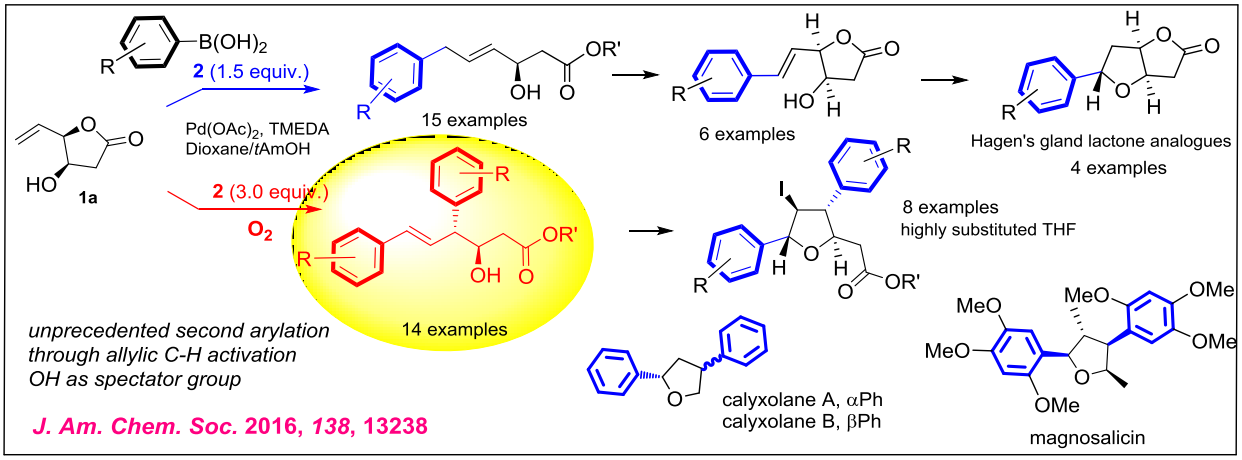
Research in our group encompasses the following 4 areas in Synthetic Organic Chemistry.

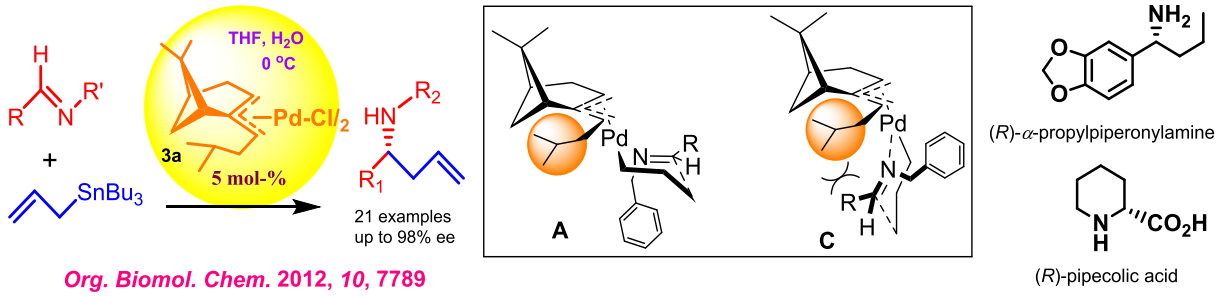
1] Development of Asymmetric Catalysis
2] Total Synthesis of Natural products
3] Development of Novel Protecting-Group-Free Synthesis
4] Development of New Synthetic Methods

1] Development of Asymmetric Catalysis

We have explored an unprecedented double arylation through π-allylpalladium formation by synergistic Pd(II) and Pd(0) dual-catalysis (***J. Am. Chem. Soc.* 2016**, *138*, 13238). The γ-vinyl-γ-lactone **1a** has been envisaged as allyl electrophile donor for allylic arylation *via* π-allylpalladium intermediate using 1.5 equiv. of aryl boronic acid **2**. Use of 3.0 equiv. of the latter resulted in monoarylation by allylic substitution and subsequent site-selective second arylation by directed allylic C-H activation giving stereoselectively *anti*-γ-(aryl,styryl)-β-hydroxy acids. Presence of O_2 was crucial for the second arylation via Pd(II) catalysis.

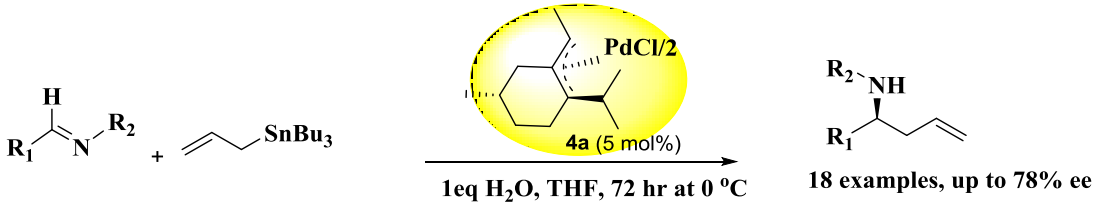


The pinane and menthane skeletons have been exploited for development of π-allylpalladium catalysis. The newly developed π-allylpalladium catalyst with (–)-*β*-pinene framework **3a** with isobutyl side chain catalyzed the enantioselective allylation of imines in good yields and enantioselectivities (21 examples, up to 98% ee). The isobutyl group rendered steric crowding for complexation of imine from the front side as in model **A** exhibiting higher enationselectivities. An efficient enantioselective synthesis of (*R*)-α-propyl piperonylamine part of DMP 777, a human leukocyte elastase inhibitor and the α-amino acid (*R*)-pipecolic acid have been achieved as a useful application of this methodology (***Org. Biomol. Chem.* 2012**, *10*, 7789).



Org. Biomol. Chem. **2012**, *10*, 7789

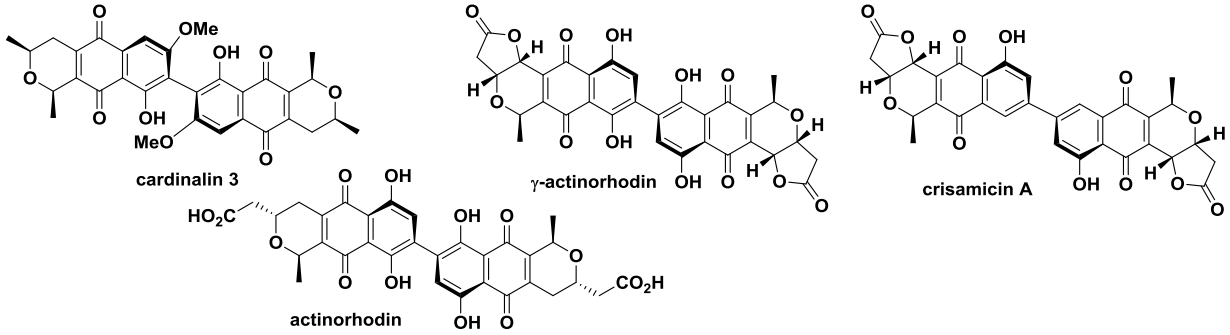
The menthane skeleton has been widely used as chiral auxiliary in main stream of organic synthesis. We have for the first time explored the menthane framework for similar chiral induction by synthesizing the menthane based π-allylpalladium catalyst **4a**. This could catalyse the enantioselective allylation of imines in good yields and enantioselectivities (18 examples, up to 78% ee, ***Eur. J. Org. Chem.* 2012**, 1945).



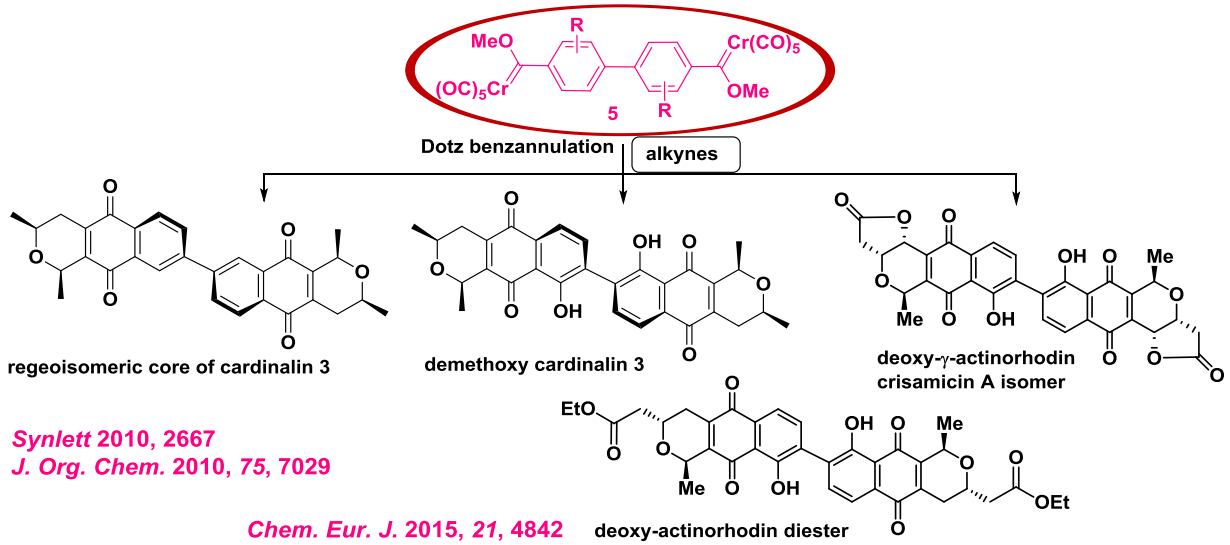
Eur. J. Org. Chem. **2012**, 1945

2] Total Synthesis of Natural products

The total synthesis of complex natural products like actinorhodins, crisamicin A and cardinalins has been executed. The synthetic strategies has been elegantly designed based on Dötz benzannulation of dimeric Fischer carbenes with requisite chiral alkynes (***Chem. Eur. J.* 2015,** *21*, 4842, ***Synlett* 2010**, 2667, ***J. Org. Chem.* 2010**, *75*, 7029, ***Eur. J. Org. Chem.* 2016**, 5778).



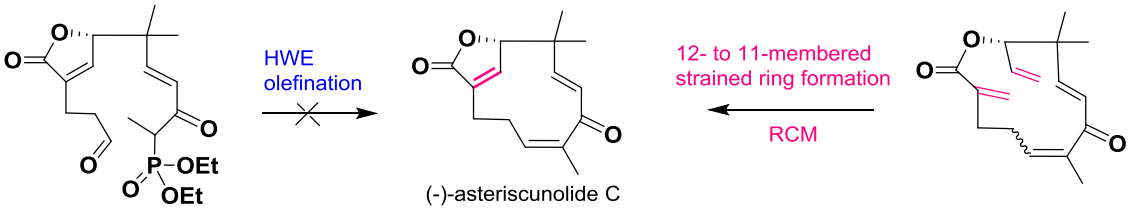
This work has led to the total synthesis of regioisomeric core structure of cardinalin 3 and demethoxy cardinalin 3. The bidirectional Dötz benzannulation of dimeric Fischer carbenes **5** was extended to the synthesis of deoxy-actinorhodin diester and deoxy-γ-actinorhodin. The latter is crisamicin A regioisomer.



Synlett 2010, 2667
J. Org. Chem. 2010, *75*, 7029

Chem. Eur. J. 2015, *21*, 4842

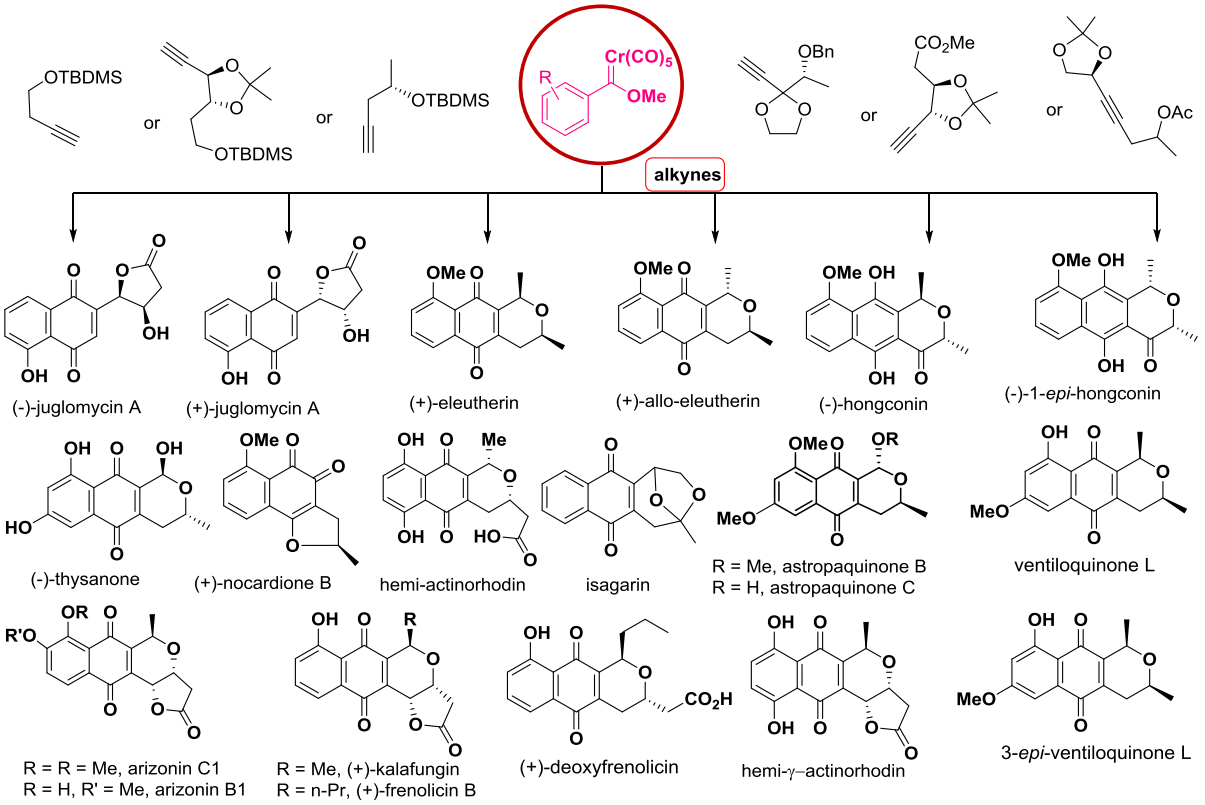
The first stereoselective total synthesis of strained 11-membered astericunolide C (anticancer) was achieved with a unique ring-contracting strategy from a 12-membered to strained 11-membered ring based on ring closing metathesis (***Chem. Commun.* 2013**, *49*, 3354).



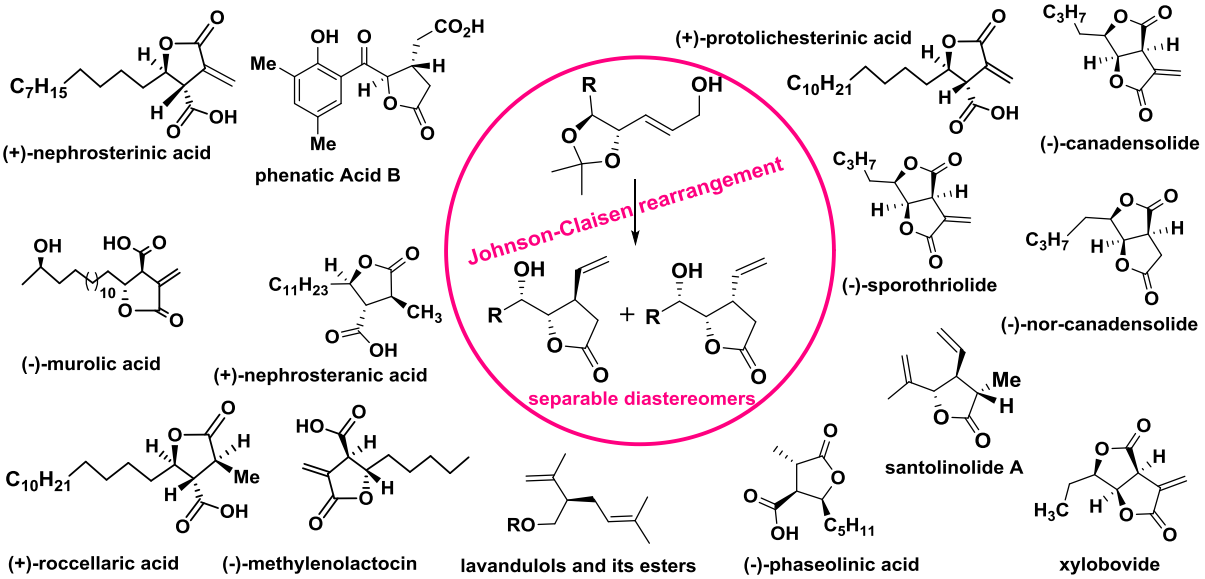
Chem. Commun. 2013, *49*, 3354

(-)-asteriscunolide C
highly strained 11-membered ring with three double bonds of which two are *trans* in the macrocycle

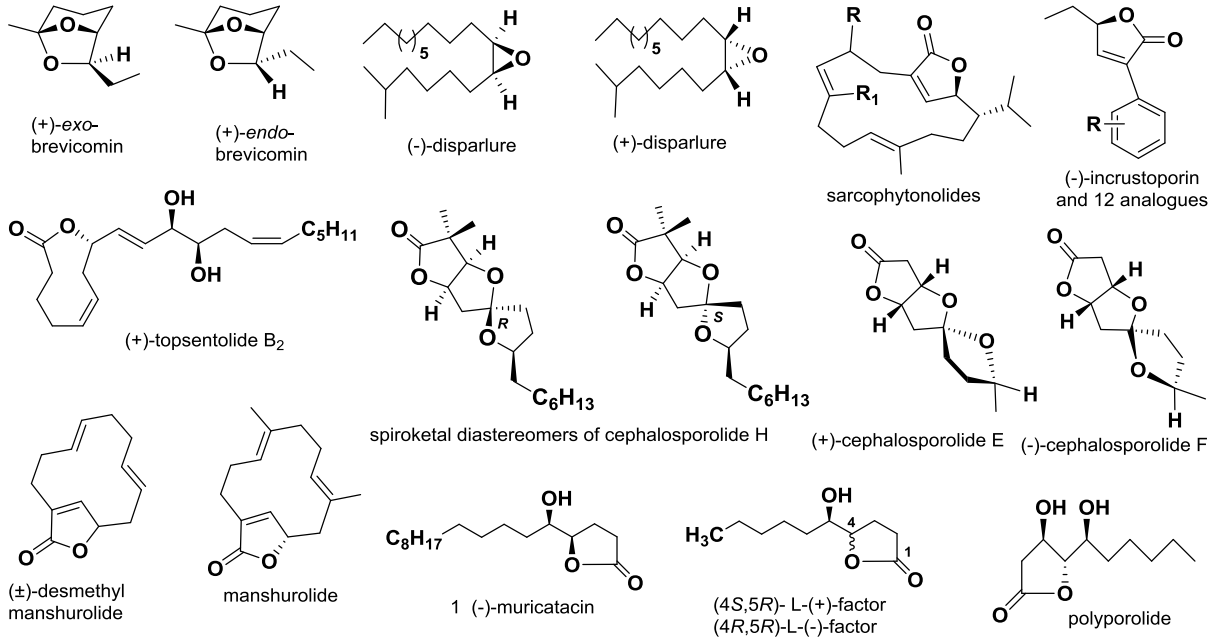
The total synthesis of other natural products like various pyranonaphthoquinones has been achieved based on Dötz benzannulation of Fischer carbenes as shown below (***Eur. J. Org. Chem.* 2015**, 4931, ***Asian J. Org. Chem.* 2015**, *4*, 560, ***Synthesis* 2014**, *46*, 1836, ***Tetrahedron: Asymmetry* 2013**, *24*, 1281, ***Tetrahedron: Asymmetry* 2013**, *24*, 1548, ***Org. Biomol. Chem.* 2012**, *10*, 4462, ***J. Org. Chem.* 2012**, *77*, 10455, ***Eur. J. Org. Chem.* 2011**, 6624, ***Tetrahedron: Asymmetry* 2011**, *22*, 1312, ***Tetrahedron: Asymmetry* 2011**, *22*, 487, ***Eur. J. Org. Chem.* 2010**, 4306).



The total synthesis of phenatic acids, various paraconic acids and related natural products has been achieved based on ortho-ester Johnson-Claisen rearrangement strategy (***Eur. J. Org. Chem.*** **2014**, 237, ***Eur. J. Org. Chem.*** **2014**, 2833, ***Eur. J. Org. Chem.*** **2013**, 5165, ***Eur. J. Org. Chem.*** **2012**, 1047, ***Tetrahedron: Asymmetry*** **2012**, *23*, 60, ***Tetrahedron: Asymmetry*** **2011**, *22*, 1114, ***Eur. J. Org. Chem.*** **2011**, 1106, ***Tetrahedron: Asymmetry*** **2009**, 20, 2835, ***J. Org. Chem.*** **2009**, *74*, 8826).



Synthesis of many other natural products as shown below has also been achieved by developing efficient and short strategies (***ChemistrySelect* 2016**, *1*, 5137, ***Asian J. Org. Chem.* 2016**, *5*, 839, ***Tetrahedron Lett*. 2016**, *57*, 3694, ***Tetrahedron: Asymmetry* 2016**, *27*, 114, ***RSC Advances* 2015**, *5*, 49189, ***RSC Advances* 2014**, *4*, 63342, ***Eur. J. Org. Chem.* 2014**, 3249, ***RSC Advances* 2014**, *4*, 14507, ***Asian. J. Org. Chem.* 2014**, *3*, 58, ***Asian J. Org. Chem.* 2013**, *2*, 74, ***Tetrahedron: Asymmetry* 2011** *22*, 1930, ***Tetrahedron Lett.* 2011**, *52*, 1788, ***Tetrahedron Lett.* 2011**, *52*, 458).



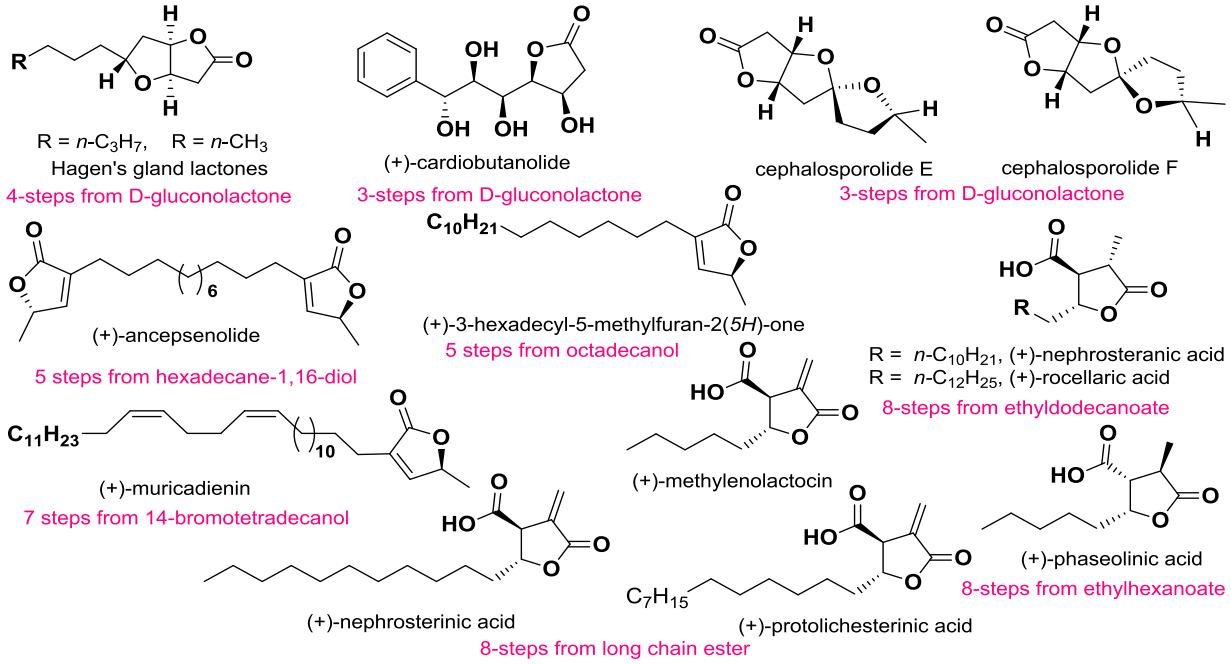
3] Development of Novel Protecting-Group-Free Synthesis

An ideal synthesis demands no use of protecting groups, enabling shorter synthesis and overall economy. Keeping this in mind, many of the earlier synthesis involving lengthy sequences have been shortened based on efficient protecting-group-free (PGF) based synthetic strategies. The research work based on "Protecting-Group-Free" strategies has been commendable for total synthesis of Hagen's gland lactones, cardiobutanolide, cephalosporolides, muricadienin, ancepsenolide and paraconic acids (***Asian J. Org. Chem.* 2013**, *2*, 74 ***featured article*, *J. Org. Chem.* 2012**, *77*, 9357, ***RSC Advances* 2015**, *5*, 42131, ***Org. Biomol. Chem.* 2016**, *14*, 9072, ***Org. Biomol. Chem.* 2017**, *15*, 708). For a few of them process patent applications have been filed as below.

1] A Process for the Preparation of Cephalosporolides E and F. Published in Indian Patent Office Journal No. 02/2017 dated 13-01-2017. Indian process patent application No. 2595/MUM/2015. Rodney A. Fernandes*, Dipali A. Chaudhari and Pullaiah Kattanguru.

2] A Novel Process for the Four-Step Protecting Group Free Synthesis of (+)-Hagen's Gland Lactones. Indian process patent application filed, No. 1908/MUM/2012. Rodney A. Fernandes* and Pullaiah Kattanguru.

3] Process for the Three Step Synthesis of (+)-Cardiobutanolide from D-Glucono-δ-lactone. Published in Indian Patent Office Journal No. 22/2014 dated 30-05-2014. Indian process patent application filed, No. 1780/MUM/2012. Rodney A. Fernandes* and Pullaiah Kattanguru.

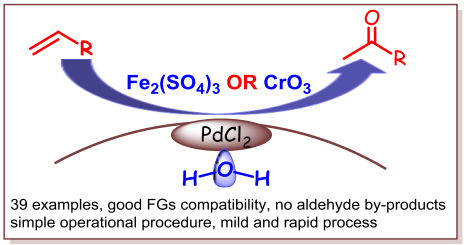


4] Development of New Synthetic Methods

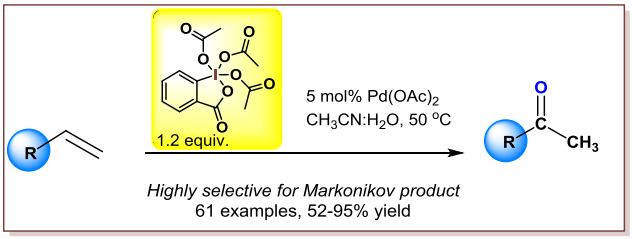
The new methods development has resulted in new reagent conditions for useful organic reactions like Wacker process and oxidation reactions (***J. Org. Chem.*** **2016**, *81*, 8577, ***J. Org. Chem.*** **2016**, *81*, 2113, ***J. Org. Chem.*** **2014**, *79*, 5787, ***Tetrahedron*** **2014**, *70*, 4760). These works have been abstracted in ChemInform 2016, vol. 47, issue 30, ChemInform 2014, vol. 45, issue 50. Highlighted in Organic Chemistry Portal, Highlights 2015, March 30 by Douglass F. Taber and Highlights 2016 by Reto Mueller.

4] A Process for Synthesis of Methyl Ketones by Wacker-Type Oxidation Reaction. Provisional Indian process patent application has been filed, No. 2965/MUM/2015. Published in Indian Patent Office Journal No. 06/2017 dated 10/02/2017.

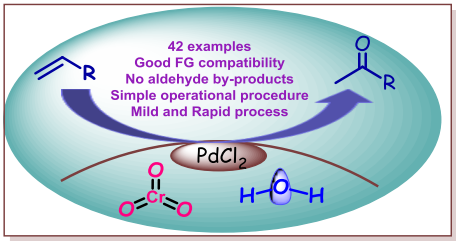
Selective new oxidation methods have also been developed. 1] An expedient method for chemoselective osmium(VI) catalyzed oxidation of benzylic, allylic and propargylic alcohols using $K_3Fe(CN)_6$ as a secondary oxidant was developed. 2] Similarly a tandem benzylic oxidative dihydroxylation of α-vinyl and α-alkenylbenzyl alcohols was also explored (***RSC Advances*** **2014**, *4*, 40561, ***Helv. Chim. Acta*** **2015**, *98*, 92).



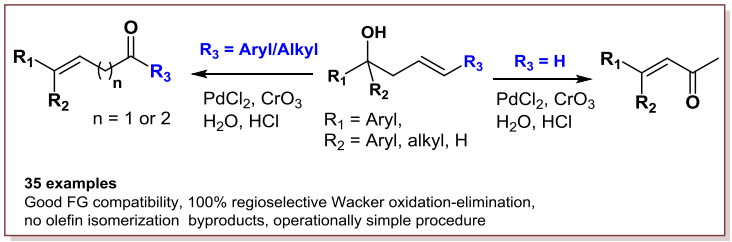
J. Org. Chem. 2014, *79*, 5787



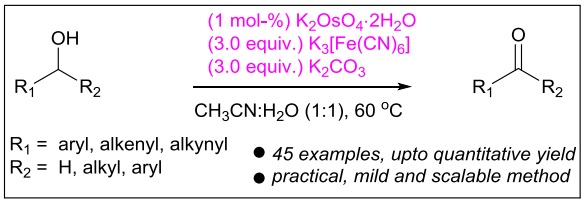
J. Org. Chem. 2016, *81*, 2113

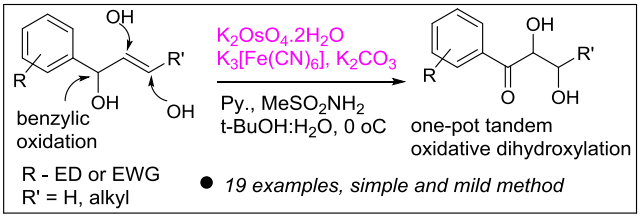


Tetrahedron 2014, *70*, 4760



J. Org. Chem. 2016, *81*, 8577





A new cascade reaction involving Aza-Cope/Aza-Prins cyclization leading to piperidine derivatives has been explored. The reaction works well on even four allyl groups on tetrabenzyl amine giving a crucifix type piperidine-4-ols (see figure). Some of these served as excellent ligands in Ulmann coupling, Sonogashira and Suzuki couplings (***Eur. J. Org. Chem.* 2015**, 2012, ***Asian J. Org. Chem.* 2015**, *4*, 552, ***Eur. J. Org. Chem.* 2015**, 3558, ***RSC Advances* 2015**, *5*, 54037).