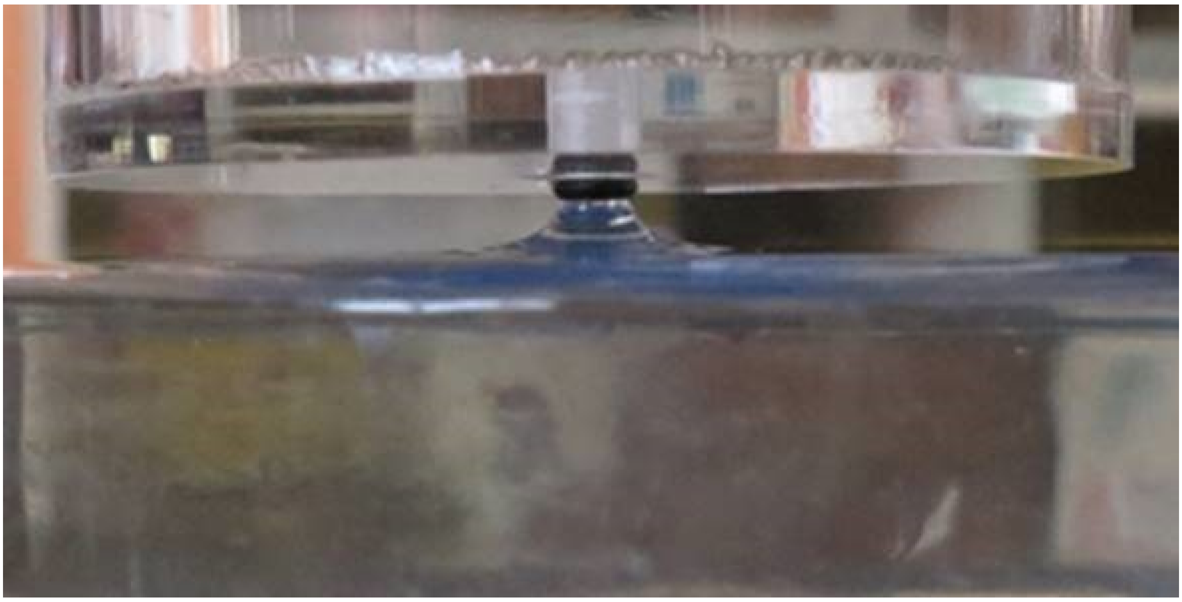


□5: □□□□□□□□□□□□□□□□2017□

□□□□□□□□□□□□□□□□□6□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□2017□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□0□□6□□□□□□□□□□□□□□□□□□□

□□□□□□□□□□□□□□□□□□□□□□□□□□0□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□1□2□3 mm□0□□□□□□□□□□□□□□□□□□□□□□□□□0□□□□□□□□□□□□□□□□□□□□0□□□□□□□□□□□□□□□□□□□□□□□□□

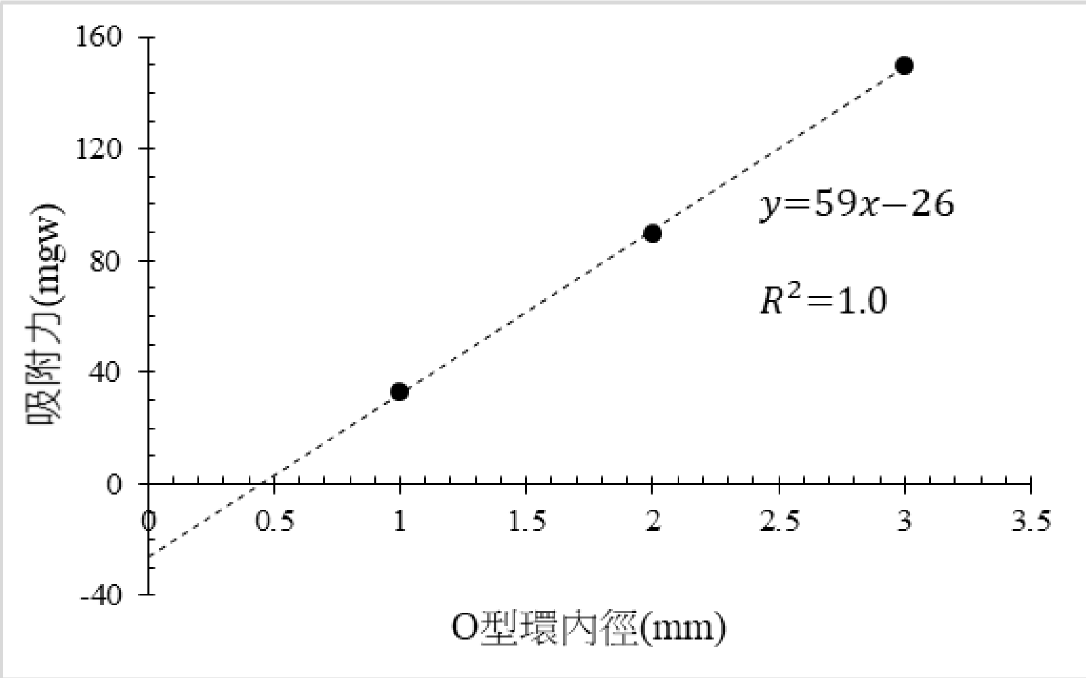
□6: 28BY J-48□□□□□□□□□□□□□□□(UNL2003) (□□□□□□□□□□2017□



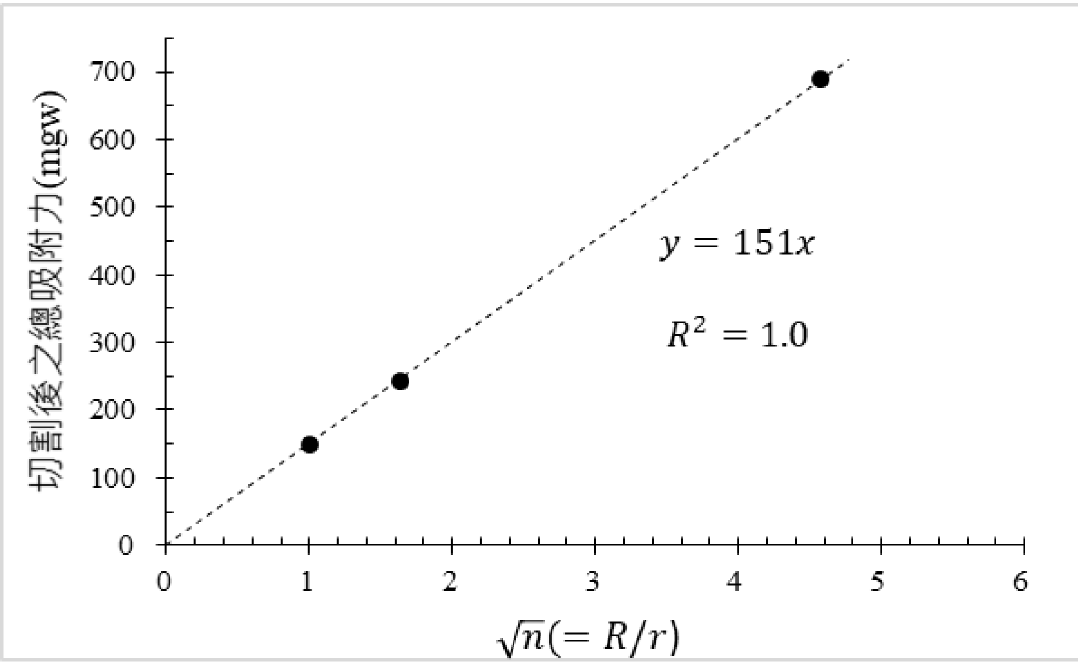
□6□□□□□□□□□□□□□□0□□□□□□□□□□□□□□□□□□□□□□2017□

□□□□□□7□□□□□□□□□□□□□□□□□□□□□□□□0□□($f \propto r$)□□□□□□□□□□□□□□□□□□0□□□□□□□□□□□□□□□□0□□□□□□□□□□□□0□□□□□□□□□□□□□□0□□□□□□□□□□□□□□□□□□□□□□□□□□□□□0.4-0.5 mm□□□□□□□□□7□□□□□0.44 mm□□□□□0□□□n□□□□□□□□f□□□n□□□□□□□□□□□□$F' = nf$□□□□□□□□□□F'□□$\sqrt{n}$□□□□□□8□□□□□□$F' \propto \sqrt{n}$□□□□□

□□□□□



□7□□□0□□□□□□□



□8□□□□□□□□□□ $\sqrt{n}$ □□□□

n □□

□□□□□□□□□□□□□□□□□□□□□□□ $\sqrt{n}(=R/r$)□□□□□□□□□

□□
□□□□□□□□□□□□□□□□□1□□

n □□□□

□□□□2017□□□□□□□□□□□□—□□□□□□□□□□□□□□□□□□□□□□□□□□

Arzt, E. (2006). Biological and artificial attachment devices: Lessons for materials scientists from flies and geckos. *Materials Science and Engineering: C*, *26*(8), 1245-1250. Doi: 10.1016/j.msec.2005.08.033

Arzt, E., Gorb, S., Spolenak, R. (2003). From micro to nano contacts in biological attachment devices. *Proceedings of the National Academy of Science of the United States of America*, *100*(19), 10603-10606. Doi: 10.1073/pnas.1534701100

Autumn, K. & Peattie, A. M. (2002). Mechanisms of Adhesion in Geckos. *Integrative and Comparative Biology*, *42*(6), 1081-1090. Doi: 10.1093/icb/42.6.1081

Autumn, K. (2006). How gecko toes stick: the powerful fantastic adhesive used by geckos is made of nanoscale hairs that engage tiny forces, inspiring envy among human imitators. *American Scientist*, *94*(2),124-136. Accessed 21 March 2021.

Autumn, K., Liang, Y. A., Hsieh, S. T., Zesch, W., Chan, W. P., Kenny, T. W., Fearing, R.,& Full, R. J. (2000). Adhesive force of a single gecko foot-hair. *Nature, 405*, 681-685. Doi:10.1038/35015073

Autumn, K., Sitti, M., Liang, Y. A., Peattie, A.M., Hansen, W. R., Sponberg, S., Kenny, T. W., Fearing, R., Israelachvili, J.N., & Full, R. J. (2002). Evidence for van der Waals adhesion in gecko setae. *Proceedings of the National Academy of Sciences of the United States of America, 99*(19), 12252-12256.Doi: 10.1073/pnas.192252799

Cao, Y., Yang, D. & Soboyejoy, W. (2005). Nanoindentation method for determining the initial contact and adhesion characteristics of soft polydimethylsiloxane. *Journal of Materials Research*, *20*, 2004-2011. Doi: 10.1557/JMR.2005.0256

Dellit, W. D. (1934). Zur anatomie und physiologie der Geckozehe. *Jena. Z. Naturwissen*, *68*, 613-658.

Hiller, U. (1968). Untersuchungen zum Feinbau und zur Funktion der Haftborsten von Reptilien. *Z. Morph. Tiere.*, *62*, 307–362.

Hora, S. L. (1923). The adhesive apparatus on the toes of certain geckos and tree frogs. *Journal of the Proceedings of the Asiatic Society*, *9*, 137-145.

Huber, G., Mantz, H., Spolenak, R., Mecke, K., Jacobs, K., Gorb,S. N., & Arzt, E. (2005). Evidence for capillarity contributions to gecko adhesion from single spatula nanomechanical measurements. *Proceedings of the National Academy of Science of the United States of America*, *102*(45) 16293-16296. Doi: 10.1073/pnas.0506328102

Johnson, K. L., Kendall, K., Roberts, A. D. (1971). Surface energy and the contact of elastic solids. *Proceedings of the Royal Society A*, *324*, 301–313. Doi: 10.1098/rspa.1971.0141

Ruibal, R. & Ernst, V. (1965). The structure of the digital setae of lizards. *Journal of Morpholgy, 117*, 271–294. Doi: 10.1002/jmor.1051170302

Schmidt, H. R. (1904). Zur anatomie und physiologie der geckopfote. *Jena. Z. Naturwissen*, *39*, 551.

Simmermacher, G. (1884). Untersuchungen űber haftapparate an tarsalgliedern von insekten. *Zeitschr. Wissen Zool.*, *40*,481–556.

Wagler, J. (1830). *Naturliches System der Amphibien*. J.G. Cotta’schen Buchhandlung, Munchen, Stuttgart unix Tubingen.

n □□□□⇓

[illegible]

[illegible]

[illegible]

[illegible]

hueiying.ho@gmail.com

[illegible]Lotus effect[illegible]2016[illegible]

▪ [illegible]

[illegible]K-12[illegible]K-12[illegible]K-12[illegible]…[illegible]K-12[illegible]

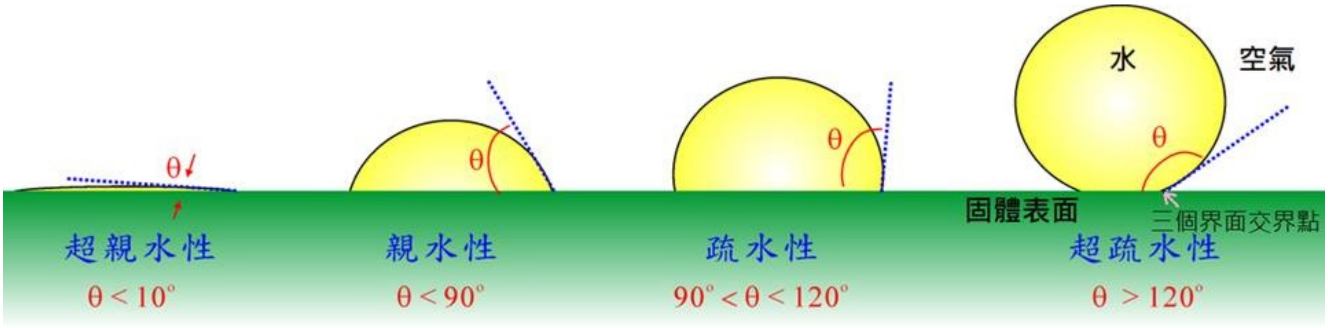
▪ [illegible]

[illegible]1[illegible]1[illegible]1[illegible]

图1[illegible](H. Zell, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=10799164)[illegible](Dat doris, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=87146272)

- [illegible]

[illegible]2[illegible]θ[illegible]/[illegible]/[illegible]/[illegible]90^o[illegible]10^o[illegible]90^o[illegible]120^o[illegible]



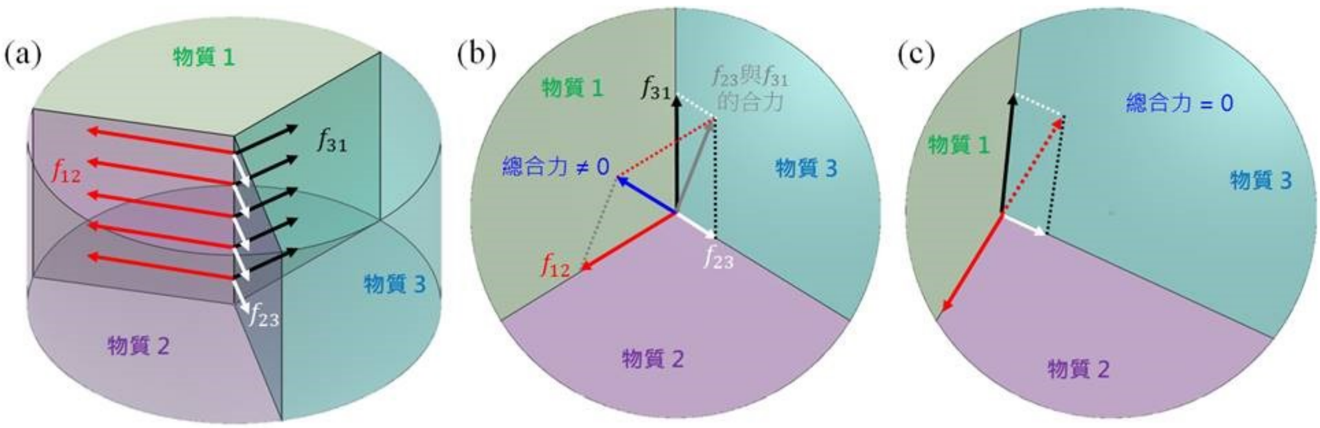
[illegible]2[illegible]/[illegible]2016[illegible]

[illegible]

▪ [illegible]

[illegible]surface tension[illegible]surface energy[illegible]cohesive force[illegible]adhesive force[illegible]

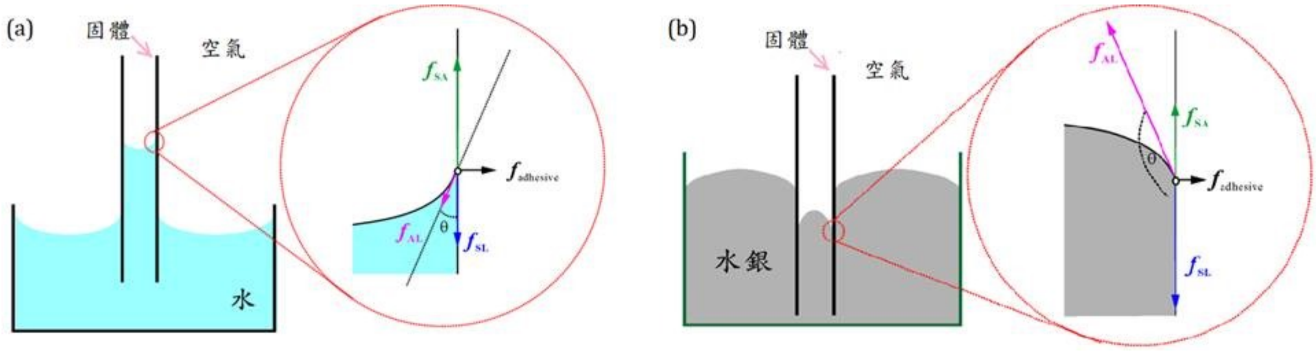
[illegible]g, surface energy density[illegible]g[illegible]g[illegible](f)[illegible]3[illegible]3a[illegible]$\gamma_{12} > \gamma_{31} > \gamma_{23}$[illegible]$f_{12} > f_{31} > f_{23}$[illegible]3b[illegible]3c[illegible]



[illegible]3[illegible] (a)[illegible](b)[illegible](c)[illegible]([illegible])

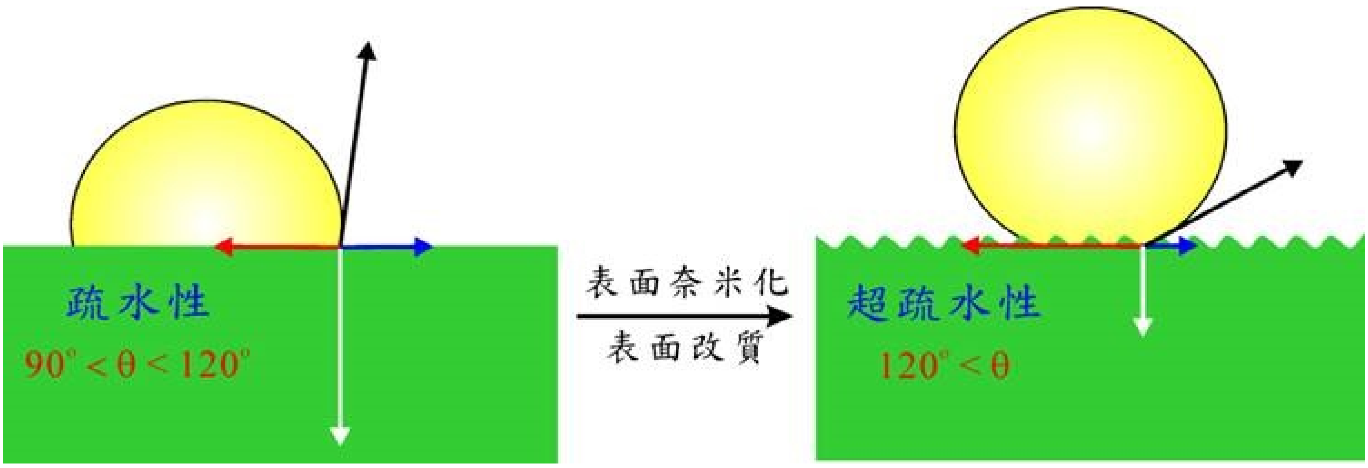
[illegible]4a[illegible]/[illegible](γ_{AL})[illegible]γ_{SA}/[illegible]

□()□□□□□/□(γ_{SL})□□□□□□□□□□□□□□f_{AL}□f_{SA}□□f_{SL}□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□f_{adhesive}□□□□□□□□□□□□□adhesive force□□4a□f_{AL}□□□□□□□□□□□$f_{SL} < f_{SA}$□□□$\theta < 90^{o}$□□□□□□□□□□□□□□□□4b□□□□□□□□□□□□□□□□□□□□□□□□□□f_{AL}□□□□□□□□□□□□$f_{SL} > f_{SA}$□□□$\theta > 90^{o}$□□□□□□



□4□□(a)□□□(b)□□□□□□□□□□□□□□□□□□□□□□□□□□□□q□□□□□□□□□□□□□□□□□□□□□□□2016□

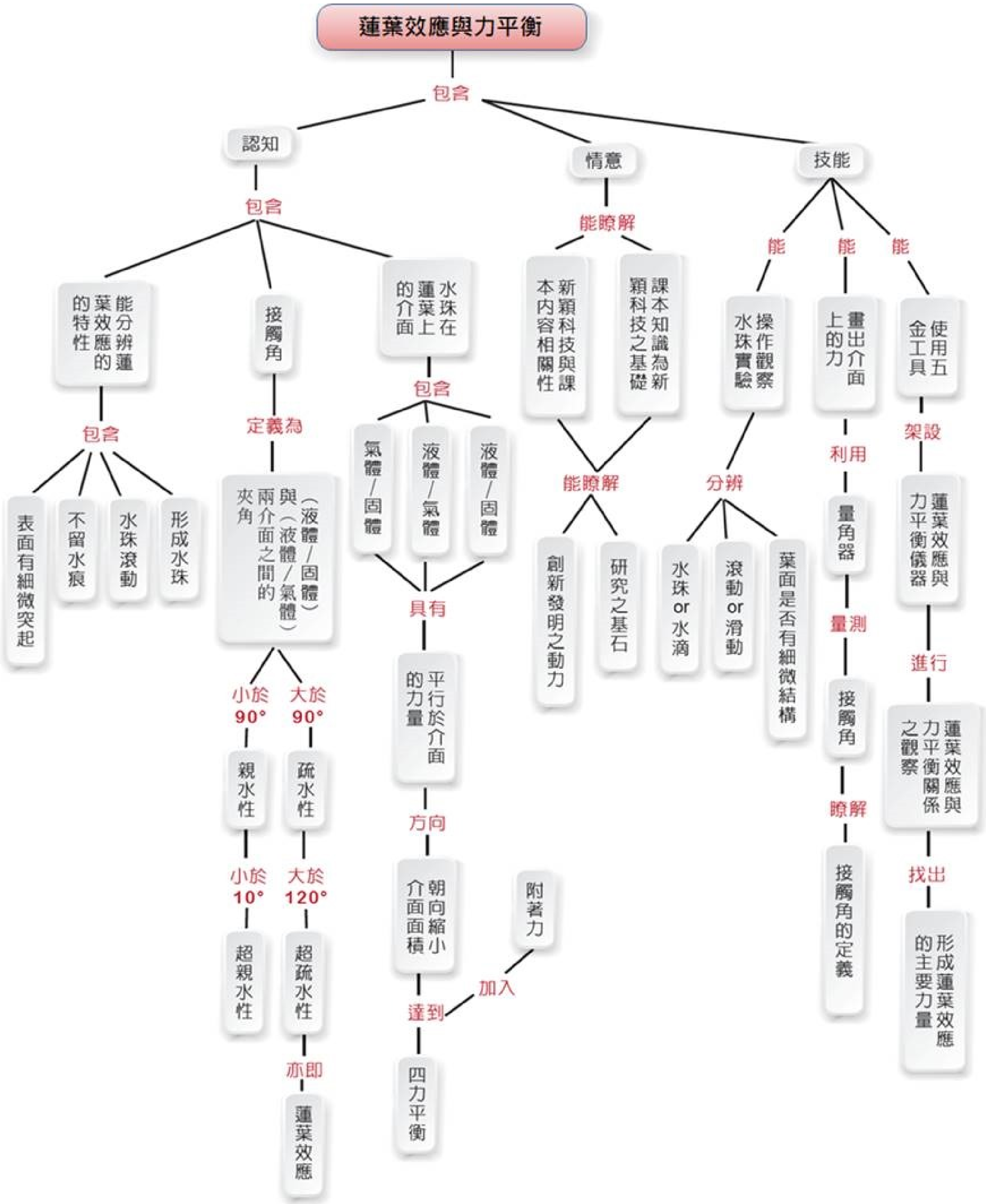
□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□/□□(f_{SL})□□□/□□(f_{SA})□□□□□□□□□□□□□□□□□□□□□□□q□□□5□□120^{o}□□



□5□□2016□

- □□□□□□□□□□□□□□□□□□

□□6□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

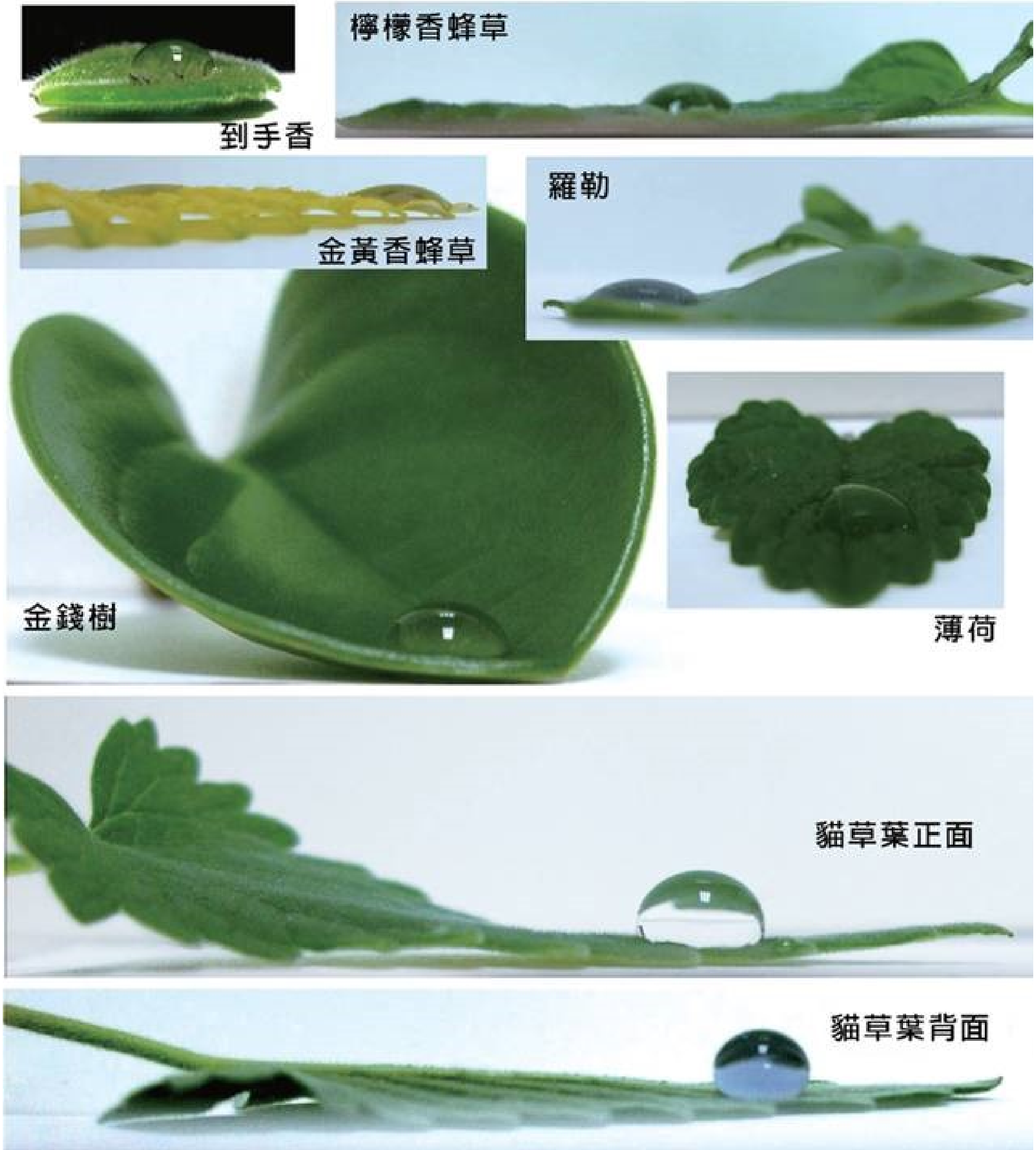


蓮葉效應與力平衡
包含
認知
情意
技能
包含
能分辨蓮葉效應的特性
接觸角
水珠在蓮葉上的介面
包含
表面有細微突起
不留水痕
水珠滾動
形成水珠
定義為
(液體/固體)與(液體/氣體)兩介面之間的夾角
小於 90°
大於 90°
親水性
疏水性
小於 10°
大於 120°
超親水性
超疏水性
亦即
蓮葉效應
包含
氣體/固體
液體/氣體
液體/固體
具有
平行於介面的力量
方向
朝向縮小介面面積
附著力
加入
達到
四力平衡
能瞭解
新穎科技與課本內容相關性
課本知識為新穎科技之基礎
能瞭解
創新發明之動力
研究之基石
能
能
能
操作觀察水珠實驗
畫出介面上的力
使用五金工具
分辨
水珠 or 水滴
滾動 or 滑動
葉面是否有細微結構
利用
量角器
量測
接觸角
瞭解
接觸角的定義
架設
蓮葉效應與力平衡儀器
進行
蓮葉效應與力平衡關係之觀察
找出
形成蓮葉效應的主要力量

[illegible]6[illegible]2016[illegible]

[illegible]

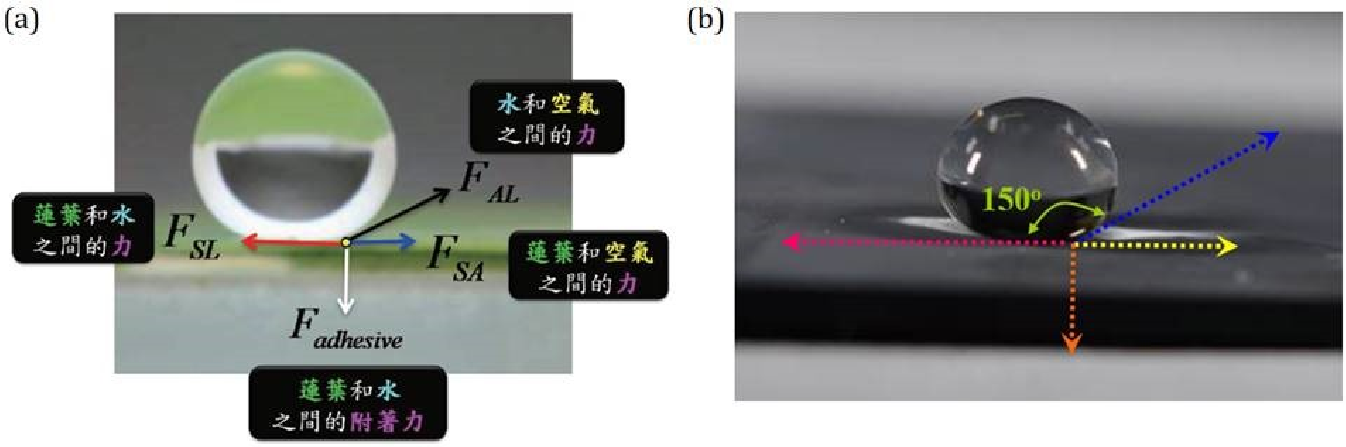
[illegible]7[illegible]



[illegible]7[illegible]（[illegible]2016）

[illegible]

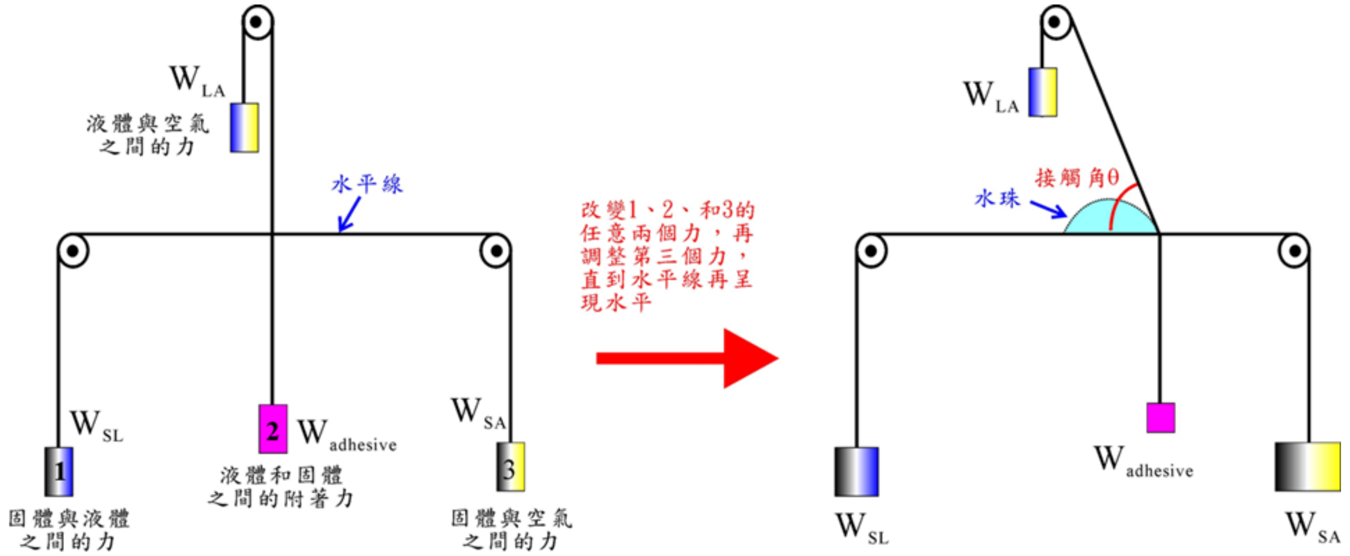
[illegible]4[illegible]4[illegible]8[illegible]



[illegible]8[illegible](a)[illegible](b)[illegible]2016[illegible]

[illegible]

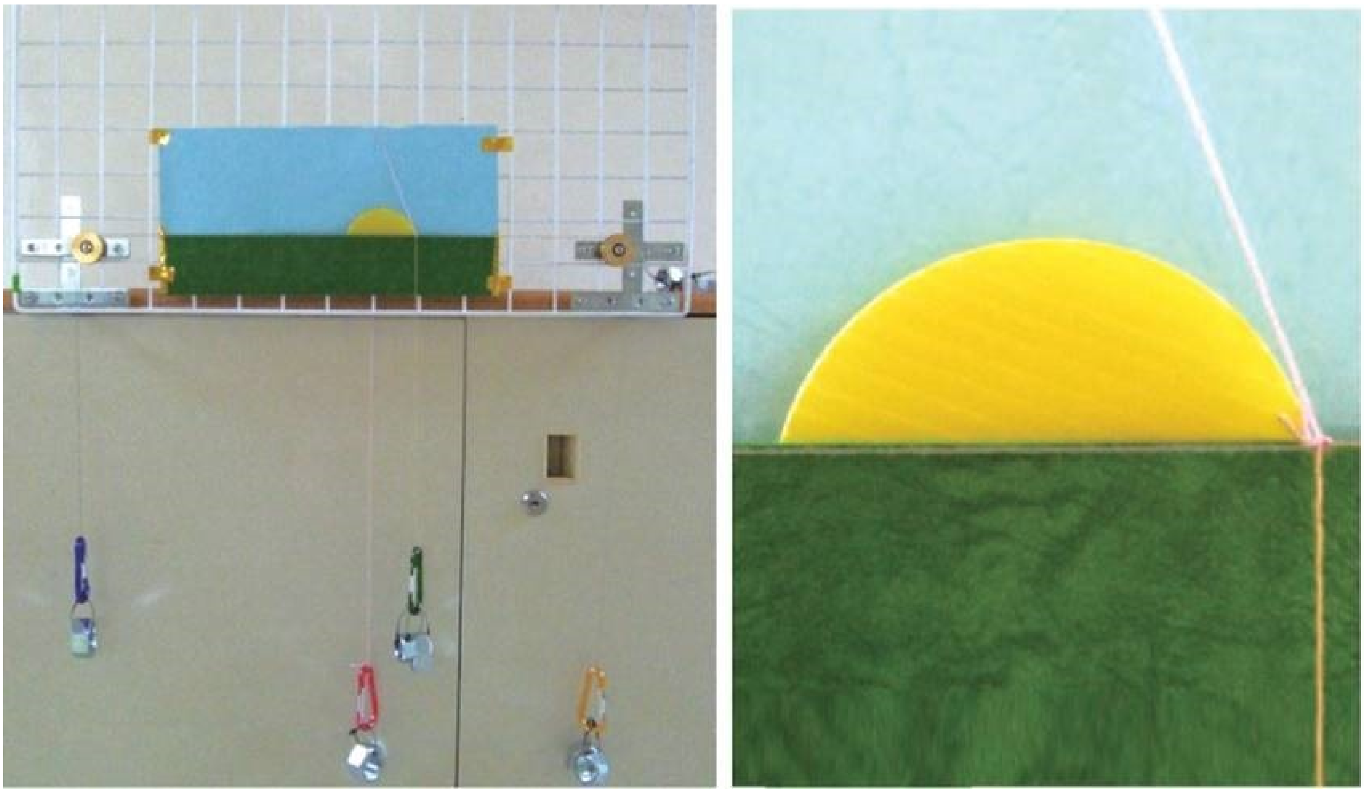
[illegible]9[illegible]10[illegible]11[illegible]4[illegible]12[illegible]13[illegible]1[illegible]$W_{SL} > W_{SA}$ [illegible]$f_{SL} > f_{SA}$[illegible]$W_{SL} < W_{SA}$ [illegible]$f_{SL} < f_{SA}$[illegible]



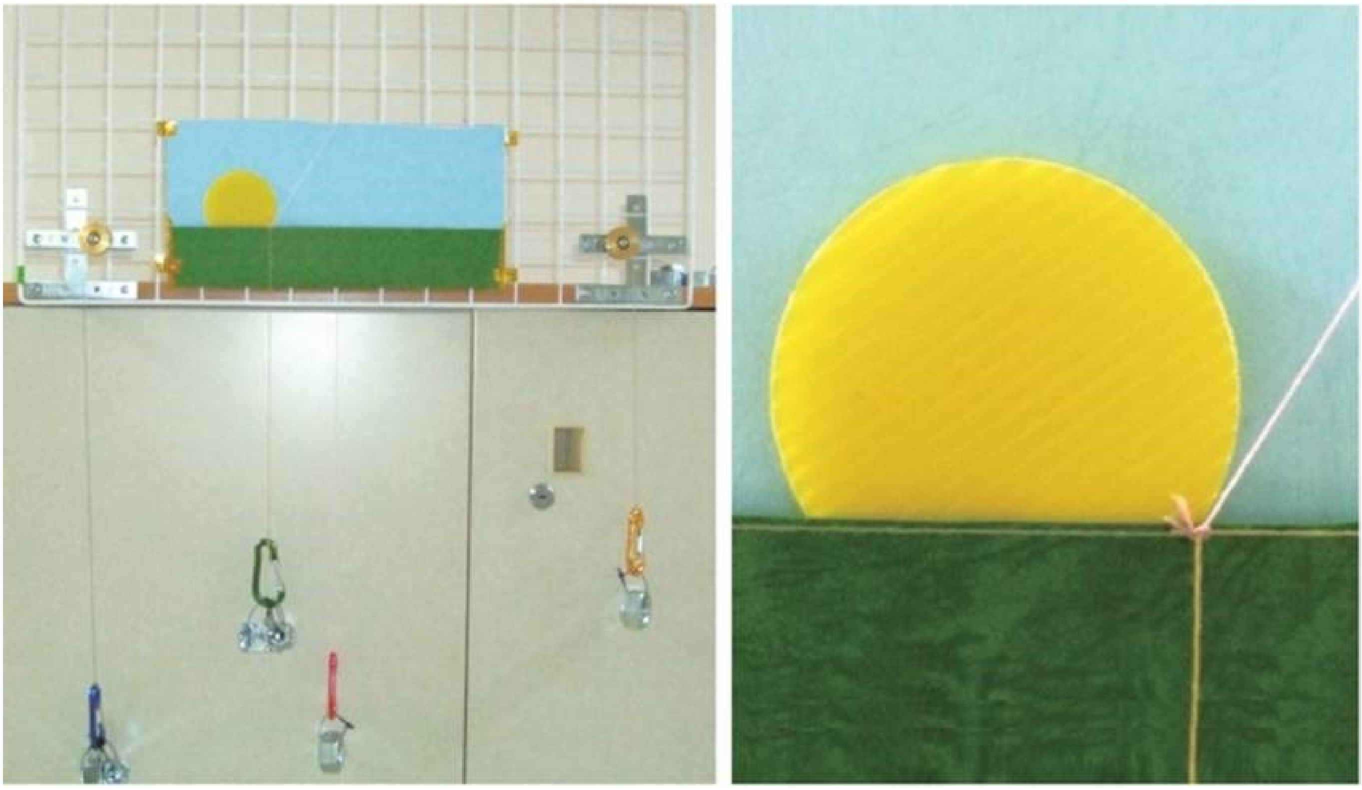
[illegible]9[illegible]2016[illegible]

[illegible]10[illegible]2016[illegible]

[illegible]11[illegible]2016[illegible]



[illegible]12[illegible]2016[illegible]



[illegible]13[illegible]2016[illegible]

[illegible]1[illegible]

吊掛的砝碼重量(gw)				接觸角θ
W_{SL} (固體/液體, f_{SL})	W_{SA} (固體/空氣, f_{SA})	W_{LA} (空氣/液體, f_{LA})	W_{adhesive} (附著力, f_{adhesive})	

[illegible]

[illegible]14[illegible]

[illegible]14[illegible]([illegible]http://www.tanida.org.tw/index.php)

- [illegible]

[illegible]

- [illegible]

[illegible]2016[illegible]K-12[illegible](ISBN[illegible]978-986-04-5288-4)