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Professor of Medical Science

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Research Interests: *Carcinogenesis and Molecular Oncology*

- DNA damage and DNA repair
- Genotoxicity of metals and formaldehyde
- Cellular stress responses to genotoxic and proteotoxic chemicals
- Resistance mechanisms for DNA-damaging cancer drugs

Education

B.Sc. (with distinction) - 1984 (biochemistry), Belarusian State University, Minsk, Belarus
Ph.D. - 1989 (biochemistry), Belarusian Academy of Science, Belarus

Faculty Appointments

2010 *Professor*, Brown University, Dept. of Pathology and Laboratory Medicine
2004 *Associate Professor* (with tenure), Brown University, Dept. of Pathology and Lab. Medicine
1998 *Assistant Professor* (tenure-track), Brown University, Dept. of Pathology and Lab. Medicine
1997 *Assistant Professor* (tenure-track), New York University, Dept. of Environmental Medicine
1993 *Research Assistant Professor*, New York University, Dept. of Environmental Medicine

Postdoctoral Positions

1991-93 *Research Associate*, NYU, Dept. of Environmental Medicine
1989-91 *Researcher*, Institute of Radiobiology, Minsk, Belarus

Awards/Honors

- *1st place award*, Team of Belarus, Undergraduate Competition in Biology (Kishinev, Moldova, 1983)
- *2nd place award (in biochemistry)*, National Undergraduate Research Conference (Novosibirsk, Russia, 1984)
- *Medal from the government of Belarus* for work in Chernobyl accident-contaminated areas (1991)
- *Manning Assistant Professor* (2000-2004)
- *Dean's Teaching Excellence Award* (2004, 2006, 2007, 2008) – Medical School teaching
- *Certificate of Recognition for Exemplary Teaching* (2009) - Medical School teaching
- *Nelson Fausto Teaching Award* (2009, inaugural award) - Undergraduate teaching
- *Dean's Excellence in Teaching Award* (2010) - Medical School teaching
- *Certificate of Recognition for Exemplary Teaching* (2011) - Medical School teaching
- *Dean's Excellence in Teaching Award* (2012) - Medical School teaching
- *Certificate of Recognition for Exemplary Teaching* (2013) - Medical School teaching

- *Dean's Excellence in Teaching Award* (2014) - Medical School teaching
- *Certificate of Recognition for Exemplary Teaching* (2015) - Medical School teaching
- *Dean's Excellence in Teaching Award* (2016)
- *Certificate of Recognition for Exemplary Teaching,* Office of Medical Education (2016)
- *William J. Waddell seminar*, Dept. of Pharmacology and Toxicology, University of Louisville School of Medicine, KY (May, 2016)
- *Keynote Lecture*, 9th Conference on Metal Toxicity and Carcinogenesis, Lexington, KY (Oct. 16-19, 2016)
- *Certificate of Recognition for Exemplary Teaching, Office of Medical Education* (2017)
- *Certificate of Recognition for Exemplary Teaching, Office of Medical Education* (2018)
- *Dean's Excellence in Teaching Award* (2019)
- *Certificate of Recognition for Exemplary Teaching,* Office of Medical Education (2019)

Professional Activities

- *Councilor*, Metals Specialty Section, Society of Toxicology (2001-2003)
- *Biomonitoring Scientific Advisory Board*, Rhode Island Dept. of Health (2002-2003)
- *Organizer and co-Chair*, Symposium on *Metal Carcinogenesis: New Concepts* (2006)
- *Editorial Board*, 10th International Symposium on Metal Ions in Biology and Medicine (2008)
- *Ph.D. Jury*, University of Coimbra, Portugal (2009)
- *NIH study section XNDA*, chartered member (2006-2010)
- *Organizing Committee* – 6th Conference on Metal Toxicity and Carcinogenesis (2010)
- *Executive Committee*, Division of Chemical Toxicology, American Chemical Society (2008-2011)
- *Chair, Peer Review Workshop* for EPA's Toxicological Review of Hexavalent Chromium (2011)
- *Editorial Board, Chemical Research in Toxicology* (2007-2012)
- *Scientific Advisory Board*, NanoMedicine Research, Ltd (2008 – 2010)
- *Organizing Committee* – 7th Conference on Metal Toxicity and Carcinogenesis (2012)
- *Consultan*t, Lynntech Inc, SBIR Phase I award from the U.S. Air Force (8/2012- 5/2013)
- *Editorial Advisory Board* member, *Chemical Research in Toxicology* (2014-present)
- Peer Review Panel for the National Toxicology Program (NTP) Report on Carcinogens: Monograph on Cobalt and Certain Cobalt Compounds (July 22, 2015)
- NIH Study Section SIEE, chartered member (7/1/15-6/30/19)
- Editorial Board, *Cancer Biology & Therapy* (2019-2021)
- Editorial Board, *Toxicological Sciences* (2020-present)
- *Grant reviewer – ad hoc* (22 NIH panels, 8 other agencies/organizations)

  2000 - Canadian Research Council
  2002 - NIH study section ALTX-1
  2003 - NIOSH intramural grant proposals
  - NIEHS Center at Vanderbilt University
  2004 - NIH study section ZAT1
  - NIH Study Section XNDA
  - Welcome Trust, Molecular and Cell Biology Panel, UK
  2005 - NIH study section ZRG1 DIG-F
  - NIH Study Section XNDA
  - NIH Study Section ZRG1 ONC-B
  - NIOSH intramural grant proposals
  2006 - NIH study section XNDA
  - NIH Study Section CE (two meetings)
  - NIH Study Section ZRG1 ONC-T
  2007 - Austrian Science Fund

2009 - NIH Study Section ZRG1 OBT-S (02) M
2010 - NIH Study Section ZRG1 DKUS-F 03
2011 - NIH Study Section ZRG1 OBT-H (02) M
2012 - NIH Study Section ZES1 JAB-D (V)
- NIEHS Center at University of Arizona
2013 - NIH Study Section SIEE (two meetings)
2014 - NIH Study Section SIEE
2015 - NIH Study Section SIEE
- NIH Study Section CE
- Partnership for Native American Cancer Prevention, University of Northern Arizona
2016 - NIH Study Section ZES1 JAB-J (TS)
2021 - NIH Study Section SIEE
2022 - NIH Study Section ZES1 LWJ-S (RI)

- EPA Science Advisory Board (SAB) Hexavalent Chromium Review Panel (10/2022-2023)

2017
- Editorial Advisory Board member, *Chemical Research in Toxicology*
- NIH Study Section SIEE, regular member

2018
- Editorial Advisory Board member, *Chemical Research in Toxicology*
- NIH Study Section SIEE, regular member

2018
- Editorial Advisory Board member, *Chemical Research in Toxicology*
- NIH Study Section SIEE, regular member

2019
- Editorial Advisory Board member, *Chemical Research in Toxicology*
- NIH Study Section SIEE, regular member (through 6/30/2019)
- Editorial Board, *Cancer Biology & Therapy*

2020
- Editorial Advisory Board member, *Chemical Research in Toxicology*
- Editorial Board, *Cancer Biology & Therapy*
- Editorial Board, *Toxicological Sciences*
- External Advisory Committee, *NYU NIEHS Center for the Investigation of Environmental Hazards*

2021
- Editorial Advisory Board member, Chemical Research in Toxicology
- Editorial Board, Cancer Biology & Therapy
- Editorial Board, Toxicological Sciences
- External Advisory Committee, NYU NIEHS Center for the Investigation of Environmental Hazards
- NIH Study section SIEE (March 2021), ad hoc reviewer

2022
- Editorial Advisory Board member, Chemical Research in Toxicology
- Editorial Board, Toxicological Sciences

- NIH Study Section ZES1 LWJ-S (RI) (November, 2022)

Professional Societies

1. AAAS (American Association for Advancement of Science)
2. AACR (American Association for Cancer Research
3. ACS (American Chemical Society)
4. EMGS (Environmental Mutagenesis and Genomics Society)
5. SOT (Society of Toxicology)

Brown University Service

- *Freshmen Advisor* (2002-2003)
- *Biology Concentration Advisor* (2007 - present)
- *Pathobiology Graduate Program committees*:
  Steering (1999-2010)
  Seminar series, chair (2003, 2007)
  Retreat, chair (2000, 2001)
  Admission (1999, 2000 co-chair)
  Award committee, chair (2008)
- *Faculty Search Committees*
  2002-2006
  2011-2012
  2013-2014 (chair)
  2017-2018
- *Grant reviewer*:
  Salomon research grants (2006, 2009, 2016)
  RIH COBRE Center for Cancer Research Development, Pilot projects (2005, 2007)
  Brown-MBL Seed Projects (2010)
  Pilot Projects in Translational Research (2010)
  Research Fund Seed Proposals (2012)
  COBRE CCRD pilot project grants (2015)
- *Presenter and Panelist*, "Navigating the Publication Process" workshop (2010)
- *EPSCoR PhD Fellowship Award Committee* (2011, 2012, 2013)
- *BioMed Space Policy Committee* (2011- 2012)
- *Strategic Planning Group* for Brown Program in Biology (2012)
- *Chair, Faculty Search Committee* (2012/2013)
- *Biology Research Space Committee* member (2013 - present)
- *Selection Committee*, Dean's Faculty Award in Grad & Postdoc Teaching and Mentoring (2013)
- *Departmental Mentor for* Dr. Thomas Bartnikas, Assistant Professor (2013- present)
- Faculty Teaching-Mentoring Award Committee (2015, 2016)
- *BioMed Division Mentor for* Dr. Michelle Dawson, Assistant Professor (2016- present)
- Responsible Conduct in Research Training for BioMed graduate students, presenter for a section on Conflict of Interest

2017

- Biology Research Space Committee
- Faculty Search Committee
- Departmental Manager Search Committee
- PhD Committees for 5 students

- Departmental Mentor for Dr. Thomas Bartnikas, Assistant Professor
- BioMed Division Junior Faculty Mentor for Dr. Michelle Dawson, Assistant Professor in MPPB

2018
- Biology Research Space Committee
- Core Infrastructure Review Committee
- Dept. Faculty Search Committee
- Dept. Faculty Appointment and Promotion Committee
- Review Panel, FY19 Core Research Facility Infrastructure Applications
- PhD Committees for 4 students
- Departmental Mentor for Dr. Thomas Bartnikas, Assistant Professor
- BioMed Division Junior Faculty Mentor for Dr. Michelle Dawson, Assistant Professor in the Dept. of Molecular Pharmacology, Physiology and Biotechnology
- COBRE Mentoring committee for Dr. Patrycja Dubielecka, Assistant Professor of Medicine

2019
- Co-Director, NIH-T32 Training Program in Environmental Pathology
- Co-Leader, Cancer Biology Program, Brown-Lifespan Cancer Center
- Biology Research Space Committee
- BioMed Core Research Facilities Oversight Committee
- Faculty Search Committee, Join Brown-Lifespan Program in Cancer Biology
- Dept. Faculty Appointment and Promotion Committee
- PhD Committees for 6 students
- Departmental Mentor for Dr. Thomas Bartnikas, Assistant Professor
- BioMed Division Junior Faculty Mentor for Dr. Michelle Dawson, Assistant Professor in the Dept. of Molecular Pharmacology, Physiology and Biotechnology
- COBRE Mentoring committee for Dr. Patrycja Dubielecka, Assistant Professor of Medicine

2020
- Leader, Cancer Biology Program, Cancer Center at Brown University
- Cancer Center Pilot Grant Review Panel
- Biology Research Space Committee
- Faculty Search Committee, Join Brown-Lifespan Program in Cancer Biology
- Dept. Faculty Appointment and Promotion Committee
- PhD Committees for 5 students
- Departmental Mentor for Dr. Thomas Bartnikas, Assistant Professor
- BioMed Division Junior Faculty Mentor for Dr. Michelle Dawson, Assistant Professor in the Dept. of Molecular Pharmacology, Physiology and Biotechnology
- COBRE Mentoring committee for Dr. Patrycja Dubielecka, Assistant Professor of Medicine

2021
- Co-Leader, Cancer Biology Program, Legorreta Cancer Center
- Biology Research Space Committee
- Faculty Search Committee, Join Brown-Lifespan Program in Cancer Biology
- Dept. Faculty Appointment and Promotion Committee
- PhD Committees for 3 students
- BioMed Division Junior Faculty Mentor for Dr. Michelle Dawson, Assistant Professor

2022

- Co-Leader, Cancer Biology Program, Legorreta Cancer Center
- Biology Research Space Committee
- Faculty Search Committee, Join Brown-Lifespan Program in Cancer Biology
- Cancer Center Pilot Grant Review Panel
- Dept. Faculty Appointment and Promotion Committee
- PhD Committees for 2 students
- BioMed Division Junior Faculty Mentor for Dr. Michelle Dawson, Assistant Professor

Journal Publications

1. Konoplya EF, Detinkin ON and Zhitkovich AV. Age-related changes of the glucocorticoid-receptor complex translocation and initiation of RNA synthesis in liver cell nuclei. *Vesti AN BSSR, ser. biol. nauk* 2: 75-79 (1987).

2. Konoplya EF, Detinkin ON and Zhitkovich AV. Study of age peculiarities of the structural state of the chromatin of rat liver cells using micrococcal nuclease and circular dichroism. *Biokhimiia (Biochemistry-Moscow)* 53: 1614-1619 (1988).

3. Konoplya EF and Zhitkovich AV. Changes of the rat liver chromatin in aging. *Vesti AN BSSR, ser. biol. nauk* 5:54-58 (1988).

4. Konoplya EF, Detinkin ON and Zhitkovitch AV. Increase in content of tightly bound complexes of DNA-protein in rat liver cell nuclei with aging. *Vopr. Med. Khim.* 35: 78-82 (1989).

5. Yegutkin GG and Zhitkovich AV. Assessment of age-related changes in the structural state of plasma membranes from rat adipose tissue using the method of inductive-resonance energy transfer. *Nauchnye Dokl. Vyss. Shkoly Biol. Nauki* 8: 30-38 (1990).

6. Konoplya EF, Bulanova KJ, Zhitkovich AV, Miliutin AA, Kiriluk AP. Lipid composition of cardiomyocyte sarcolemma in rats of various age. *Vesti AN BSSR, seria biol. nauk* 2: 88-92 (1990).

7. Konoplya EF, Luksha GL, Detinkin ON, Zhitkovich AV, Gavrilin MA, Montik VI, Fil'tchenkov GN. The mechanism of transduction of glucocorticoid effects in ageing. *Fiziol. Zh. SSSR Im. IM Sechenova* 76: 1224-1230 (1990).

8. Yegutkin GG, Sambursky SS, Zhitkovitch AV and Gatsko GG. Evaluation of age-related changes of physicochemical properties and functional activity of rat adipose plasma membranes and their possible relationship. *Mech. Ageing Dev.* 59: 1-16 (1991).

9. Yanushevsky DS, Konevalova NJ, Zhitkovich AV, Detinkin ON and Chirkin AA. Effect of low dose ionizing irradiation on lipid transportation and cholesterol esterification in blood and subfraction composition of histone H1 from rat liver chromatin: correlation with age-related changes. *Vesti AN BSSR, seria biol. nauk* 3-4: 46-50 (1992).

10. Konoplya EF, Voitkun VA, Zhitkovich AV and Miliutin AA. Effect of phorbol esters and amiloride on the radiation-induced interphase death of thymocytes. *Dokl. Akad. Nauk* 324: 452-455 (1992).

11. Zhitkovich A and Costa M. A simple sensitive assay to detect DNA-protein crosslinks in intact cells and in vivo. *Carcinogenesis* 13: 1485-1489 (1992).

12. Salnikow K, Zhitkovich A and Costa M. Analysis of the binding sites of chromium to DNA and protein in vitro and in intact cells. *Carcinogenesis* 13: 2341-2346 (1992).

13. Lipskaya LA, Zhitkovich AV, Vasyukhin VI, Tsvetkov AG and Salnikow KV. The participation of endonuclease in the formation of extrachromosomal DNA and the possible mechanisms of gene amplification. *Tsitologiia* 35: 70-78 (1993).

14. Costa M, Zhitkovich A and Toniolo P. DNA-protein crosslinks in welders: molecular implications. *Cancer Res.* 53: 460-463 (1993).

15. Kargacin B., Squibb K.S., Cosentino S., Zhitkovich A. and Costa M. Comparison of the uptake and distribution of chromium in rats and mice. *Biol. Trace Element Res.* 36: 307-318 (1993).

16. Taioli E, Kinney P, Zhitkovich A, Fulton H, Voitkun V, Cosma G, Frenkel K, Toniolo P, Garte S and Costa M. Application of reliability models to studies of biomarker validation. *Environ. Health Perspect.* 102: 306-309 (1994).

17. Voitkun V, Zhitkovich A and Costa M. Complexing of amino acids to DNA by chromate in intact cells. *Environ. Health Perspect.* 102 (suppl. 3): 251-255 (1994).

18. Zhitkovich A, Voitkun V and Costa M. Glutathione and free amino acids form stable adducts with DNA following exposure of intact mammalian cells to chromate. *Carcinogenesis* 16: 907-913 (1995).

19. Taioli E, Zhitkovich A, Toniolo P, Costa M. Normal values of DNA-protein crosslinks in mononuclear cells of a population of healthy controls. *Cancer J.* 8: 76-78 (1995).

20. Lee Y-W, Klein CB, Kargacin B, Salnikow K, Kitahara J, Dowjat K, Zhitkovich A, Christie NT and Costa M. Carcinogenic nickel silences gene expression by chromatin condensation and DNA methylation: a new model for epigenetic carcinogens. *Mol. Cell. Biol.* 15: 2547-2557(1995).

21. Huang X, Kitahara J, Zhitkovich A, Dowjat K and Costa M. Heterochromatic proteins specifically enhance nickel-induced 8-oxo-dG formation. *Carcinogenesis* 16: 1753-1759 (1995).

22. Taioli E, Zhitkovich A, Kinney P, Udasin I, Toniolo P and Costa M. Increased DNA-protein crosslinks in lymphocytes of residents living in chromium contaminated areas. *Biol. Trace Element Res.* 50: 175-180 (1995).

23. Taioli E, Zhitkovich A, Toniolo P, Bernstein J, Blum R, Costa M. DNA-protein crosslinks as a biomarker of cis-platinum activity in cancer patients. *Oncol. Rep.* 3: 439-441 (1996).

24. Zhitkovich A, Lukanova A, Popov T, Taioli E, Cohen H, Costa M and Toniolo P. DNA-protein crosslinks in peripheral lymphocytes of individuals exposed to hexavalent chromium compounds. *Biomarkers* 1: 86-93 (1996).

25. Zhitkovich A, Voitkun V and Costa M. Formation of the amino acid-DNA complexes by hexavalent and trivalent chromium in vitro: importance of trivalent chromium and the phosphate group. *Biochemistry* 35: 7275-7282 (1996).

26. Costa M, Zhitkovich A, Gargas M, Paustenbach D, Finley B, Kuykendall J, Billings R, Carlson T, Wetterhahn K, Xu J, Patierno S, Bogdanffy M. Interlaboratory validation of a new assay for DNA-protein crosslinks. *Mutat. Res.* 369: 13-21 (1996).

27. Costa M, Zhitkovich A, Toniolo P, Taioli E, Popov T and Lukanova A. Monitoring of human lymphocytic DNA-protein crosslinks as a biomarker of biologically active doses of chromate. *Environ. Health Perspect.* 104 (suppl. 5): 917-919 (1996).

28. Lukanova A, Toniolo P, Zhitkovich A, Nikolova V, Panev T, Popov T, Taioli E and Costa M. Occupational exposure to Cr(VI): comparison between chromium levels in lymphocytes, erythrocytes and urine. *Int. Arch. Occup. Environ. Health* 69: 39-44 (1996).

29. Costa M, Zhitkovich A, Harris M, Paustenbach D and Gargas M. DNA-protein crosslinks produced by various chemicals in cultured human lymphoma cells. *J. Toxicol. Environ. Health* 50: 433-449 (1997).

30. Voitkun V, Zhitkovich A and Costa M. Cr(III)-mediated crosslinks of glutathione or amino acids to the DNA phosphate backbone are mutagenic in human cells. *Nucleic Acids Res.* 26: 2024-2030 (1998).

31. Zhitkovich A, Voitkun V, Kluz T and Costa M. Utilization of DNA-protein crosslinks as a biomarker of chromium exposure. *Environ. Health Perspect.* 106 (suppl. 4): 969-974 (1998).

32. Voitkun V and Zhitkovich A. Analysis of DNA-protein crosslinking activity of malondialdehyde in vitro. *Mutation Research*, 424: 97-106 (1999).

33. Sutherland JE, Zhitkovich A, Kluz T and Costa M. Rats retain chromium in tissues following chronic ingestion of drinking water containing 3 or 10 ppm hexavalent chromium. *Biol. Trace Element Res.* 74: 41-53 (2000).

34. Quievryn G and Zhitkovich A. Loss of DNA-protein crosslinks from formaldehyde-exposed cells occurs through spontaneous hydrolysis and an active repair process linked to proteosome function. *Carcinogenesis* 21: 1573-1580 (2000).

35. Zhitkovich A, Messer J and Shrager S. Reductive metabolism of Cr(VI) by cysteine leads to the formation of binary and ternary Cr-DNA adducts in the absence of oxidative DNA damage. *Chem. Res. Toxicol.* 13: 1114-1124 (2000).

36. Zhitkovich A, Song Y, Quievryn G and Voitkun V. Non-oxidative mechanisms are responsible for the induction of mutagenesis by reduction of Cr(VI) with cysteine: role of ternary DNA adducts in Cr(III)-dependent mutagenesis. *Biochemistry* 40: 549-560 (2001).

37. Quievryn G, Goulart M, Messer J and Zhitkovich A. Reduction of Cr(VI) by cysteine: significance in human lymphocytes and formation of DNA damage in reactions with variable reduction rates. *Mol. Cell. Biochem.* 222: 107-118 (2001).

38. Quievryn G, Messer J and Zhitkovich A. Carcinogenic chromium(VI) induces cross-linking of vitamin C to DNA *in vitro* and in human lung A549 cells. *Biochemistry* 41: 3156-3167 (2002).

39. Zhitkovich A, Quievryn G, Messer J and Motylevich Z. Reductive activation with cysteine represents a chromium(III)-dependent pathway in the induction of genotoxicity by carcinogenic chromium(VI). *Environ. Health Perspect.* 110: 729-731 (2002).

40. Medeiros MG, Rodrigues AS, Batoreu MC, Laires A, Rueff J and Zhitkovich A. Elevated levels of DNA-protein crosslinks and micronuclei in peripheral lymphocytes of tannery workers exposed to trivalent chromium. *Mutagenesis* 18: 19-24 (2003).

41. Quievryn G, Peterson E, Messer J and Zhitkovich A. Genotoxicity and mutagenicity of chromium(VI)/ascorbate-generated DNA adducts in human and bacterial cells. *Biochemistry* 42: 1062-1070 (2003).

42. Dickinson DA, Warnes GR, Quievryn G, Messer J, Zhitkovich A, Rubitski E and Aubrecht J. Differentiating DNA-reactive and non-reactive genotoxic mechanisms using gene expression profile analysis. *Mutat. Res.* 549: 29-41 (2004).

43. Reynolds M, Peterson E, Quievryn G and Zhitkovich A. Human nucleotide excision repair efficiently removes DNA phosphate-chromium adducts and protects cells against chromate toxicity. *J. Biol. Chem*. 279: 30419-30424 (2004).

44. Salnikow K, Donald SP, Bruick RK, Zhitkovich A, Phang JM and Kasprzak KS. Depletion of intracellular ascorbate by the carcinogenic metals nickel and cobalt results in the induction of hypoxic stress. *J. Biol. Chem*. 279: 40337-40344 (2004).

45. Zhitkovich A. Importance of chromium-DNA adducts in mutagenicity and toxicity of chromium(VI). *Chem. Res. Toxicol*. 18: 3-11 (2005).
   *** Journal Cover** (January issue)
   *** #1 downloaded paper for 2005**
   *** #1 cited paper published in this journal in 2005**

46. Peterson-Roth E, Reynolds M, Quievryn G and Zhitkovich A. Mismatch repair proteins are activators of toxic responses to chromium-DNA damage. *Mol. Cell. Biol.* 25: 3596-3607 (2005). PMC1084304

47. Zhitkovich A, Peterson-Roth E, Reynolds M. Killing of chromium-damaged cells by mismatch repair and its relevance to carcinogenesis. *Cell Cycle* 4: 1050-1052 (2005).

48. Karaczyn A, Ivanov S, Reynolds M, Zhitkovich A, Kasprzak KS and Salnikow K. Ascorbate depletion mediates up-regulation of hypoxia-associated proteins by cell density and nickel. *J. Cell. Biochem.* 97: 1025-1035 (2006).

49. Messer J, Reynolds M, Stoddard L and Zhitkovich A. Causes of DNA single-strand breaks during reduction of chromate by glutathione in vitro and in cells. *Free Radic. Biol. Med.* 40: 1981-1992 (2006).

50. Quievryn G, Messer J and Zhitkovich A. Lower mutagenicity but higher stability of Cr-DNA adducts formed during gradual chromate activation with ascorbate. *Carcinogenesis* 27: 2316-2321 (2006).

51. Reynolds M, Stoddard L, Bespalov I and Zhitkovich A. Ascorbate acts as a highly potent inducer of chromate mutagenesis and clastogenesis: linkage to DNA breaks in G2 phase by mismatch repair. *Nucleic Acids Res.* 35: 465-476 (2007). PMC1802609
   *** Brown University press release** (3/12/2007)

*** NIH-NIEHS Research Briefs** (April 2007)
*** EnviroNews: "***Mutagenic mix". Environ. Health Perspect. 115 (7), p. A349 (2007)*
*** Highlighted accomplishment,** *Brown Division of Biology and Medicine, 2008-2009 Annual Report*

52. Reynolds M and Zhitkovich A. Cellular vitamin C increases chromate toxicity via a death program requiring mismatch repair but not p53. *Carcinogenesis* 28: 1613-1620 (2007).

53. Liu X, Gurel V, Morris D, Murray D, Zhitkovich A, Kane AB and Hurt RH. Bioavailability of nickel in single-wall carbon nanotubes. *Advanced Materials* 19: 2790-2796 (2007).

54. Salnikow K and Zhitkovich A. Genetic and epigenetic mechanisms in metal carcinogenesis and cocarcinogenesis: nickel, arsenic and chromium. *Chem. Res. Toxicol.* 21: 28-44 (2008). PMC2602826
*** #2 downloaded paper for 2008**
*** Highly Cited Paper** (top 1% cited paper in pharmacology/toxicology, Web of Science)

55. Branco R, Chung AP, Johnston T, Gurel V, Morais P and Zhitkovich A. Chromate-inducible *chrBACF* operon from transposable element Tn*OtChr* confers resistance to chromium(VI) and superoxide. *J. Bacteriol.* 190: 6996-7003 (2008). PMC2580707
***News report** in *NIH-NIEHS e-Posted Notes*. *November 5, 2008 (Issue 59)*

56. Guttmann D, Poage G, Johnston T and Zhitkovich A. Reduction with glutathione is a weakly mutagenic pathway in chromium(VI) metabolism. *Chem. Res. Toxicol.* 21: 2188-2194 (2008). PMC2665875

57. Reynolds MF, Peterson-Roth EC, Johnston T, Gurel VM, Menard HL and Zhitkovich A. Rapid DNA double-strand breaks resulting from processing of Cr-DNA crosslinks by both MutS dimers. *Cancer Res.* 69: 1071-1079 (2009). PMC3226787
***Spotlight: "**Cr-DNA lesion misrepair*". Chem. Res. Toxicol.* 22 (4), p. 608 (2009)

58. Zecevic A, Menard H, Gurel V, Hagan E, DeCaro R and Zhitkovich A. WRN helicase promotes repair of DNA double-strand breaks caused by aberrant mismatch repair of chromium-DNA adducts. *Cell Cycle* 8: 2769-2778 (2009). PMC3226781

59. Macfie A, Hagan E and Zhitkovich A. Mechanism of DNA-protein cross-linking by chromium. *Chem. Res. Toxicol.* 23: 341-347 (2010). PMC2822107
*** Editorial Highlight** *"In this Issue"*
*** Highlighted research in the testimony by the Director of NIEHS before the Senate Committee on Environmental and Public Works (February 2, 2011)**

60. Zecevic A, Hagan E, Reynolds M, Poage G, Johnston T and Zhitkovich A. XPA impacts formation but not proteasome-sensitive repair of DNA-protein crosslinks induced by chromate. *Mutagenesis* 25: 381-388 (2010). PMC2893307

61. Pietruska JR, Johnston T, Zhitkovich A, Kane AB. XRCC1 deficiency sensitizes human lung epithelial cells to genotoxicity by crocidolite asbestos and Libby amphibole. *Environ. Health Perspect*. 118: 1707-1713 (2010). PMC3205592

62. Zhitkovich A. Chromium in drinking water: sources, metabolism, and cancer risks. *Chem. Res. Toxicol.* 24: 1617-1629 (2011). PMC3196244
*** Journal Cover** (October issue)
*** #1 cited paper published in this journal in 2011**
*** Highly Cited Paper** (top 1% cited paper in pharmacology/toxicology, Web of Science)

63. Pietruska JR, Liu X, Smith A, McNeil K, Weston P, Zhitkovich A, Hurt R, Kane AB. Bioavailability, intracellular mobilization of nickel, and HIF-1α activation in human lung epithelial cells exposed to metallic nickel and nickel oxide nanoparticles. *Toxicol. Sci.* 124: 138-148 (2011). PMC3196652

64. Reynolds M, Armknecht S, Johnston T and Zhitkovich A. Undetectable role of oxidative DNA damage in cell cycle, cytotoxic and clastogenic effects of Cr(VI) in human lung cells with restored ascorbate levels. *Mutagenesis* 27: 437-443 (2012). PMC3382305

65. Wong V, Armknecht S and Zhitkovich A. Metabolism of Cr(VI) by ascorbate but not glutathione is a low oxidant-generating process. *J. Trace Elem. Med. Biol.* 26: 192-196 (2012). PMC3380165

66. Wong VC, Cash HL, Morse JL, Lu S and Zhitkovich A. S-phase sensing of DNA-protein crosslinks triggers TopBP1-independent ATR activation and p53-mediated cell death by formaldehyde. *Cell Cycle* 11: 2526-2537 (2012). PMC3404879

67. Wong VC, Morse JL and Zhitkovich A. p53 activation by Ni(II) is a HIF-1α independent response causing caspases 9/3-mediated apoptosis in human lung cells. *Toxicol. Appl. Pharmacol.* 269: 233-239 (2013). PMC3666101

68. Morse JL, Luczak MW and Zhitkovich A. Chromium(VI) causes interstrand DNA cross-linking in vitro but shows no hypersensitivity in cross-link repair-deficient human cells. *Chem. Res. Toxicol*. 26: 1591-1598 (2013). PMC3838998

69. Luczak MW and Zhitkovich A. Role of direct reactivity with metals in chemoprotection by N-acetylcysteine against chromium(VI), cadmium(II) and cobalt(II). *Free Radic. Biol. Med.* 65: 262-269 (2013). PMC3823631

70. Green SE, Luczak MW, Morse JL, DeLoughery Z and Zhitkovich A. Uptake, p53 pathway activation and cytotoxic responses for Co(II) and Ni(II) in human lung cells: implications for carcinogenicity. *Toxicol. Sci.* 136: 467-477 (2013). PMC3858198

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***Journal Cover** (January issue)

73. Ortega-Atienza S, Green SE and Zhitkovich A. Proteasome activity is important for replication recovery, CHK1 phosphorylation and prevention of G2 arrest after low-dose formaldehyde. *Toxicol. Appl. Pharmacol.* 286: 135-141 (2015). PMC4458209

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75. Luczak MW, Green SE and Zhitkovich A. Different ATM signaling in response to chromium(VI) metabolism via ascorbate and nonascorbate reduction: implications for in vitro models and toxicogenomics. *Environ. Health Perspect*. 124: 61-66 (2016). PMC4710604

76. Ortega-Atienza S, Wong VC, DeLoughery Z, Luczak MW and Zhitkovich A. ATM and KAT5 safeguard replicating chromatin against formaldehyde damage. *Nucleic Acids Res.* 44: 198-209 (2016). PMC4705693

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78. Ortega-Atienza S, Krawic C, Watts L, McCarthy C, Luczak MW and Zhitkovich A. 20S immunoproteasomes remove formaldehyde-damaged cytoplasmic proteins suppressing caspase-independent cell death. *Sci. Rep.* 7: 654 (2017). PMC5429636

79. Luczak MW and Zhitkovich A. Nickel-induced HIF-1α promotes growth arrest and senescence in normal human cells but lacks toxic effects in transformed cells. *Toxicol. Appl. Pharmacol.* 331: 94-100 (2017). PMC5568485

80. Krawic C, Luczak MW and Zhitkovich A. Variation in extracellular detoxification is a link to different carcinogenicity among chromates in rodent and human lungs. *Chem. Res. Toxicol.* 30: 1720–1729 (2017). PMC5605882
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81. Luczak MW and Zhitkovich A. Monoubiquitinated γ-H2AX: Abundant product and specific biomarker for non-apoptotic DNA double-strand breaks. *Toxicol. Appl. Pharmacol.* 355: 238-246 (2018). PMC6754567

82. Krawic C and Zhitkovich A. Toxicological antagonism among welding fume metals: inactivation of soluble Cr(VI) by iron. *Chem. Res. Toxicol.* 31: 1172-1184 (2018). PMC6247247

83. Blaszczak W, Barczak W, Masternak J, Kopczynski P, Zhitkovich A and Rubis B. Vitamin C as a modulator of the response to cancer therapy. *Molecules* 24, 453 (2019). PMC6384696

84. Rubis B, Luczak MW, Krawic C and Zhitkovich A. Vitamin C increases DNA breaks and suppresses DNA damage-independent activation of ATM by bleomycin. *Free Radic. Biol. Med.* 136: 12-21 (2019). PMC6488359

85. Zhitkovich A. *N*-acetylcysteine: antioxidant, aldehyde scavenger, and more. *Chem. Res. Toxicol.* 32: 1318-1319 (published online May 2, 2019). PMC6757335
***Top 10 read articles in 2019**

86. Luczak MW, Krawic C and Zhitkovich A. p53 activation by Cr(VI): a transcriptionally limited response induced by ATR kinase in S-phase. *Toxicol. Sci*. 172: 11-22 (2019). PMC6813752

87. Zhitkovich A. Nuclear and cytoplasmic functions of vitamin C. *Chem. Res. Toxicol.* 33: 2515-2526 (2020). PMC7572711

88. Luczak MW, Krawic C and Zhitkovich A. NAD^+ metabolism controls growth inhibition by HIF1 in normoxia and determines differential sensitivity of normal and cancer cells. *Cell Cycle* 20: 1812-1827 (2021). PMC8525932

89. Zhitkovich A. Ascorbate: antioxidant and biochemical activities and their importance for *in vitro* models. *Arch. Toxicol*. 95: 3623-3631 (2021). PMC8541910

90. Cyran AM and Zhitkovich A. Heat shock proteins and HSF1 in cancer. *Front. Oncol*. 12: 860320 (2022). PMC8924369

91. Meyers LM, Luczak MW, Krawic C. and Zhitkovich A. Vulnerability of HIF1α and HIF2α to damage by proteotoxic stressors. *Toxicol. Appl. Pharm.* 445: 116041 (2022). PMC9334845

92. Cyran AM and Zhitkovich A. HIF1, HSF1 and NRF2: oxidant-responsive trio raising cellular defenses and engaging immune system. *Chem. Res. Toxicol*. 35(10): 1690-1700 (2022). PMC9580020

93. Krawic C. and Zhitkovich A. Chemical mechanisms of DNA damage by carcinogenic chromium(VI). *Adv. Pharm*. (published online Aug. 26, 2022). doi: 10.1016/bs.apha.2022.07.003

Book Chapters

1. Astakhova L.M., Polyanskaya O., Mityukova T.A. and Zhitkovich A.V. Isotope investigation methods for the estimation of thyroid system status in children living in contaminated districts of Byelorussia. In: *Developments in radioimmunoassay and related procedures*. International Atomic Energy Agency, Vienna, 1992, pp.317-324.

2. Zhitkovich A. and Costa M. Biological markers. In: *Occupational and Environmental Medicine.* 3rd edition, pp. 177-186. W. Rom, ed.; Lippincott and Raven, Philadelphia (1998).

3. Zhitkovich A. Chromium: exposure, toxicity and biomonitoring approaches. In: *Biomarkers of Environmentally Associated Disease: Technologies, Concepts, and Perspectives*. Eds. S.H. Wilson, W.A. Suk. CRC Press, New York, pp. 267-285 (2002).

4. Zhitkovich A. Chromium binding to DNA. In: *Encyclopedia of Metalloproteins*. Eds. R.H. Kretsinger, V.N. Uversky, E.A. Permyakov; Springer Science, New York, pp.630-635 (2013).

Meeting Proceedings

1. Zhitkovich A.V. and Detinkin O.N. Age-related changes in DNA-protein interaction in rat liver chromatin. In: *USSR symposium on Cell Biology*, Moscow. Vol. 1, pp. 273-275 (1985).

2. Zhitkovich A.V. Histone H1 subfractions and composition of non-histone proteins in liver cells from rats of different age. In: *17th Scientific Symposium of Young Investigators on Issues in Current Biology*, Moscow State University. Vol. 3, pp. 94-97 (1986).

3. Toniolo P., Zhitkovich A., Costa M. Development and utilization of a new simple assay for DNA-protein crosslinks as a biomarker of exposure to welding fumes. *Int. Arch. Occup. Environ. Health* 65: S87-S89 (1993).

4. Costa M, Zhitkovich A., Taioli E. and Toniolo P. Preliminary report on a simple new assay for DNA-protein cross-links as a biomarker of exposure experienced by welders. *J. Toxicol. Environ. Health,* 40: 217-222 (1993).

5. Zhitkovich A., Voitkun V., Song Y., Quievryn G. and DeLucia A. Chromium(III)-DNA adducts are the major form of mutagenic DNA lesions produced during reductive metabolism of chromate by cysteine. In: *Metal Ions in Biology and Medicine*, vol. 6, pp. 113-115. Eds. J. A. Centeno, Ph. Collery, G. Vernet, R. B. Finkelman, H. Gibb, J. C. Etienne. John Libbey Eurotext, Paris (2000).

6. Medeiros M.G., Rodrigues A.S., Batoreu M.C., Laires A., Zhitkovich A., Rueff J. Trivalent and hexavalent chromium exposure: a comparative study in tannery workers and welders. *Polish J. Environ. Studies*, 11 (suppl. II): 80-82 (2002).

7. Medeiros M.G., Rodrigues A.S., Batoreu M.C., Laires A., Zhitkovich A., Rueff J. Biomarkers of chromium exposure and cytogenetic damage in leather tanning and welding industry workers. In: *Human Biomonitoring for Genetic Effects* (A.C. Cebulska-Wasilewska, W.W. Au and R.J. Sram, eds), NATO Science Series I: Life and Behavioural Sciences, vol. 351, pp. 132-141, IOS Press (2003).

8. Quievryn G., Peterson E. and Zhitkovich A. Mutagenic DNA damage generated by chromium(VI) during its reductive activation with ascorbic acid. In: *Metal Ions in Biology and Medicine*, vol. 8, pp. 246-249. Eds. M.A. Cser, I. Sziklai Laszlo, J.-C. Etienne, Y. Maymard, J. Centeno, L. Khassanova, Ph. Collery. John Libbey Eurotext, Paris (2004).

9. Reynolds M. and Zhitkovich A. Ascorbate-mediated toxicity of hexavalent chromium in human cells. In: *Metal Ions in Biology and Medicine*, vol. 10, pp. 304-309. Eds. Ph. Collery, I. Maymard, L. Khassanova, T. Collery. John Libbey Eurotext, Paris (2008).

Commentaries

Bartley E. and Zhitkovich A. Do not cross your DNA. *Chem. Res. Toxicol*. 21: 275 (2008).

Patents

Costa M, Zhitkovich A. Assay for Detecting Covalent DNA-protein Complexes. U.S. patent Nº 5545529. *Biotechnol. Adv.* 15(2): 410 (1997).

Invited Lectures

1. 2nd International Meeting on Molecular Mechanisms of Metal Toxicity and Carcinogenicity, Madonna di Campiglio, Italy (1993).
2. Workshop on Biomarkers to Toxic and Carcinogenic Metals, Park City, Utah (1996)
3. Pathology Research Rounds, Brown University (1998)

4. Pathobiology Graduate Program, Brown University (1999)
5. University of Rhode Island, RI (2000)
6. International Conference on Arctic Development, Pollution and Biomarkers of Human Health. Anchorage, Alaska (2000)
7. Conference on Molecular Mechanisms of Metal Toxicity and Carcinogenesis. Morgantown, WV (2000)
8. Molecular and Cell Biology Graduate Program, Brown University (2000)
9. 3rd International Meeting on Molecular Mechanisms of Metal Toxicity and Carcinogenesis. Stintino, Italy (2001)
10. Pfizer, Inc. Groton, CT (2001)
11. 2nd Conference on Molecular Mechanisms of Metal Toxicity and Carcinogenesis. Morgantown, WV (2002)
12. Conference on Preventing Toxic Health Threats to Rhode Island Communities. Providence, RI (2002)
13. New York University School of Medicine (2003)
14. University of Texas Medical Branch, Galveston, TX (2003)
15. Lifespan COBRE Cancer Center, Providence, RI (2003)
16. National Cancer Institute, Frederick, MD (2003)
17. Vanderbilt University, Center in Molecular Toxicology, Nashville, TN (2003)
18. Pathology Research Rounds, Brown University (2003)
19. 3rd Conference on Molecular Mechanisms of Metal Toxicity and Carcinogenesis. Morgantown, WV (2004)
20. Gordon Research Conference on Genetic Toxicology. New London, NH (2005)
21. 232nd Annual Meeting of the American Chemical Society. San Francisco, CA (2006)
22. University of North Carolina, Chapel Hill, NC (2006)
23. Brown MCB Graduate Program, annual retreat (2007)
24. NUTMEG Conference, Woods Hole, MA (2007)
25. Miriam Hospital, Center for Behavioral and Preventive Medicine, Providence, RI (2007)
26. Superfund Basic Research Program: 20th anniversary conference, Durham, NC (2007)
27. 47th Annual Meeting of the Society of Toxicology, Seattle, WA (2008)
28. 236th Annual Meeting of the American Chemical Society, Philadelphia, PA (2008)
29. 5th Conference on Metal Toxicity and Carcinogenesis, Morgantown, WV (2008)
30. University of Connecticut, Storrs, PHAR-6455 Advanced Toxicology, 2-h lecture (2008)
31. University of Kentucky, Lexington (2008)

32. University of Pittsburgh (2009)
33. Pathology Research Rounds, Brown University (2009)
34. Wheeler School, Providence, RI (2010)
35. Rhode Island Hospital, Pathology Research Conference (2010)
36. 16th International Charles Heidelberger Symposium on Cancer Research, Portugal (2010)
37. 9th Meeting of International Society for Trace Elements Research in Humans, Turkey (October, 2011)
38. University of Connecticut, Storrs, PHAR-6455 Advanced Toxicology, 2-h lecture (November, 2011)
39. Michigan State University, East Lansing (September, 2012)
40. 7th Conference on Metal Toxicity and Carcinogenesis, Albuquerque, NM (October, 2012)
41. University of Arizona, Tucson (November, 2012)
42. 4th Georgian Bay International Conference on Bioinorganic Chemistry, Canada (May, 2013)
43. University of Connecticut, Storrs, PHAR-6455 Advanced Toxicology, 2-h lecture (October, 2013)
44. William J. Waddell seminar, Dept. of Pharmacology and Toxicology, University of Louisville School of Medicine, KY (May, 2016)
45. Annual retreat, Brown Graduate Program in Molecular Pharmacology and Physiology (May, 2016)
46. Keynote Lecture - 9th Conference on Metal Toxicity and Carcinogenesis, Lexington, KY (October 17, 2016)
47. University of Connecticut, Storrs, PHAR-6455 Advanced Toxicology, 2-h lecture (Nov. 11, 2016)
48. Tulane University Cancer Center (March 8, 2018)
49. Dept. of Toxicology and Cancer Biology, University of Kentucky, Lexington (April 30, 2018)
50. 10th Conference on Metal Toxicity and Carcinogenesis, Albuquerque, NM (October 29, 2018)
51. Brown University Cancer Biology seminar series (May 24, 2019)
52. University of Connecticut, Storrs, PHAR-6455 Advanced Toxicology, 2-h lecture (Nov. 13, 2020)
53. Dept. of Pathology and Lab Medicine, Brown University (Oct. 28, 2020)
54. 11th Conference on Metal Toxicity and Carcinogenesis, Montreal, Canada (October 16-19, 2022)

Funding (current)

1) NIH R01 ES031979 "*Nickel and toxic topoisomerase I products"*
Funding period: 3/18/21-12/31/25
Role: PI
Total project cost: $1,787K
Direct cost: $1,125K
Indirect cost: $ 662K

2) NIH R01 ES031002 "*Indirect Genotoxicity in Metal Carcinogenicity*"
Funding period: 1/15/20-11/30/24
Role: PI
Total project cost: $1,828K
Direct cost: $1,125K
Indirect cost: $ 703K

3) NIH R01 ES028072 "*Regulation of p53 and Checkpoint Signaling by Chromium(VI)*"
Funding period: 12/1/17-11/30/23
Role: PI
Total project cost: $1,828K
Direct cost: $1,125K
Indirect cost: $ 703K

4) NIH T32 ES007272 "*Training in Environmental Pathology*"
Funding period: 11/1/2020 - 6/30/2023
Role: PI
Total annual cost: $501K
Direct annual cost: $471K

Past Funding (as PI)

R01 grants

1) R01 ES008786 "*Genotoxicity of Chromium Compounds*"
Funding period: 8/1/1997 - 7/31/2003
Role: PI
Total cost: $1,134K

2) R01 ES008786 "*Genotoxicity of Chromium Compounds*"
Funding period: 9/23/2003 - 5/30/2009
Role: PI
Total cost: $1,611K

3) R01 ES012915 "*Sensitivity Mechanisms in Chromium Toxicity*"
Funding period: 7/1/2004 – 5/31/2011
Role: PI
Total cost: $1,584K

4) R01 ES008786 "*Genotoxicity of Chromium Compounds*"
Funding period: 6/1/2009 - 3/31/2015
Role: PI
Total cost: $1,821K

5) R01 ES020689 "*Formaldehyde Genotoxicity*"
Funding period: 6/29/2012 - 3/31/2018
Role: PI
Total cost: $1,983K

6) R01 ES008786 "*Genotoxicity of Chromium Compounds*"

Funding period: 4/1/2015 - 1/31/2021
Role: PI
Total cost: $1,828K

Program Projects

1) P20-RR015578 "Center for Genetics and Genomics" (PI – J. Sedivy)
Funding period: 9/1/2003 – 6/31/2004
Role: Leader for Project "*Stress Signaling by DNA Methylation Damage*"
Total cost: $76K

2) P20 RR015578 "Cancer Signaling Networks" (PI – J. Sedivy)
Funding period: 7/1/2005 - 4/30/2006
Role: Leader of Project #5: "*Genetic Damage by Lipid Peroxidation*"
Total cost for Project #5: $175K

3) Superfund Basic Research Program P42 ES013660 "Reuse in RI: a State-Based Approach to Complex Exposures" (PI – K. Boekelheide).
Funding period: 4/18/2005 – 3/31/2009
Role: Leader of Project #4: "*Biological Dosimetry of Hexavalent Chromium*"
Total cost for Project #4: $1,279K

4) Superfund Research Program P42 ES013660 "Reuse in RI: a State-Based Approach to Complex Exposures" (PI – K. Boekelheide).
Funding period: 4/1/2009 - 3/31/2014
Role: Leader of Project #4: "*Biological Dosimetry of Hexavalent Chromium*"
Total cost for Project #4: $1,368K

Contracts

U.S. Air Force SBIR Phase II Award No. FA8222-14-C-0004 "*Label-free Immunoassay-Based Assessment for Chromate Exposure."* Subcontract from Lynntech Inc.
Funding period: 10/6/14 - 7/22/15
Role: PI for Brown subcontract
Total cost: $132K

Small awards

1) Salomon Faculty Research Award "*Mutagenic Potential of DNA-Vitamin C Crosslinks Induced by Carcinogenic Hexavalent Chromium*". Funding period: 5/2002-12/2002
Role: PI
Direct cost: $10K

2) Rhode Island Cancer Council, Transition Support Grant "*Role of DNA-Protein Crosslinks in Genotoxicity of Malondialdehyde*".
Funding period: 8/1/2001 – 12/31/2001
Role: PI
Total/direct cost: $15K

3) NIH R13CA124263-01 "*Metal Carcinogenesis: New Concepts*"
Funding period: 7/10/2006 - 7/9/2007
Role: PI

Total/direct cost: $8K

4) Research Gift from Lifespan, Division of Hematology and Oncology (May, 2018)
Role: PI
Total/direct cost: $22.5K

Teaching

Total number of courses directed: 22 (through 12/2022)

Last 5 years teaching:

2018 *Contact hours* = 4.5
- BIOL 3645 *General Pathology*
- *Fall Semester – sabbatical leave*

2019 *Contact hours* = 31.5
- BIOL 1290 *Cancer Biology* (30 students), course director

2020 *Contact hours* = 28.5
- BIOL 1290 *Cancer Biology* (22 students), course director

2021 *Contact hours* = 30
- BIOL 1290 *Cancer Biology* (22 students), course director

2022 *Contact hours* = 30
- BIOL 1290 *Cancer Biology* (33 students), course director