Pew Research Proposal Form
Union University
Fall 2018

Cover Sheet

Name(s) of Applicant(s): **E. Blake Watkins, PhD**

Title of Proposed Project:

The Development of a Rapid, Efficient, and Economical Means of Preparing Biologically Active Molecules as Drug Candidates

Primary Discipline: Medicinal Chemistry Secondary Discipline(s): Pharmacy

Has this proposal been submitted to another agency, publication, or program? No

If so, which one(s)?

Location of proposed research: Laboratory 220, Providence Hall

Desired start date: December 2018

Recommending Scholars and their disciplines:

External: Professor J. Philip Bowen, PhD, Professor of Pharmaceutical Sciences, Mercer School of Pharmacy, Atlanta, GA

Union: Professor Joel Owen, PhD, Professor of Pharmaceutical Sciences, College of Pharmacy, Union University, Jackson, TN

In consultation together, we recommend the approval of the proposal as an acceptable project and affirm that the applicant has the professional wherewithal to accomplish the project satisfactorily.

Chair of your department _____ Date: _____

Dean of your school: Sheila Mitchell Date: 10-10-18

If the chair and/or dean do not recommend the proposal, the applicant should seek a conference to discuss the reasons.

Proposals should be submitted by the applicant in person to the chair of the Research Committee.

PEW RESEARCH PROPOSAL

1. **Title of the project**.

   The Development of a Rapid, Efficient, and Economical Means of Preparing Biologically Active Molecules as Drug Candidates

2. **Statement of the end product(s)** (book, chapter, article, play composition, exhibit, or other dissemination means appropriate to your discipline).

   This project will result in at least one publication in an international, peer-reviewed chemistry journal. There is a very strong likelihood that we will seek patent protection for this method as it will be extremely beneficial to pharmaceutical companies and chemical companies.

3. **Explanation of the scholarly activity.**

   I. Statement of the Scholarly Activity

   The scholarly activity involves the development of a new synthetic chemistry method that will permit rapid and economical access to a variety of compounds that possess activity of pharmaceutical interest. In order to publish a new synthetic method and in order to patent a new synthetic method, we must demonstrate that the chemistry works with a myriad of materials and generates the desired products each time. No method currently exists in the literature to accomplish the preparation of these agents in a single synthetic step, under mild conditions. Successful completion of this project will provide a valuable tool to synthetic and medicinal chemists around the world.

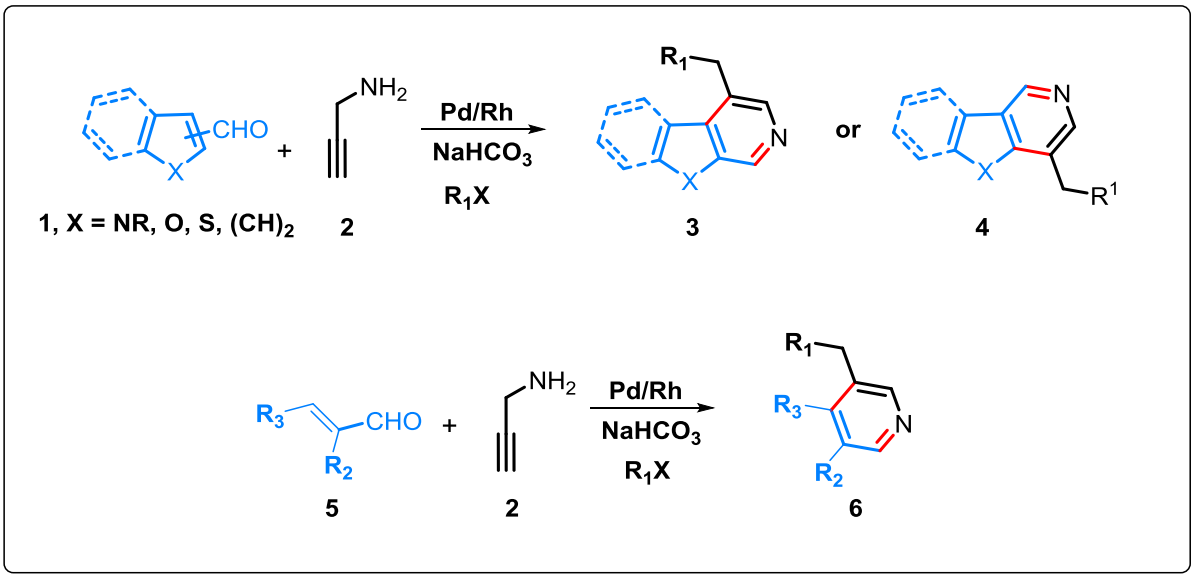
   The PEW grant is needed to purchase the chemicals and supplies for this project as well as to help cover the cost of high resolution mass spectral analysis of each product, as required for publication.

   II. Description of the activity and its goals

   The cost of prescription drugs is a topic of national conversation currently and has become a political "hot potato" of sorts. While the actual contributing factors to drug costs are complex, numerous and variable, one factor permeates—the cost of producing the drug. Costs associated with drug production and synthesis are passed on to consumers. A key goal of my research is to develop new methods of preparing drug candidates that are more economical, environmentally friendly, and more efficient, thus helping to drive down drug production costs and, in the process, reduce the cost to consumers.

   The reaction scheme below provides a brief synopsis of the types of compounds that we could potentially produce using this new method. As shown below, the method would lend itself to the production of a wide variety of products, from simple structures (pyridine derivatives) to bi-, tri-, or even tetracyclic, complex molecules with drug-like properties (carbolines). For instance, products like **3** and **4** (see below) are known to possess potent **anti-cancer activity** or to function as **anti-epileptic agents**.

The proposed method aims to accomplish two significant synthetic goals within a single reaction vessel. The first is to append a new ring onto an existing molecule (compound **1** or **5** below). The second is to attach a third molecule (**R_1X**) to the newly formed ring to give substituted products like **3**, **4**, or **6** below where the R_1 group has been attached to the newly formed ring from the first step via palladium or rhodium catalysis. The beauty of this method is that it would allow for tunable variability in the product (simple to complex structures) and would be expandable in a variety of directions depending on the actual final structure desired. Currently, no such method exists in the chemistry literature. A variety of methods exist to produce the aforementioned products, but these require multiple synthetic steps, harsh conditions, and several days to complete. **We propose to produce these complex molecules in a single synthetic step under mild conditions and in a short time frame (a few hours)**.



Figures 1 and 2 provide a sampling of readily available aldehydes that could be used in the above transformations. Additional aldehydes could be prepared synthetically depending on the actual product needs of the researcher. Aldehydes are easily produced using currently available chemistry methods from inexpensive starting materials, if needed.

Figure 1. A sample of starting aldehydes for the preparation of 3 and 4:

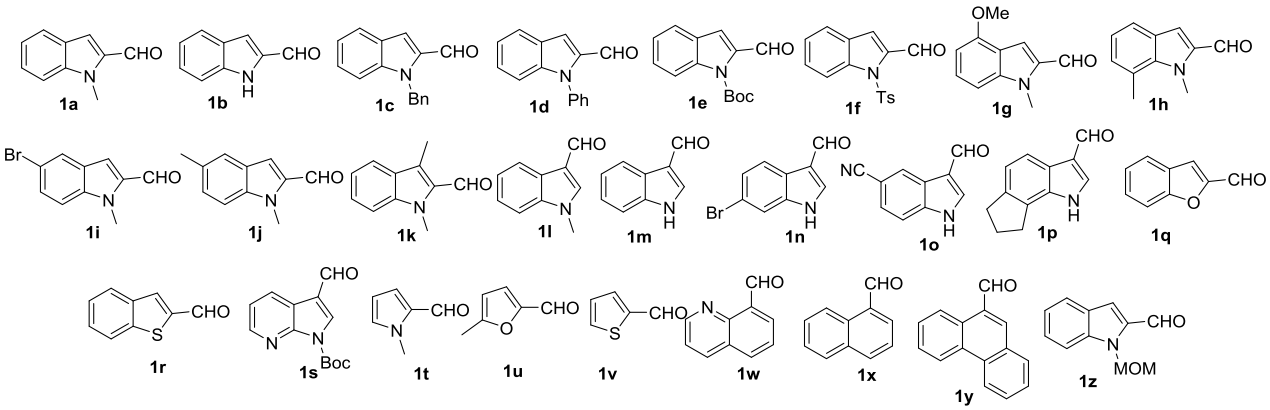
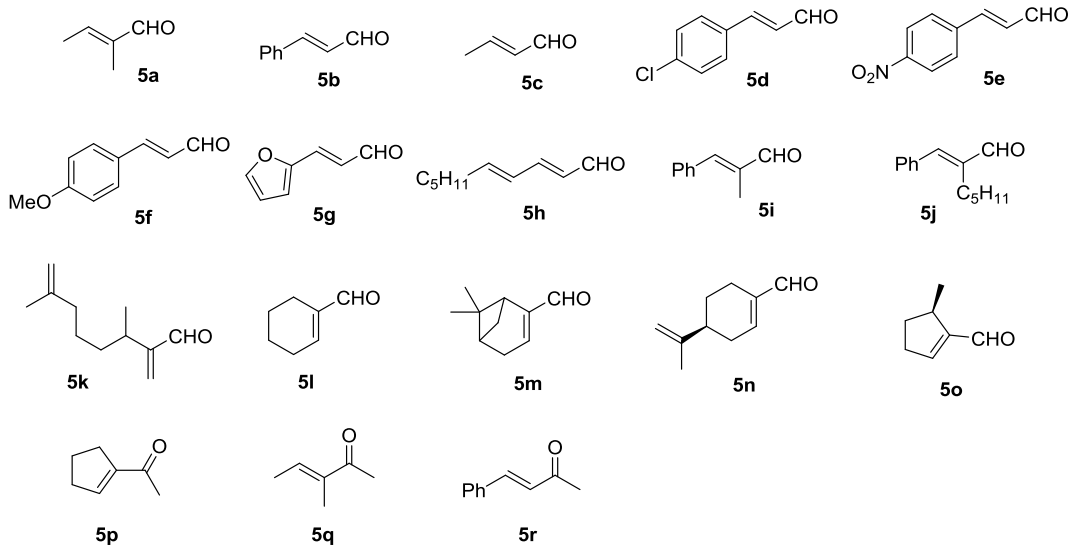


Figure 2. A sample of starting aldehydes for the preparation of 6.



The specific goals of this project are:

1. **To identify the specific reagents and reaction conditions necessary to produce targeted products**

    a. We recently published a manuscript detailing a new synthetic method that we developed. Based on our findings, we hope to expand its use to allow for the production of a tremendous number of biologically active compounds. The current proposal is significantly different from our previous work and will serve as an additional cost-saving means of drug production.
    b. The first step in this goal will be to identify a model system and then experiment with various reaction conditions (reagents, metals, temperatures, etc.) to successfully produce the desired compounds in high yield.

2. **To demonstrate that the method works with a wide variety of starting materials**

    a. In order to publish a new synthetic chemistry method, journals require that a minimum number of reactions involving various starting materials be conducted. Typically, the minimum number is in the 20-30 range. Hence, once we have identified the ideal chemical conditions necessary to produce the products, we will purchase 20-30 starting aldehydes (**1** and **5**, Figures 1 and 2) along with a variety of coupling partners (**R_1X**).
    b. We will then apply the new method to the preparation of a vast array of products to show its scope and limitations (**3**, **4**, and **6** above).

3. **To demonstrate the application of the new method by synthesizing natural products or drug intermediates possessing biological activity**

a. The development of a new chemical synthetic method requires a demonstration of its application. To accomplish this, we will prepare several key intermediates of natural products or drug candidates. We will also demonstrate the time/material savings from using our method compared to what is currently in the literature.
b. In addition to preparing compounds of biological interest, we will also be required to demonstrate that our new method can be conducted on a large scale. Conducting the reaction on an industrial scale, however, is not necessary. We will simply perform the reaction on gram quantities. Results of this experiment will give us a good idea of how well the method will work on production scale.

III. Theoretical Framework and brief examination of scholarly literature or context of the activity within your discipline

While the Bischler-Napieralski,[1] Pictet-Spengler,[2] and Graebe-Ullmann[3] reactions are the conventional approaches for the synthesis of β- or γ-carboline derivatives, in recent years several new protocols for the synthesis of β- or γ- carboline frameworks have been developed using a range of starting materials and metal catalysts. Examples include the cyclization/iminoannulation of acetylene derivatives with pre-functionalized indoles;[4] metal-catalyzed cyclization/functionalization of various precursors prepared in multiple steps;[5] synthesis of 3-amino-β-carbolines via gold-catalyzed formal [4+2] cycloaddition of azides and ynamides;[6] synthesis of either β- or γ-carbolines using ruthenium or rhodium catalyzed [2+2+2] cycloaddition reactions;[7] arene-ynamide cyclization via copper catalysis;[8] palladium-catalyzed, imidoylative cyclization of tryptophan-derived isocyanides;[9] and others.[10] In this regard, while much effort has been devoted to the development of metal-catalyzed cyclizations, these methods require exhaustive preparation of complex starting materials and/or multiple reaction steps to accomplish the final products. Reactions employing mild protocols are ideal because they circumvent the preconstruction of starting materials in multiple steps and provide the product in a single reaction flask. A domino reaction for the synthesis of complex heterocyclic scaffolds is a highly attractive strategy as an atom-economic and environmentally benign process. No current method exists in the literature to accomplish what we are proposing. Publication of the results of this study will significantly enhance the production of substituted pyridines in a variety of applications.

References:

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4. **An essay (500 - 1000 words) describing how the Christian faith relates to your understanding of your discipline and how it relates to this scholarly endeavor.**

From Genesis 3 until present day, sin has wreaked havoc on creation and on mankind. Adam and Eve purposely disobeyed God's direct command and ushered in a new era where sin and death reigned on this planet. Thankfully, we serve a sovereign and merciful God who did not leave us to ourselves; rather, He set in motion a plan to redeem us and set us free from the divine punishment that sin demands through Jesus Christ and His death, burial and resurrection. He also promised to glorify us and to redeem us from the effects of sin. Unfortunately for us, that promise is to be fulfilled at a future time. In the meantime, we continue to contend with the effects of sin all around us. One manifestation of sin or the effect of sin is disease, not that all diseases are the direct result of a particular sin, but that all disease is the result of sin coming into the world through Adam's disobedience (Romans 5:12).

When God pronounced his curse upon creation and upon Adam (Genesis 3:17-18), hard work was required to overcome the effects of sin (agriculture). Since Genesis 3, man has had to work hard to battle the thorns, thistles, pests, and disease that seek to destroy the fruits of his labors. Historically, the church has taken a similar approach to healthcare and disease treatment. While on Earth, Jesus Christ commanded the church to care for the sick (Matthew 10:7). The church in turn has responded to this command in a myriad of ways throughout history, from appointing men in the early church to

oversee care for the needy to caring for victims of historic plagues in Northern Africa, Europe and the Middle East. Forsaking their own lives, they freely gave of themselves to care for others because of what Christ had given them and had promised them. In the 4th century, we see this dedication to the sick take a significant new direction with the actions of St. Basil who opened the Basiliad of Caesarea to take in travelers and the infirm to ensure their needs were met. This, arguably, was the first hospital. Since this time, the church has devoted countless resources to carrying out the commands of Christ in order to meet the needs of the poor, sick, and needy.

With the advent of modern science, the church has a new opportunity to continue to fulfill the commands of Christ and to expand its approach. While the church has often kept its distance from science, this is an unfortunate response rather than a necessity. Science and scientific endeavors (notably pharmacy and medicine) are a gift from God, in the same way that agricultural methods are, to help us mediate the effects of sin in this life until Christ returns. My hope, my vision, and my goals are to use the talents God has given me to provide relief of pain and suffering to patients and to do so in a cost-effective manner (stewardship) by discovering new drug candidates and new methods of producing these drug candidates. The church has a responsibility to continue to care for and provide for the needs of people. Pharmacy, and particularly medicinal chemistry, should be explored to their limits in order to help us continue to truly reflect the heart of Christ to a hurting world and to provide as much relief from suffering as possible.

5. **A time frame for the completion and a plan for the dissemination of the project.**

   This project will likely take 10-12 months to complete. Prior to publication, we may seek patent protection. Once patent protection is received, if warranted, we will submit a manuscript for publication.

6. **A brief budget.**

Budget Category	Amount
Chemicals and Solvents	$2500
Laboratory Supplies	$1000
Analytical Analysis	$1000
Total	**$4500**

7. **A current *curriculum vitae*.**

   (*Attached*)

8. **Two letters of recommendation should be submitted directly to the Chair of the Research Committee.**

   Recommending Scholars and their disciplines:

   External: Professor J. Philip Bowen, PhD, Professor of Pharmaceutical Sciences, Mercer School of Pharmacy, Atlanta, GA

   Union: Professor Joel Owen, PhD, Professor of Pharmaceutical Sciences, College of Pharmacy, Union University, Jackson, TN

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EDUCATION

1994-2000 **Ph.D., Chemistry, University of Georgia, Athens, GA**
Dissertation: "Synthesis and Kinetic Evaluation of Tyrosine Analogs—Implications for the Catalytic Mechanism of Tyrosine Phenol-lyase from *Citrobacter freundii*"
Advisor: Professor Robert S. Phillips

1989-1994 **B.S.**, **Chemistry and Mathematics**
Union University, Jackson, Tennessee

PROFESSIONAL EXPERIENCE

2015-present **Professor and Chair, Department of Pharmaceutical Sciences**, Union University College of Pharmacy, Jackson, Tennessee

2010-2015 **Chair, Department of Pharmaceutical Sciences and Associate Professor of Pharmacy**, Union University School of Pharmacy, Jackson, Tennessee

Administrative/Leadership Roles

School of Pharmacy Accreditation Process

- Involved in all areas of preparation for continued Candidate Status review: ACPE site visit April 2011 (granted June 2011)
- Involved in all areas of preparation for full accreditation visit: ACPE site visit April 2012 (granted June 2012)
- Involved in preparation for ACPE focused accreditation visit, April 2014 (continued accreditation granted June 2014)

Research Program Development

- Ordered laboratory equipment and set up laboratories
- Attended training workshops on the operation of key laboratory equipment
- Developed didactic and Advanced Pharmacy Practice Experiences (APPEs) as part of the pharmacy curriculum
- Train students in the art and practice of molecular design and synthesis of drug candidates
- Worked closely with administration to create avenues of research opportunities with various undergraduate institutions
- Maintain laboratory instrumentation
- Train students on the operation of laboratory equipment
- Teach students spectral interpretation and acquisition of molecular data
- Train students in the assimilation and presentation of research findings

- Worked closely with SOP Executive Leadership Team and Faculty of the Department of Pharmaceutical Sciences to implement a Pharmacy Post-graduate research fellowship program
- Worked closely with faculty to recruit and identify qualified candidates for the inaugural Pharmaceutical Sciences Fellowship Program in Medicinal Chemistry, Pharmaceutics, and Pharmacokinetics
- Developed an ongoing research collaboration with Emory University College of Medicine and Mercer University College of Pharmacy in Atlanta, Georgia

Chair, School of Pharmacy Admissions Committee

- Work closely with the Director of Pharmacy Admissions to identify highly qualified undergraduate students for admission
- Review each undergraduate application which meets our admissions requirements
- Interview SOP candidates each Admissions Day (September to May)
- Worked closely with Assistant Dean of Student Services and the Admissions Committee to develop an early admissions program (PEAP) for incoming Union University undergraduate students

2008-2010 **Chair, Department of Pharmaceutical Sciences and Assistant Professor of Pharmacy**, Union University School of Pharmacy, Jackson, Tennessee

Administrative/Leadership Roles

School of Pharmacy Accreditation Process

- Involved in all areas of preparation for Pre-Candidate Status review: ACPE site visit April 2008 (granted June 2008)
- Involved in all areas of preparation for Candidate Status review: ACPE site visit April 2009 (granted June 2009)

Research Program Development

- Involved in the design of Providence Hall and 8000 square feet of dedicated laboratory research space
- Ordered research equipment and established research laboratories
- Began to hire faculty with research expertise in the major sub-disciplines of pharmacy

2006-2008 **Math/Science Teacher**, Regents School of Oxford, Oxford, Mississippi

- Taught middle school mathematics and science
- Developed a curriculum for middle and high school science
- Organized the annual Regents Science Fair

2006-2008 **Research Associate**, Department of Medicinal Chemistry, School of Pharmacy, University of Mississippi, University, MS

- Prepared and edited manuscripts for publication in peer-reviewed scientific journals
- Edited/assembled grant renewals for the Medicinal Chemistry Department

2004-2006 **Research Assistant Professor of Medicinal Chemistry**, Department of Medicinal Chemistry, School of Pharmacy, University of Mississippi, University, Mississippi

- Managed the daily operations of a medicinal chemistry laboratory (19 people)
- Assembled and prepared grant renewals for the Medicinal Chemistry Department
- Prepared and edited manuscripts for publication
- Instructed graduate students and postdoctoral associates in the proper operation and maintenance of laboratory instrumentation
- Provided research assistance and guidance to graduate students and postdoctoral associates

2002-2004 **Research Scientist**, Department of Medicinal Chemistry, School of Pharmacy, University of Mississippi, University, Mississippi
Mentor: Professor Mitchell A. Avery

- Applied model study conditions to the total synthesis of pseudolaric acid B, a natural product possessing antifungal and anticancer activities
- Responsible for the general operation and maintenance of laboratory instrumentation in the Laboratory for Applied Drug Design and Synthesis (LADDS)—(i.e. Waters Q-TOF Micro High Resolution Mass Spectrometer, Waters Alliance HPLC, Waters Alliance/ZQ LC/MS, Trident Combinatorial Synthesizer, Waters DeltaPrep HPLC, Trident Sample Processing Station, etc.)
- Directed the research projects of two medicinal chemistry graduate students
- Conducted mass spectral analysis of samples using a Waters/Micromass ESI-oa-Q-TOF Micro mass spectrometer with lockspray source
- Prepared and edited manuscripts from our research group for publication in peer-reviewed journals

1999-2002 **Postdoctoral Research Associate**, Department of Medicinal Chemistry, School of Pharmacy, University of Mississippi, University, Mississippi
Mentor: Professor Mitchell A. Avery

- Performed preliminary synthetic studies on a model system of pseudolaric acid B, a natural product possessing antifungal and anticancer activities
- Conducted stereoselective, ultra high pressure (13 kbar) Diels-Alder reactions with chiral vinyl boronates
- Synthesized various boron-containing vinyl compounds
- Utilized NMR, HPLC, FT-IR, GC/MS, and LC/MS instrumentation to characterize synthesized compounds

1995-1999 **Graduate Assistant**, Department of Chemistry, University of Georgia, Athens, Georgia
Adviser: Professor Robert S. Phillips

- Performed multi-step synthesis, purification, and characterization of mechanism-based inhibitors using synthetic and enzymatic techniques
- Synthesized and purified chiral amino acids
- Conducted kinetic studies of enzyme substrates and inhibitors
- Directed the research projects of numerous undergraduate chemistry majors

1994-1997 **Teaching Assistant**, Department of Chemistry, University of Georgia, Athens, Georgia

- Responsible for teaching 2 or 3 undergraduate Organic Chemistry pre-lab lectures per week to an estimated 110 students
- Responsible for overseeing the operation of the chemistry laboratory sections and successful completion of the assigned laboratory experiments.
- Responsible for the preparation of materials and chemicals necessary for the operation of the laboratory sections

TEACHING

Fall 2018
Union University College of Pharmacy

- Principles of Pharmaceutical Sciences (PHRM 716, 2 hours)
- Principles of Drug Action (PHRM 755, 3 hours)

Summer 2018
Union University College of Pharmacy

- Principles of Pharmaceutical Sciences Remediation (PHRM 716R, 3 hours)
- Principles of Drug Action Remediation (PHRM 755R, 3 hours)

Spring 2018
Union University College of Pharmacy

- Chemical Basis of Drug Action I (PHRM 728, 3 hours)
- Pharmacy Foundations (2 hours)

Winter 2018
Union University College of Pharmacy

- Principles of Pharmaceutical Sciences Remediation (PHRM 716-R, 2 hours)
- Principles of Drug Action (PHRM 755-R, 3 hours)

Fall 2017
Union University College of Pharmacy

- Principles of Pharmaceutical Sciences (PHRM 716, 2 hours)
- Principles of Drug Action (PHRM 755, 3 hours)

Spring 2017
Union University School of Pharmacy

- Chemical Basis of Drug Action I (PHRM 728, 3 hours)
- Pharmacy Foundations (2 hours)

Winter 2017
Union University School of Pharmacy

- Principles of Pharmaceutical Sciences Remediation (PHRM 716-R, 2 hours)
- Principles of Drug Action (PHRM 755-R, 3 hours)

Fall 2016

Union University School of Pharmacy
- Principles of Pharmaceutical Sciences (PHRM 716, 2 hours)
- Principles of Drug Action (PHRM 755, 3 hours)

Summer 2016
Union University School of Pharmacy
- Chemical Basis of Drug Action I Remediation (PHRM 728R, 3 hours)
- Principles of Drug Action Remediation (PHRM 755R, 3 hours)

Spring 2016
Union University School of Pharmacy
- Chemical Basis of Drug Action I (PHRM 728, 3 hours)
- Introduction to Drug Design and Synthesis (PHRM 732, 2 hours, 30 contact hours)
- Drug Design and Synthesis I (APPE 770A-1, 4 hours, 160 contact hours)
- Drug Design and Synthesis II (APPE 770A-2, 4 hours, 160 contact hours)
- Pharmacy Foundations (2 hours)

Winter 2016
Union University School of Pharmacy
- Principles of Pharmaceutical Sciences Remediation (PHRM 716-R, 2 hours)

Fall 2015
Union University School of Pharmacy
- Principles of Pharmaceutical Sciences (PHRM 716, 2 hours)
- Principles of Drug Action (PHRM 755, 3 hours)

Summer 2015
Union University School of Pharmacy
Summer Research Experience
- Mentored one (2) undergraduate students in drug synthesis research 320 contact hours

Spring 2015
Union University School of Pharmacy
- Chemical Basis for Drug Action I (PHRM 728, 3 hours)

Winter 2015
Union University School of Pharmacy
- Principles of Pharmaceutical Sciences Remediation (PHRM 716-R, 2 hours)

Fall 2014
Union University School of Pharmacy
- Principles of Pharmaceutical Sciences (PHRM 716, 2 hours)
- Principles of Drug Action (PHRM 785, 3 hours)
- Introduction to Drug Design and Synthesis (PHRM 732, 2 hours, 30 contact hours)
- Drug Design and Synthesis I (APPE 770A-1, 4 hours, 160 contact hours)
- Drug Design and Synthesis II (APPE 770A-2, 4 hours, 160 contact hours)

Summer 2014
Union University School of Pharmacy
Summer Research Experience

- Mentored one (1) undergraduate student in drug synthesis research
- 240 contact hours

Spring 2014
Union University School of Pharmacy

- Chemical Basis for Drug Action I (PHRM 728, 3 hours)
- Pharmaceutical Sciences Foundational Review (PHRM 785-2-4, 2 hours)

Fall 2013
Union University School of Pharmacy

- Principles of Pharmaceutical Sciences (PHRM 716-C4, 2 hours)
- Christian Faith and Pharmacy (PHRM 785, 2 hours)

Summer 2013
Union University School of Pharmacy
Summer Research Experience

- Mentored two (2) undergraduate and two (2) graduate pharmacy students in drug synthesis research
- 240 contact hours

Spring 2013
Union University School of Pharmacy

- Chemical Basis for Drug Action I (PHRM 728, 3 hours)
- Pharmaceutical Sciences Foundational Review (PHRM 785-2-4, 2 hours)

Winter 2013
Union University School of Pharmacy

- Principles of Pharmaceutical Sciences Remediation (PHRM 716-C4-R, 2 hours)

Fall 2012
Union University School of Pharmacy

- Principles of Pharmaceutical Sciences (PHRM 716-C4, 2 hours)
- Christian Faith and Pharmacy (PHRM 785, 2 hours)
- Introduction to Drug Design and Synthesis (PHRM 732, 2 hours, 30 contact hours)
- Drug Design and Synthesis I (APPE 770A-1, 4 hours, 160 contact hours)
- Drug Design and Synthesis II (APPE 770A-2, 4 hours, 160 contact hours)

Summer 2012
Union University School of Pharmacy
Summer Research Experience

- Mentored one (1) undergraduate and four (4) graduate pharmacy students in drug synthesis research
- 240 contact hours

Spring 2012

Union University School of Pharmacy

- Chemical Basis for Drug Action I (PHRM 728, 3 hours)
- Introduction to Drug Design and Synthesis (PHRM 732, 2 hours, 30 contact hours)
- Drug Design and Synthesis I (APPE 770A-1, 4 hours, 160 contact hours)
- Drug Design and Synthesis II (APPE 770A-2, 4 hours, 160 contact hours)

Spring 2012
Union University School of Nursing

- Anesthesia Pharmacology (NUR 531, 8 contact hours)

Winter 2012
Union University School of Pharmacy

- Principles of Pharmaceutical Sciences Remediation (PHRM 716-C4-R, 2 hours)

Fall 2011
Union University School of Pharmacy

- Principles of Pharmaceutical Sciences (PHRM 716-C4, 2 hours)
- Christian Faith and Pharmacy (PHRM 785, 2 hours)
- Introduction to Drug Design and Synthesis (PHRM 732, 2 hours, 30 contact hours)
- Drug Design and Synthesis I (APPE 770A-1, 4 hours, 160 contact hours)
- Drug Design and Synthesis II (APPE 770A-2, 4 hours, 160 contact hours)
- Medical Biochemistry (CHE 585, 3 hours)

Spring 2011
Union University School of Pharmacy

- Chemical Basis for Drug Action I (PHRM 728, 3 hours)
- Introduction to Drug Design and Synthesis (PHRM 732, 2 hours, 30 contact hours)
- Drug Design and Synthesis I (APPE 770A-1, 4 hours, 160 contact hours)
- Drug Design and Synthesis II (APPE 770A-2, 4 hours, 160 contact hours)

Spring 2011
Union University School of Nursing

- Anesthesia Pharmacology (NUR 531)

Winter 2011
Union University School of Pharmacy

- Principles of Pharmaceutical Sciences Remediation (PHRM 716-C4-R, 2 hours)

Fall 2010
Union University School of Pharmacy

- Principles of Medicinal Chemistry (PHRM 715, 2 hours)
- Faith and Science (PHRM 705, 2 hours)

Spring 2010
Union University School of Pharmacy

- Medicinal Chemistry of Therapeutic Agents I (PHRM 725, 2 hours)

- Medicinal Chemistry of Therapeutic Agents III (PHRM 745, 2 hours)

Spring 2010
Union University School of Nursing
- Anesthesia Pharmacology (NUR 531)

Fall 2009
Union University School of Pharmacy
- Principles of Medicinal Chemistry (PHRM 715, 2 hours)
- Faith and Science (PHRM 705, 2 hours)
- Medicinal Chemistry of Therapeutic Agents II (PHRM 735, 2 hours)

Spring 2009
Union University School of Pharmacy
- Medicinal Chemistry of Therapeutic Agents I (PHRM 725, 2 hours)

Fall 2008
Union University School of Pharmacy
- Principles of Medicinal Chemistry (PHRM 715, 2 hours)
- Faith and Science (NUR 720, 3 hours)

PROFESSIONAL SERVICE

- Manuscript Reviewer
  - *Chemical Science, 2018-present*
  - *ACS Chemical Neuroscience, 2018-present*
  - *Future Medicinal Chemistry, 2018-present*
  - *Tetrahedron, 2018-present*
  - *Journal of Natural Products*, 2004-present
  - *ChemComm, 2016-present*
  - *Bioorganic and Medicinal Chemistry,* 2013-present
  - *Bioorganic and Medicinal Chemistry Letters, 2016-present*
  - *European Journal of Organic Chemistry*, 2006-present
  - *Journal of Organic Chemistry*, 2008-present
  - *Organic Letters*, 2008-present
  - *Journal of Agricultural and Food Chemistry*, 2009-present
  - *Arkivoc*, 2006-present
  - *Synthetic Communications*, 2013-present
  - *Medicinal Chemistry Research, 2014-present*
  - *Journal of Drug Design and Research, 2014-present*
  - *American Journal of Pharmaceutical Education, 2014-present*

- Member, Resolution Committee of the Chemistry Section for the 2019 AACP Annual Meeting, Chicago, IL

- Member, Program Committee of the Chemistry Section for the 2018 AACP Annual Meeting, Boston, MA

- Member, Program Committee for the 2017 AACP Annual Meeting, Gaylord Hotel and Convention Center, Nashville, TN

- Member, Program Committee of the Chemistry Section for the 2017 AACP Annual Meeting, Gaylord Hotel and Convention Center, Nashville, TN

- Reviewer of Chemistry Section Abstracts for the 2017 AACP Annual Meeting.

- Reviewer for New Investigator Award (NIA) Grants for Chemistry Section of AACP, 2012, 2015, 2016, 2018

- Union University Institutional Review Board, 2008-present; vice-chair (2014-present)

- Editorial board, *Journal of Drug Design and Research*

MEMBERSHIPS

- The American Chemical Society (ACS)
- Medicinal Chemistry Section of ACS
- Organic Chemistry Section of ACS
- The American Association of Colleges of Pharmacy (AACP)
- Chemistry Section of AACP
- Biology Section of AACP

ACADEMIC SERVICE

- Vice President, Union University Athletic Booster Club Board (August 2018-present)
- Board Member, Union University Athletic Booster Club (August 2017-Present)
- Union University Athletic Booster Club Member (2008-present)
- Union University Scholars of Excellence Weekend (Table Host and Interviewer), February 19-20 and February 26-27, 2016
- Union University Scholars of Excellence Weekend (Table Host and Interviewer), February 20-21 and February 27-28, 2015
- Food Service Selection Committee (2015)
- Union University Scholars of Excellence Weekend (Interviewer), February 2014
- Union University Scholars of Excellence Weekend (Table Host and Interviewer), February 2013
- Union University Scholars of Excellence Weekend (Table Host and Interviewer), February 2012
- Search Committee, Dean of the College of Arts and Sciences, Union University, May 2012-March 2013

2009-Present

- Chair, School of Pharmacy Admissions Committee
- SOP Curriculum Committee
- SOP Executive Leadership Council
- Union University Institutional Review Board
- SOP Academic Standing and Progression Review Committee
- Union University Academic Council

2009-2012

- SOP Assessment Committee

MEETINGS/CONFERENCES

- *Student Affairs: Strategies to Promote a Culture of Well-being Among Students and Faculty*, AACP Fall Institute, October 15-17, 2018, Herndon, VA
- AACP Annual Meeting, July 2018, Boston, MA.
- 254th American Chemical Society Meeting, Washington, DC, August 2017.
- AACP Annual Meeting, July 2017, Nashville, TN
- AACP Annual Meeting, July 2016, Anaheim, CA.
- AACP Annual Meeting, July 2016, Anaheim, CA.
- Joint Southeast/Southwest Regional Meeting of the American Chemical Society, November 4-7, 2015, Memphis, TN
- Southwest Regional Meeting of the American Chemical Society (SWRM), November 19-22, 2014, Fort Worth, TX.
- Midwest Regional Meeting of the American Chemical Society, November 12-15, 2014, Columbia, MO.
- Southeast Regional Meeting of the American Chemical Society (SERMACS), October 16-19, 2014, Nashville, TN.
- American Association of Colleges of Pharmacy (AACP) Annual Meeting, Grapevine, TX, July 24-30, 2014.
- Residential School on Medicinal Chemistry and Biology in Drug Discovery, June 8-13, 2014, Drew University, Madison, NJ.
- AACP Interim Meeting, Arlington, VA, February 2014
- AACP Annual Meeting, Chicago, IL, July 2013
- Service and Maintenance Course, Bruker Biospin, Billerica, MA, May 14-17, 2013.
- Pharmacy Curriculum Outcomes Assessment (PCOA) Forum, National Association of Boards of Pharmacy, Mount Prospect, IL, April 25, 2013.
- American Chemical Society Annual Meeting, New Orleans, LA, April 7-10, 2013.
- ASHP Mid-year Meeting, Las Vegas, NV, December 2012
- 34th Annual Reaction Mechanisms Conference at the University of Missouri, Columbia, Missouri, June 2012.
- Nouns, Verbs, and Pronouns: Solving the Mystery of Getting Published (A Seminar in Academic Writing), Carey C. Newman, PhD, Director, Baylor University Press, Union University, 2012.
- ASHP, Midyear Meeting, Faculty/Resident Recruiting, Las Vegas, NV, December 2012.
- Avance I NMR Training Course, Bruker Biospin, Billerica, MA, September 12-15, 2011
- Maintaining the ACQUITY UPLC H-Class System Training Course, Waters Corporation, Morrisville, NC, November 7-11, 2011
- AACP Annual Meeting, Seattle, WA, July 2010.
- Combined Southeast and Southwest Regional Meetings of the American Chemical Society, New Orleans, LA, November 2010.
- AACP Annual Meeting, Boston, MA, July 2009.

PRESENTATIONS

- Watkins, E. B. **Learning to Abandon Assumptions and to Ask the Right Questions or A Mild, Metal-Free Method for the Synthesis of Fused**

Azaheteroaromatics, Kentucky Lake Section of the American Chemical Society Meeting, *invited talk*, Union University, September 2018.

- Reddy, M. D., Blanton, Alex N., and Watkins, E. B. **Palladium-catalyzed, *N*-(2-aminophenyl)acetamide-assisted *ortho*-arylation of substituted benzamides—application to the synthesis of urolithins B, M6, and M7**. Southeast Regional Meeting of the American Chemical Society, Charlotte, NC, November 7-11, 2017.

- Reddy, M. D. and Watkins, E. B., **Palladium-catalyzed Direct Arylation of C(sp^3)-H Bonds of α-Cyano Aliphatic Amides**. Joint Southeast/Southwest Regional Meeting of the American Chemical Society, Memphis, TN, November 4-7, 2015.

- Castleman, A., Mohan, D., Hunter, N., Watkins, EB, and Philip, A. **A Virtual Screening Protocol to Identify Potential Small Molecule Inhibitors of PknG**. 42nd Annual MALTO Medicinal Chemistry and Pharmacognosy Meeting in Miniature. The University of Mississippi, May 2015.

- Goad, Jeff; Helms, Kristen; Jones, Jocelyn; Kahaleh, Abby; Knoderer, Chad; Watkins, E. Blake; Rospond, Raylene. **Assessment of Faculty Perceptions of Promotion**. 2014 American Association of Colleges of Pharmacy (AACP) Annual Meeting, Grapevine, TX, July 24-30, 2014.

- Goad, Jeff; Helms, Kristen; Jones, Jocelyn; Kahaleh, Abby; Knoderer, Chad; Watkins, E. Blake; Rospond, Raylene. **Assessment of Faculty Perceptions of Promotion**. 2014 Midwest Social and Administrative Pharmacy Conference, Purdue University, West Lafayette, IN, July 16-18, 2014.

- Watkins, E. Blake; Philip, Ashok E.; Stephens, Mark A.; Mitchell, Sheila. **Innovations in Education: Design and Implementation of a Laboratory-Based Drug Design and Synthesis APPE**. AACP Annual Meeting, Round-table Discussion, Pharmacy Education July 2013, Chicago, IL.

- Watkins, E. B. **Alzheimer's Disease: Understanding the Future of Drug Discovery.** Invited talk, Alzheimer's Disease Caregivers Support Group, West Tennessee Healthcare/Jackson Madison County General Hospital, June 6, 2013.

- Watkins, E. B. **Pseudolaric Acid B (PLAB): A Novel Antifungal/Anticancer Natural Product**. Invited talk, Mercer University College of Pharmacy and Health Sciences, March 28, 2013.

- Watkins, E. B. **Clickers in the Classroom: Keeping Students Engaged**. uTech Expo 2013, Union University, Jackson, TN, March, 2013.

- Watkins, E. B. and Reid, J. **Advanced Tips and Tricks for ANY Rotary Evaporator**, webinar, American Pharmaceutical Review, February 28, 2013.

- Avery, M. A.; Watkins, E. B.; Vines, K. K.; Weldon, D.; Feller, D. R. **Progress towards the total synthesis of pseudolaric acid B, a novel antipneumocystic**

and antifungal natural product from *Pseudolarix kaempferi*. 55th Southeast Regional Meeting of the American Chemical Society, Atlanta, GA, 2003, Plenary presentation.

POSTERS

- Smith, C., Damoder Reddy, M., Dilipkumar, U., E. B. Watkins. **Visible Light-Induced, Regioselective, Remote Halogenation of 1,2-Diamino Benzene Derivatives**. 255th American Chemical Society Meeting, March 18-22, 2018, New Orleans, LA.

- Jones, K.; Castleman, A.; Phillip, A.; and Watkins, E. B. **Progress Towards Structure-based *De Novo* Design and Synthesis of Small Molecule Inhibitors of Protective Antigen (PA): An Anti-toxin Approach for Combating Anthrax**. 251st American Chemical Society Meeting, March 13-17, 2016, San Diego, CA.

- Addo, R.; Davis, K.; Ubale, R.; Owen, J.; and Watkins, E. B. **Development and Validation of a UPLC Method for Rapid and Simultaneous Analysis of Proton Pump Inhibitors**. American Association of Pharmaceutical Scientists Annual Meeting and Exposition, November 2-6, 2014, San Diego, CA.

- Mohan, Devipriya; Hunter, Neil; Nguyen, Dan; Watkins, E. Blake; Philip, Ashok. **Virtual screening for potential small molecule inhibitors of protein kinase G: a promising target for multidrug resistant tuberculosis.** Union University Fall Poster Session, November 19, 2013, Jackson, TN.

- Watkins, E. Blake; Philip, Ashok E.; Stephens, Mark A.; Mitchell, Sheila. **Innovations in Education: Design and Implementation of a Laboratory-Based Drug Design and Synthesis APPE**. AACP Annual Meeting, Pharmacy Education July 2013, Chicago, IL.

- Karlsson, I.; Bonner, M. Y.; Zhou, X.; Zhang, J.; Watkins, E. Blake; Bowen, JP; and Arbiser, J. L. **Novel Synthesis and Activity of Solenopsin A and Analogs, Topical Inhibitors of Phosphoinositol-3 Kinase/Akt with Ceramide-like Properties.** International Investigative Dermatology Conference, May 8-11, 2013, Edinburg, Scotland.

- Blanton, A; Philip, A.; and Watkins, E. B. **Structure-Based De Novo Design and Synthesis of Protein-Protein Interaction Inhibitors: A Novel Anti-Toxin Approach for Combating Anthrax.** Honors Research Symposium, Mississippi University for Women, November 2012, Columbus, Mississippi.

- Shah, S., Hunter, N.; Mohan, D.; Philip, A.; and Watkins, E. B. **"Progress towards structure-based de novo design and synthesis of small molecule inhibitors of protective antigen (PA): an anti-toxin approach for combating anthrax**. Annual Union University Scholarship Symposium, November, 2012, Jackson, TN.

- Hise, N. W. V.; Mitchell, J.; Hunter, N.; Mohan, D.; Philip, A.; and **Watkins, E. B**. **Solution-phase parallel synthesis of small molecule inhibitors of protective antigen (PA): a novel anti-toxin approach for combating anthrax**. Tennessee Pharmacists Association, February 2012, Nashville, TN.

- Smith, A. T.; Pierce, B. A.; Philip, A.; and **Watkins, E. B**. **Progress Towards the Total Synthesis of Crotogoudin: A Potent Cytotoxic 3,4-*seco*-atisane from *Croton goudotii*.** Union University Scholarship Symposium, May 2011, Jackson, TN.

- Hise, N. W. V.; Mitchell, J.; Hunter, N.; Mohan, D.; Philip, A.; and **Watkins, E. B**. **Solution-phase parallel synthesis of small molecule inhibitors of protective antigen (PA): a novel anti-toxin approach for combating anthrax**. Union University Scholarship Symposium, May 2011, Jackson, TN.

- **Watkins, E. B**., DeMaagd, G., Owen, J., King, S., Jones, K., Stephens, M., Kuhl, D., Martin, A., Mitchell, S., Clarke, J. **Evaluation of Potential Determinants of Successful Performance in First Year Pharmacy Students**. AACP Annual Meeting, July 2010. Seattle, WA.

- Hunter, N.; Mohan, D.; Mitchell, J.; Hise, N. W. V.; Watkins, E. B.; and Philip, A. **"Structure-based de novo design of small molecule inhibitors of protective antigen (PA): a novel anti-toxin approach for combating anthrax**. 8th Annual Union University Scholarship Symposium, May, 2011, Jackson, TN.

- Vines, K. K.; Watkins, E. B.; Avery, M. A.; Feller, D. R. **Progress towards the total synthesis of pseudolaric acid B: a novel antipneumocystic and antifungal natural product.** 228th National Meeting of the American Chemical Society, Philadelphia, 2004.

BOOK REVIEWS

- **Watkins, E. Blake**, [Review of the book *The Diels Alder Reaction. Selected Practical Methods* by Francesco Fringuelli and Aldo Taticchi]. *Current Medicinal Chemistry: Anti-Infective Agents*, 1(3), 2002.

AWARDS AND HONORS

- Granted Tenure, Union University, February 2014
- Union University School of Pharmacy Faculty Member of the Year, 2013-2014
- Selected to be a member of the AACP 2013-2014 Academic Leadership Fellows Program cohort class
- Selected by the organic chemistry faculty of the University of Georgia to film a series of laboratory experiments as part of a federal grant to improve the undergraduate chemistry laboratory experience. These videos were aired throughout the day on a local cable channel and prior to each laboratory session to facilitate student comprehension
- Outstanding Teaching Assistant in Chemistry, University of Georgia, 1995
- *Magna Cum Laude*, Union University, 1994
- Undergraduate Research Award in Chemistry, Union University, 1994
- National Science Foundation Summer Undergraduate Research Program, Baylor University, Waco, Texas, 1993

PATENTS

- **Watkins, E. B.**; Uredi, D.; Motati, D. R. *A Mild, Metal-free Method for the Preparation of Substituted/Fused Pyridines and Carbolines*. Application US62735517, filed September 24, 2018.
- Guner, O; Lassegue, B.; Griendling, K.; Xu, Q.; Brown, D.; Bowen, J.P.; Kulkarni, A.; **Watkins E. B.** *NADPH Oxidase Inhibitors and Uses Thereof*, Application PCT/US18/43890, filed July 26, 2018.
- Guner, O; Lassegue, B.; Griendling, K.; Xu, Q.; Brown, D.; Bowen, J.P.; Kulkarni, A.; **Watkins E. B.** *NADPH Oxidase Inhibitors*, Application 62/537,267, filed July 26, 2017.
- Arbiser, J. L.; Bowen, J. P.; **Watkins, E. B.** *Solenopsin and Derivatives, Therapeutic Compositions, and Methods Related Thereto*. U.S. Patent Number 9592226 issued March 14, 2017.
- Griendling, K.; Lassegue, B.; Guner, O. F.; Bowen, J. P.; **Watkins, E. B.**; Brown, D. I.; Lundgren, T. *Novel 1,2-Diarylethanone NOX inhibitors*. U.S. Provisional Patent Application 62010670, filed June 11, 2014.
- Guner, O. F.; Bowen, J. P.; Griendling, K.; Lassegue, B.; **Watkins, E. B.**; Brown, D. I.; Lundgren, T. *Small Molecule Inhibitors of NADPH Oxidase*, U.S. Provisional Patent Application 62011230, file June 12, 2014.

PUBLICATIONS

- Motati, D. R. Uredi, D., **Watkins, E. B.** Metal-catalyzed, bidentate directing group-assisted C-H functionalization—application to the synthesis of complex natural products. *Studies in Natural Products Chemistry*, 2018, *in press*.

- **Watkins, E. B.**, Güner, O. F., Kulkarni, A., Lassègue, B., Griendling, K. K., and Bowen, J. P. Discovery and Therapeutic Relevance of Small-Molecule Nox4 Inhibitors. *Medicinal Chemistry Reviews*, 2018, *in press*.

- Uredi, D., Motati, D. R., and **Watkins, E. B**. A Unified Strategy for the Synthesis of β-Carbolines, γ-Carbolines, and Other Fused Azaheteroaromatics under Mild, Metal-Free Conditions. *Org. Lett*. 2018, [doi: 10.1021/acs.orglett.8b02441].

- Reddy, M. D., Dilipkumar, U., and **Watkins, E. B**. A General Method for the Metal-free, Regioselective, Remote C-H Halogenation of 8-Substituted Quinolines. *Chem. Sci*. 2018, 9, 1782-1788.

- Xu, Q., Kulkarni, A. A., Sajith, A. M., Hussein, D., Brown, D., Güner, O. F., Reddy, D. M., **Watkins, E. B.**, Lassègue, B., Griendling, K. K., and Bowen, J. P. Design, Synthesis, and Biological Evaluation of Inhibitors of the NADPH Oxidase, Nox4. *Bioorg. Med. Chem*. 26, 2018, 989-998.

- Reddy, M. D.; Kobori, H.; Mori, T.; Wu, J.; Kawagishi, H.; **Watkins, E. B.** Gram-scale, Stereoselective Synthesis and Biological Evaluation of (+)-Armillariol C, *J Nat. Prod*. 2017, 80(9), 2561-2565.

- Reddy, M. D.; Blanton, A. N.; **Watkins, E. B.** Palladium-Catalyzed, *N*-(2-Aminophenyl) Acetamide-Assisted *ortho*-Arylation of Substituted Benzamides—Application to the Synthesis of Urolithins B, M6, and M7, *J. Org. Chem.* 2017, 82, 5080-5095.

- Reddy, M. D.; Fronczek, F. R.; **Watkins, E. B.** Rh-Catalyzed, Regioselective, C-H Bond Functionalization: Access to Quinoline-Branched Amines and Dimers, *Org. Lett.*, 2016, 18, 5620-5623.

- Reddy, M. D. and **Watkins, E. B.**, Palladium-catalyzed Direct Arylation of C(sp^3)-H Bonds of α-Cyano Aliphatic Amides, *J. Org. Chem.*, 2015, 80(22), 11447-11459.

- Karlsson, I.; Zhou, X.; Thomas, R.; Smith, A. T.; Bonner, M. Y.; Li, X.; Chen, G.; Bowen, J. P.; Qabaja, G.; Ford, S. F.; Ballard, M. D.; Petersen, K. S.; **Watkins, E. B.**; Ogretmen, B.; Zhang, J.; Arnold, R. S.; Arbiser, J. L. Context Dependent Activity of Solenopsin A and Analogs: Implications for Ceramide Biology, *Vascular Cell*, 2015, 7:5.

- Philip, A.; Stephens, M.; Mitchell, S. L.; **Watkins, E. B.** Design and Implementation of a Laboratory-based Drug Design and Synthesis Advanced Pharmacy Practice Experience (APPE), *American Journal of Pharmaceutical Education*, 2015: 79(3), Article 43.

- Addo, R.; Davis, K.; Ubale, R.; Owen, J. S.; **Watkins, E. B.** Development and Validation of a UPLC Method for Rapid and Simultaneous Analysis of Proton Pump Inhibitors, *AAPS PharmSciTech, 2015, 16(1), 30-34.*

- Smith, A. T. and **Watkins, E. B.** Recent Advances in the Development of $P2Y_{12}$ Receptor Antagonists as Antiplatelet Agents. In Manoj C. Desai, editor: *Annual Reports in Medicinal Chemistry*, Vol 40, ARMC, UK: Academic Press, 2014, pp. 87-99.

- Addo, R. T; **Watkins**, **E. B.**; Owen, J. S.; Davis, K. R.; and Bingham, R. C. End of Supply Chain Screening to Assess Drug Product Quality in the U.S. Market–Omeprazole as a Case Study. *Advances in Analytical Chemistry*, 2013, 3(4), 48-53.

- **Watkins, E. B.**, "*The Future of Pharmaceutical Care*" in Renewing Minds, Union University, **2**, 2012.

- **Watkins, E. B.,** "*The Study of Healthcare at the Christian University*" in *Faith and Learning: A Handbook for Christian Higher Education*. David S. Dockery ed. 2012: B&H Publishing, Nashville, pp. 409-429.

- Li, Z.; **Watkins, E. B**.; Liu, H.; Chittiboyina, A. G.; Carvalho, P. B.; Avery, M.A. 1,3-Diaxially Substituted *trans*-Decalins: Potential Nonsteroidal Human Progesterone Receptor Inhibitors. *JOC* 2008, **73**, 7764-7767.

- Choi, S. R.; Beeler, A. B.; Pradhan, A.; **Watkins**, **E. B.**; Rimoldi, J. M.; Tekwani, B.; Avery, M. A. Generation of Oxamic Acid Libraries: Antimalarials and Inhibitors of *Plasmodium falciparum* Lactate Dehydrogenase. *J. Comb. Chem.* 2007, **9**(2), 292-300.

- **Watkins, E. B.**; Chittiboyina, A. G.; Avery, M. A. Recent Developments in the Syntheses of the Epothilones and Related Analogues. *Eur. JOC*, 2006, **18**, 4071-4084.

- **Watkins, E. B.**; Chittiboyina, A. G.; Jung, J.-C.; Avery, M. A. The Epothilones and Related Analogues—A Review of Their Syntheses and Anti-Cancer Activities. *Curr. Pharm. Design*. 2005, **11**(13), 1615-1653.

- Reddy, C. R.; Chittiboyina, A. G.; Kache, R.; Jung, J.-C.; **Watkins, E. B.**; Avery, M. A. The Trimethylsilyl Xylyl (TIX) Ether: A Useful Protecting Group for Alcohols. *Tetrahedron.* 2005, **61**(5), 1289-1295.

- Jung, J.C., **Watkins, E. B.**, Avery, M. A. Synthesis and cyclization reactions of pyrazolin-5-one derivatives. *Heterocycles*. 2005, **65**(1), 77-94.

- Goud, P. M.; Sheri, A.; Desai, P. V.; **Watkins, E. B.**; Tekwani, B.; Sabnis, Y.; Gut, J.; Rosenthal, P. J.; and Avery, M. A. Design, synthesis and evaluation of trisubstituted thiazoles targeting *Plasmodium falciparum* cysteine proteases. *Med. Chem. Res.* 2005, **14**(2), 74-105.

- Chittiboyina, A. G.; Reddy, C. R.; **Watkins, E. B.**; Avery, M. A. First synthesis of antimalarial Machaeriols A and B. *Tetrahedron Lett.* 2004, **45**(8), 1689-1691.

- Wu, B.; Karle, J. M.; **Watkins, E. B**.; Avery, M. A. Toward the total synthesis of pseudolaric acid B. Preparation of a key intermediate by degradation and its use in the reassembly of the natural product. *Tetrahedron Lett.* 2002, **43**(22), 4095-4098.

- Jung, J. C.; **Watkins, E. B**.; Avery, M. A. Synthesis of 3-substituted and 3,4-disubstituted pyrazolin-5-ones. *Tetrahedron*, 2002, **58**(18), 3639-3646.

- Jung, J. C.; **Watkins, E. B**.; Avery, M. A. Efficient synthesis of 3-substituted pyrazolin-5-ones. *Synth. Commun.* 2002, **32**(24), 3767-3777.

- **Watkins, E. B**.; Phillips, R. S. Inhibition of Tyrosine Phenol-lyase from *Citrobacter freundii* by 2-azatyrosine and 3-azatyrosine. *Biochemistry*, 2001, **40**(49), 14862-14868.

- **Watkins, E. B**.; Phillips, R. S. Enzymatic synthesis of azatyrosines. *Bioorg. Med. Chem. Lett.* 2001, **11**(16), 2099-2100.