

GENERAL BEAD SELECTION & PHAGOCYTOSIS RATES

Thiele L, Diederichs JE, Reszka R, Merkle HP, Walter E. (2003) **Competitive adsorption of serum proteins at microparticles affects phagocytosis by dendritic cells.** *Biomaterials*; 24(8):1409-18. (1µm Polybead® and Fluoresbrite® Carboxylate microspheres)

Ahsan F, Rivas IP, Khan MA, Torres Suarez AI. (2002) **Targeting to macrophages: role of physicochemical properties of particulate carriers--liposomes and microspheres--on the phagocytosis by macrophages.** *J Controlled Release*; 79:29-40.

Thiele L, Rothen-Rutishauser B, Jilek S, Wunderli-Allenspach H, Merkle HP, Walter E. (2001) **Evaluation of particle uptake in human blood monocyte-derived cells in vitro. Does phagocytosis activity of dendritic cells measure up with macrophages?** *J Controlled Release*; 76:59-71.

Koval M, Preiter K, Adles C, Stahl PD, Steinberg TH. (1998) **Size of IgG-opsonized particles determines macrophage response during internalization.** *Exp Cell Res*; 242(1):265-73. (0.2-0.3µm Polybead® microspheres; trypan blue quenching)

Tabata Y, Ikada Y. (1988) **Effect of the size and surface charge of polymer microspheres on their phagocytosis by macrophage.** *Biomaterials*; 9(4):356-62.

MONOCYTES

Gu BJ, Duce JA, Valova VA, Wong B, Bush AI, Petrou S, Wiley JS. (2012) **P2X7 receptor-mediated scavenger activity of mononuclear phagocytes toward non-opsonized particles and apoptotic cells is inhibited by serum glycoproteins but remains active in cerebrospinal fluid.** *Journal of Biological Chemistry*. May 18;287:17318-30. (1µm Fluoresbrite® YG microspheres)

Dumrese C, Slomianka L, Ziegler U, Choi SS, Kalia A, Fulurija A, Lu W, Berg DE, Benghezal M, Marshall B, Mittl PR. (2009) **The secreted Helicobacter cysteine-rich protein A causes adherence of human monocytes and differentiation into a macrophage-like phenotype.** *FEBS Lett*. May 19;583(10):1637-43. (1µm green fluorescent beads)

Savard M, Bélanger C, Tardif M, Gourde P, Flamand L, Gosselin J. (2000) **Infection of primary human monocytes by Epstein-Barr virus.** *Journal of Virology*;74(6):2612-9. (2µm Fluoresbrite® YG Carboxylate microspheres)

MACROPHAGES

Acharya, D., Li, X. R., Heineman, R. E., & Harrison, R. E. (2020). **Complement receptor-mediated phagocytosis induces proinflammatory Cytokine production in murine macrophages.** *Frontiers in Immunology*, 10. <https://doi.org/10.3389/fimmu.2019.03049> (The goal of this experiment was to determine if CR-mediated phagocytosis is proinflammatory. Opsonized Bangs beads were used to ensure that proinflammatory effects were not due to components on the sRBC membranes. These opsonized beads invoked high expression of proinflammatory mediators.)

Jaumouillé, V., Cartagena-Rivera, A. X., & Waterman, C. M. (2019). **Coupling of β2 integrins to actin by a mechanosensitive molecular clutch drives complement receptor-mediated phagocytosis.** *Nature Cell Biology*, 21(11), 1357-1369. <https://doi.org/10.1038/s41556-019-0414-2> (Bead internalization was driven by formation of Arp2/3 and formin-dependent actin protrusions that wrapped around polystyrene Bangs beads.)

Jay SM, Skokos EA, Zeng J, Knox K, Kyriakides TR. (2010) **Macrophage fusion leading to foreign body giant cell formation persists under phagocytic stimulation by microspheres in in vitro and in vivo in mouse models.** *J Biomed Mater Res A*. April;93(1):189-99. (3µm Fluoresbrite® YG microspheres)

Takahashi T, Kinoshita M, Shono S, Habu Y, Ogura T, Seki S, Kazama T. (2010) **The effect of ketamine anesthesia on the immune function of mice with postoperative Septicemia.** *Anesthesia & Analgesia*. Oct; 111(4):1051-8. (75nm Fluoresbrite® YG Carboxylate microspheres)

Steinberg BE, Scott CC, Grinstein S. (2007) **High-throughput assays of phagocytosis, phagosome maturation, and bacterial invasion.** *Am J Physiol Cell Physiol*;292:C945-52. (3µm and 8µm undyed PS beads from Bangs)

Ablin J, Verbovetski I, Trahtemberg U, Metzger S, Mevorach D. (2005) **Quinidine and procainamide inhibit murine macrophage uptake of apoptic and necrotic cells: A novel contributing mechanism of drug-induced-lupus.** *Apoptosis*; 10(5):1009-18. (1µm green fluorescent beads)

Ahsan F, Rivas IP, Khan MA, Torres Suarez AI. (2002) **Targeting to macrophages: role of physicochemical properties of particulate carriers--liposomes and microspheres--on the phagocytosis by macrophages.** *J Controlled Release*; 79:29-40.

Reichner JS, Fitzpatrick PA, Wakshull E, Albina JE. (2001) **Receptor-mediated phagocytosis of rat macrophages is regulated differentially for opsonized particles and non-opsonized particles containing beta-glucan.** *Immunology* Oct; 104(2):198-206. (3µm Fluoresbrite® YG microspheres)

Koval M, Preiter K, Adles C, Stahl PD, Steinberg TH. (1998) **Size of IgG-opsonized particles determines macrophage response during internalization.** *Exp Cell Res*; 242(1):265-73. (0.2µm - 3µm Polybead® microspheres, Trypan Blue quenching)

Tabata Y, Ikada Y. (1988) **Effect of the size and surface charge of polymer microspheres on their phagocytosis by macrophage.** *Biomaterials*; 9(4):356-62.

Steinkamp JA, Wilson JS, Saunders GC, Stewart CC. (1982) **Phagocytosis: flow cytometric quantitation with fluorescent microspheres.** *Science*; 215:64-66.

DENDRITIC CELLS

Wu Z, Rothwell L, Young JR, Kaufman J, Butter C, Kaiser P. (2010) **Generation and characterization of chicken bone marrow-derived dendritic cells.** *Immunology*. Jan;129(10):133-45. (0.5µm Fluoresbrite® YG Carboxylate microspheres)

Byrne SN, Halliday GM. (2003) **Phagocytosis by dendritic cells rather than MHC IIhigh macrophages is associated with skin tumour regression.** *Int J Cancer*: 106:736-44. (0.5µm Fluoresbrite® YG Carboxylate microspheres)

Thiele L, Diederichs JE, Reszka R, Merkle HP, Walter E. (2003) **Competitive adsorption of serum proteins at microparticles affects phagocytosis by dendritic cells.** *Biomaterials*; 24(8):1409-18. (1µm Polybead® and Fluoresbrite® Carboxylate microspheres)

Thiele L, Rothen-Rutishauser B, Jilek S, Wunderli-Allenspach H, Merkle HP, Walter E. (2001) **Evaluation of particle uptake in human blood monocyte-derived cells in vitro. Does phagocytosis activity of dendritic cells measure up with macrophages?** *Journal of Controlled Release*; 76:59-71. (1µm Fluoresbrite® and 4.5µm Polybead®, both surface-labeled with BSA-FITC)

NEUTROPHILS

Fleming JC, Bao G, Cepinskas G, Weaver LC. (2010) **Anti-α4 integrin antibody induces receptor internalization and does not impair the function of circulating neutrophilic leukocytes.** *Inflamm Res*; 59:647-57. (0.75µm Fluoresbrite® YG COOH)

Herant M, Heinrich V, Dembo M. (2005) **Mechanics of neutrophil phagocytosis: Behavior of the cortical tension.** *Journal of Cell Science*, 118(9): 1789-97. (2-10µm undyed Polybead®, opsonized)

Radsak MP, Hilf N, Singh-Jasuja H, Braedel S, Brossart P, Rammensee H-G, Schild H. (2003) **The heat shock protein Gp96 binds to human neutrophils and monocytes and stimulates effector functions.** *Blood*. April 1; 101(7):2810-15. (1µm Fluoresbrite® PC Red)

Ogle JD, Noel JG, Sramkoski RM, Ogle CK, Alexander JW. (1988) **Phagocytosis of opsonized fluorescent microspheres by human neutrophils.** *J Immunological Methods*. Nov. 25;115(1):17-29. (0.75µm Fluoresbrite® YG COOH)

ADHERENT CELLS

Dumrese C, Slomianka L, Ziegler U, Choi SS, Kalia A, Fulurija A, Lu W, Berg DE, Benghezal M, Marshall B, Mittl PR. (2009) **The secreted Helicobacter cysteine-rich protein A causes adherence of human monocytes and differentiation into a macrophage-like phenotype.** *FEBS Lett*. May 19;583(10):1637-43. (1µm green fluorescent beads)

MICROGLIAL CELLS

Beutner C, Roy K, Linnartz B, Napoli I, Neumann. (2010) **Generation of microglial cells from mouse embryonic stem cells.** *Nature Protocols*;5:1481-94. (1µm PC Red - flow cytometric detection)

Skripuletz T, Miller E, Grote L, Gudi V, Pul R, Voss E, Skuljec J, Moharreggh-Khiabani D, Trebst C, Stangel M. (2011) **Lipopolysaccharide delays demyelination and promotes oligodendrocyte precursor proliferation in the central nervous system.** *Brain, Behavior, and Immunity*;25:1592-1606. (1µm carboxyl-modified fluorescent beads added to microglia cells at a ratio of 1:200 (cells:beads presumably))

Krabbe G, Matyash V, Pannasch U, Mamer L, Boddeke HWGM, Kettenmann H. (2012) **Activation of serotonin receptors promotes microglial injury-induced motility but attenuates phagocytic activity.** *Brain, Behavior, and Immunity*;26(3):419-28. (3µm YG COOH - confocal microscopy detection)

IN VIVO

Jay SM, Skokos EA, Zeng J, Knox K, Kyriakides TR. (2010) **Macrophage fusion leading to foreign body giant cell formation persists under phagocytic stimulation by microspheres in vitro and in vivo in mouse models.** *J Biomed Mater Res A*. April; 93(1):189-99. (3µm Fluoresbrite® YG)

Takahashi T, Kinoshita M, Shono S, Habu Y, Ogura T, Seki S, Kazama T. (2010) **The effect of ketamine anesthesia on the immune function of mice with postoperative Septicemia.** *Anesthesia & Analgesia*. Oct; 111(4):1051-8. (75nm Fluoresbrite® YG COOH)

Byrne SN, Halliday GM. (2003) **Phagocytosis by dendritic cells rather than MHC IIhigh macrophages is associated with skin tumour regression.** *Int J Cancer*. 106:736-44. (0.5µm Fluoresbrite® YG COOH)

FLOW CYTOMETRIC DETECTION

Gu BJ, Duce JA, Valova VA, Wong B, Bush AI, Petrou S, Wiley JS. (2012) **P2X7 receptor-mediated scavenger activity of mononuclear phagocytes toward con-opsonized particles and apoptotic cells is inhibited by serum glycoproteins but remains active in cerebrospinal fluid.** *Journal of Biological Chemistry*. May 18;287:17318-30. (1µm Fluoresbrite® YG)

Haugland GT, Jakobsen RA, Vestvik N, Ulven K, Stokka L, Wergeland HI. (2012) **Phagocytosis and respiratory burst activity in Lump sucker (*Cyclopterus lumpus* L.) leukocytes analysed by flow cytometry.** *PLOS ONE*. Oct.; 7(10):e47909. (1µm Fluoresbrite® YG COOH)

Fleming JC, Bao G, Cepinskas G, Weaver LC. (2010) **Anti-α4 integrin antibody induces receptor internalization and does not impair the function of circulating neutrophilic leukocytes.** *Inflamm Res*, 59:647-57. (0.75µm Fluoresbrite® YG COOH)

Ablin J, Verbovetski I, Trahtenberg U, Metzger S, Mevorach D. (2005) **Quinidine and procainamide inhibit murine macrophage uptake of apoptotic and necrotic cells: A novel contributing mechanism of drug-induced-lupus.** *Apoptosis*; 10(5):1009-18. (1µm green fluorescent beads)

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Radsak MP, Hilf N, Singh-Jasuja H, Braedel S, Brossart P, Rammensee H-G, Schild H. (2003) **The heat shock protein Gp96 binds to human neutrophils and monocytes and stimulates effector functions.** *Blood*. April 1; 101(7):2810-15. (1µm Fluoresbrite® PC Red)

Savard M, Bélanger C, Tardif M, Gourde P, Flamand L, Gosselin J. (2000) **Infection of primary human monocytes by Epstein-Barr virus.** *Journal of Virology*; 74(6):2612-9. (2µm Fluoresbrite® YG Carboxylate microspheres)

Lehmann AK, Sørnes S, Halstensen A. (2000) Phagocytosis: **Measurement by flow cytometry.** *J Immunological Methods*; 243:229-42. (1µm Fluoresbrite® PC Red)

Steinkamp JA, Wilson JS, Saunders GC, Stewart CC. (1982) **Phagocytosis: Flow cytometric quantitation with fluorescent microspheres.** *Science*; 215:64-66.

OPSONIZED BEADS FOR PHAGOCYTOSIS

Wen, X., Xu, X., Sun, W., Chen, K., Pan, M., Wang, J. M., Bolland, S. M., & Jin, T. (2019). **G-protein-coupled formyl peptide receptors play a dual role in neutrophil chemotaxis and bacterial phagocytosis.** *Molecular Biology of the Cell*, 30(3), 346-356. <https://doi.org/10.1091/mbc.e18-06-0358> (This study demonstrates how G-protein-coupled formyl peptide receptors (FPRs) directly mediates neutrophil phagocytosis. fMLP on the surface of 5µm Streptavidin Bangs beads interacts with formyl peptide receptors to trigger a Ca²⁺ response and induce actin-polymerization to form a phagocytic cup for engulfment of the bead.)

Bakalar, M. H., Joffe, A. M., Schmid, E. M., Son, S., Podolski, M., & Fletcher, D. A. (2018). **Size-dependent segregation controls macrophage phagocytosis of antibody-opsonized targets.** *Cell*, 174(1), 131-142.e13. <https://doi.org/10.1016/j.cell.2018.05.059> (Research quantified phagocytosis of target Bangs beads with biotinylated Fib1L, Fib3L, Fib5L, and Fib7L protein antigens opsonized with anti-biotin IgG. There was a decrease in phagocytosis with increasing antigen height.)

Holt, B. A., Bellavia, M. C., Potter, D., White, D., Stowell, S. R., & Sulchek, T. (2017). **Fc microparticles can modulate the physical extent and magnitude of complement activity.** *Biomaterials Science*, 5(3), 463-474. <https://doi.org/10.1039/c6bm00608f> (Fc-functionalized 1µm and 4µm carboxyl polystyrene Bangs beads were designed to either enhance or diminish the local cytotoxic effect of complement activation in human serum. The beads had antibodies with the Fc domains oriented outward or randomly adsorbed to the bead surface. The effects of these complement-modulating microspheres can provide new possibilities of achieving a desired clinical result.)

Blanchette CD, Woo Y-H, Thomas C, Shen N, Sulcheck TA, Hiddessen AL. (2009) **Decoupling internalization, acidification and phagosomal-lysosomal/lysosomal fusion during phagocytosis of In1A coated beads in epithelial cells.** *PLoS ONE*, 4(6):e6056 (2µm undyed PS-COOH beads from Bangs)

Dumrese C, Slomianka L, Ziegler U, Choi SS, Kalia A, Fulurija A, Lu W, Berg DE, Benghezal M, Marshall B, Mittl PR. (2009) **The secreted Helicobacter cysteine-rich protein A causes adherence of human monocytes and differentiation into a macrophage-like phenotype.** *FEBS Lett.* May 19;583(10):1637-43. (1µm green fluorescent beads)

Sulahian TH, Imrich A, DeLoid G, Winkler AR, Kobzik L. (2008) **Signaling pathways required for macrophage scavenger receptor-mediated phagocytosis: analysis by scanning cyometry.** *Respiratory Research*; 9:59. (1µm green fluorescent COOH)

Steinberg BE, Scott CC, Grinstein S. (2007) **High-throughput assays of phagocytosis, phagosome maturation, and bacterial invasion.** *Am J Physiol Cell Physiol*; 292:C945-52. (3µm and 8µm undyed PS beads from Bangs)

Herant M, Heinrich V, Dembo M. (2005) **Mechanics of neutrophil phagocytosis: Behavior of the cortical tension.** *Journal of Cell Science*; 118(9):1789-97. (2-10µm undyed Polybead[®], opsonized)

Reichner JS, Fitzpatrick PA, Wakshull E, Albina JE. (2001) **Receptor-mediated phagocytosis of rat macrophages is regulated differentially for opsonized particles and non-opsonized particles containing beta-glucan.** *Immunology*, Oct; 104(2):198-206.(3µm Fluoresbrite[®] YG)

Lehmann AK, Sørnes S, Halstensen A. (2000) **Phagocytosis: Measurement by flow cytometry.** *J Immunological Methods*; 243:229-42. (1µm Fluoresbrite[®] PC Red)

QUENCHING FITC-LABELED BEADS WITH TRYPAN BLUE

Thiele L, Rothen-Rutishauser B, Jilek S, Wunderli-Allenspach H, Merkle HP, Walter E. (2001) **Evaluation of particle uptake in human blood monocyte-derived cells in vitro. Does phagocytosis activity of dendritic cells measure up with macrophages?** *Journal of Controlled Release*; 76:59-71. (1µm Fluoresbrite[®] and 4.5µm Polybead[®], both surface-labeled with BSA-FITC)

Koval M, Preiter K, Adles C, Stahl PD, Steinberg TH. (1998) **Size of IgG-opsonized particles determines macrophage response during internalization.** *Exp Cell Res*; 242 (1):265-73. (0.2µm - 3µm Polybead[®], Trypan Blue quenching)

Blanchette CD, Woo Y-H, Thomas C, Shen N, Sulcheck TA, Hiddessen AL. (2009) **Decoupling internalization, acidification and phagosomal-lysosomal/lysosomal fusion during phagocytosis of InLA coated beads in epithelial cells.** *PLoS ONE*; 4(6):e6056 (2µm undyed PC beads from Bangs) *method: opsonize beads with Alexa Fluor® (AF)488- or FITC-protein conjugates; perform phagocytosis studies; quench AF488 fluorescence with anti-AF488 antibody or distinguish uningested/ingested FITC-conjugate fluorescence by pH difference in environment inside/outside the phagosome in epithelial cells. ****contains detailed EDAC coupling procedure**

Sulahian TH, Imrich A, DeLoid G, Winkler AR, Kobzik L. (2008) **Signaling pathways required for macrophage scavenger receptor-mediated phagocytosis: analysis by scanning cyometry.** *Respiratory Research*; 9:59. (1µm green fluorescent COOH) *method: coat beads with biotin-BSA so that uningested beads can be labeled w/ SA-Texas Red to distinguish from ingested beads

Steinberg BE, Scott CC, Grinstein S. (2007) **High-throughput assays of phagocytosis, phagosome maturation, and bacterial invasion.** *Am J Physiol Cell Physiol*; 292:C945-52. (3µm and 8µm undyed PS beads from Bangs) *method: beads opsonized w/ Human IgG and labeled with CyTM3 anti-Human conjugate; after phagocytosis, uningested beads identified by staining with a CyTM5 anti-Human conjugate.

Ogle JD, Noel JG, Sramkoski RM, Ogle CK, Alexander JW. (1988) **Phagocytosis of opsonized fluorescent microspheres by human neutrophils.** *J Immunological Methods*. Nov. 25; 115(1):17-29. (0.75µm Fluoresbrite® YG COOH)