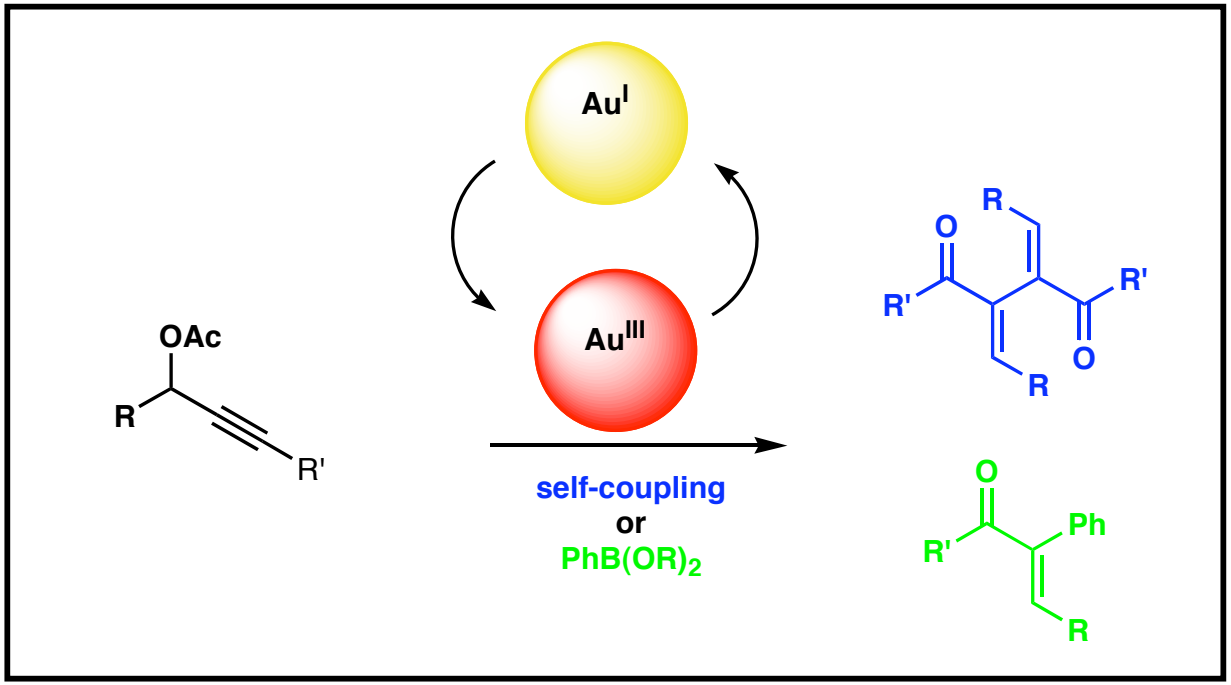
Gold-Catalyzed Homogeneous Oxidative Cross-Coupling Reactions

Guozhu Zhang, Yu Peng, Li Cui, and Liming Zhang*

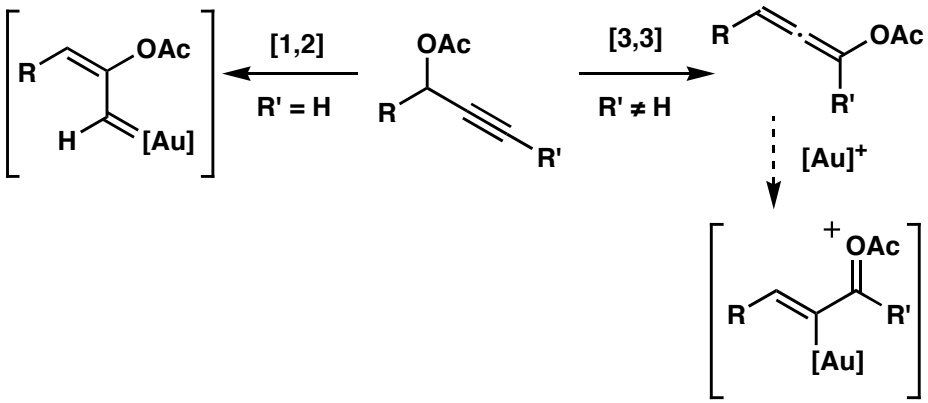
Angew. Chem. Int. Ed., **2009**, *48*, 3112-3115
DOI: 10.1002/anie.200900585



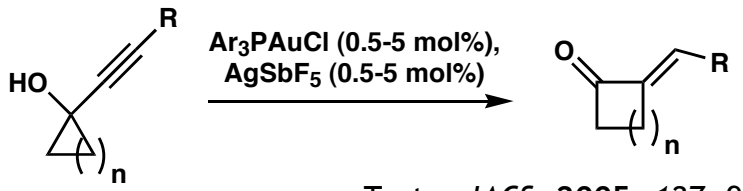
Adam Hoye
Wipf Group
Current Literature
April 11th, 2009

Gold reactions

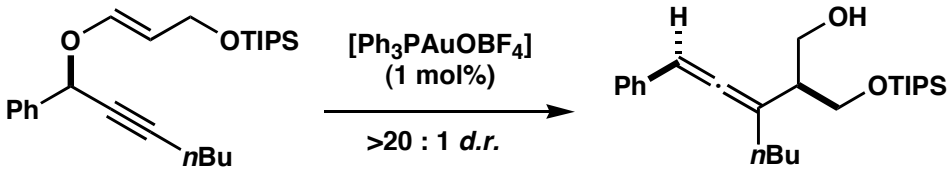
Rearrangements



Nolan, *ACIE*, **2006**, *45*, 3647
Zhang, *Adv. Synth. Catal.*, **2007**, *349*, 871

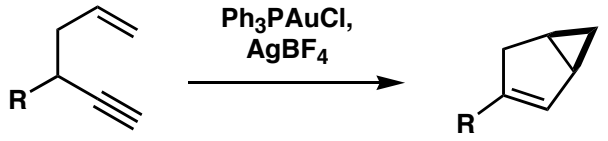


Toste, *JACS*, **2005**, *127*, 9708

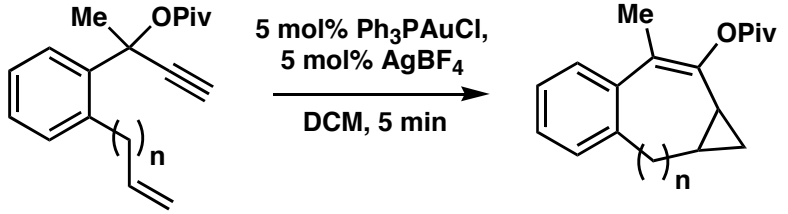


Toste, *JACS*, **2004**, *126*, 15978

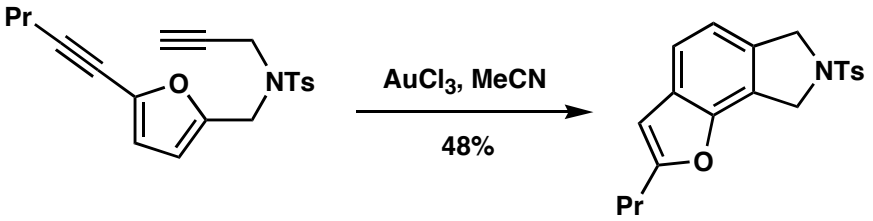
Cyclizations



Toste, *JACS*, **2004**, *126*, 10858

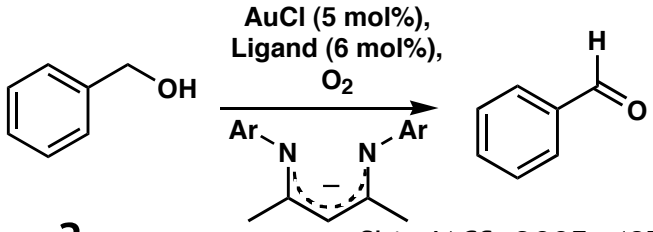


Toste, *JACS*, **2009**, *131*, 2056



Hashmi, *OL*, **2001**, *3*, 3769

Oxidations/reductions



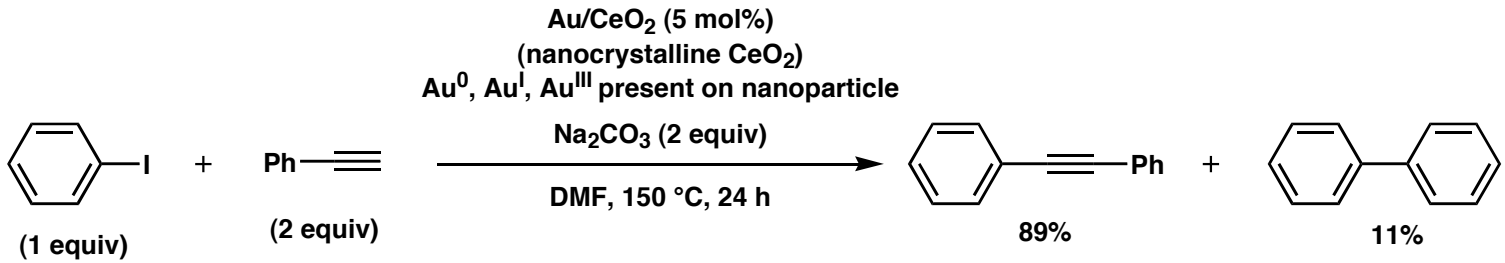
Shi, *JACS*, **2005**, *127*, 18004

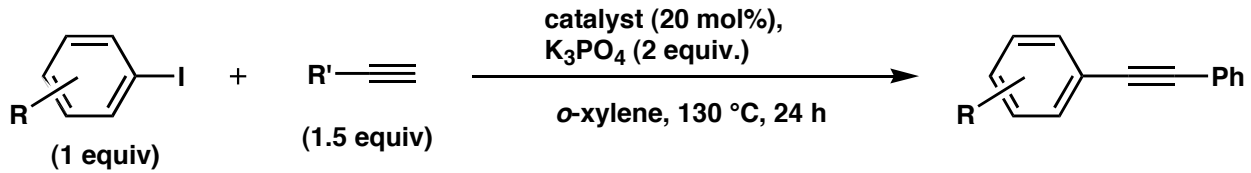
Cross-couplings?

Gold in cross-coupling reactions

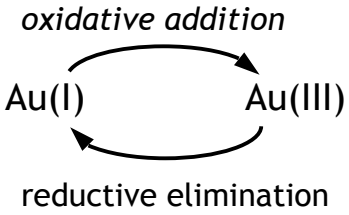
Au(I), Cu(I) and Pd(0) possess the same d^{10} electron structure

Copper-free Sonogashira reaction:





R	R′	Yield [%]			
		Pd^0	Pd^{II}	Au^I	$[AuCl(PPh_3)]$
H	Ph	23	30	54	35
H	*n*-$C_{10}H_{17}$	20	25	10[b] (50)[c]	97[b] (80)[c]
H	$CH_2CH(CO_2Me)_2$	25	15	10	40
COOEt	Ph	25	14	10[b] (90)[c]	95[b] (30)[c]

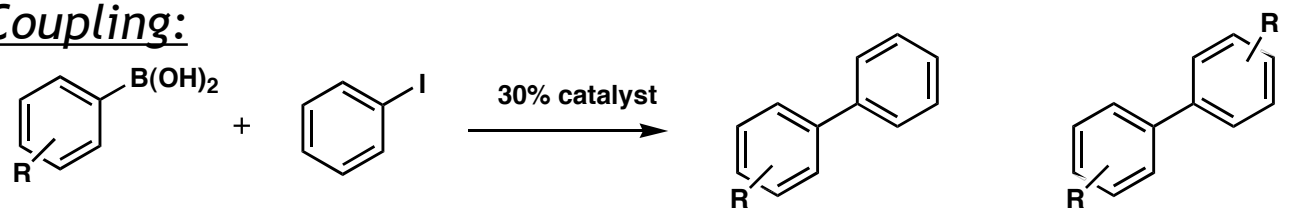


Presumably a Au(I)/Au(III) catalytic cycle

Corma, *ACIE*, **2007**, *46*, 1536

Cross-coupling reactions with gold

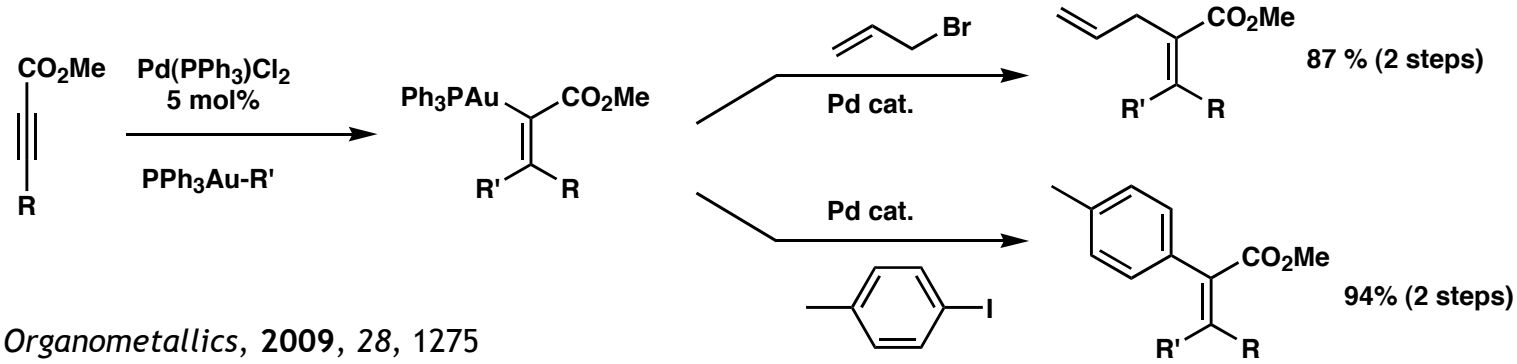
Suzuki Coupling:



Corma, *J. Catal.*, **2006**, *238*, 497

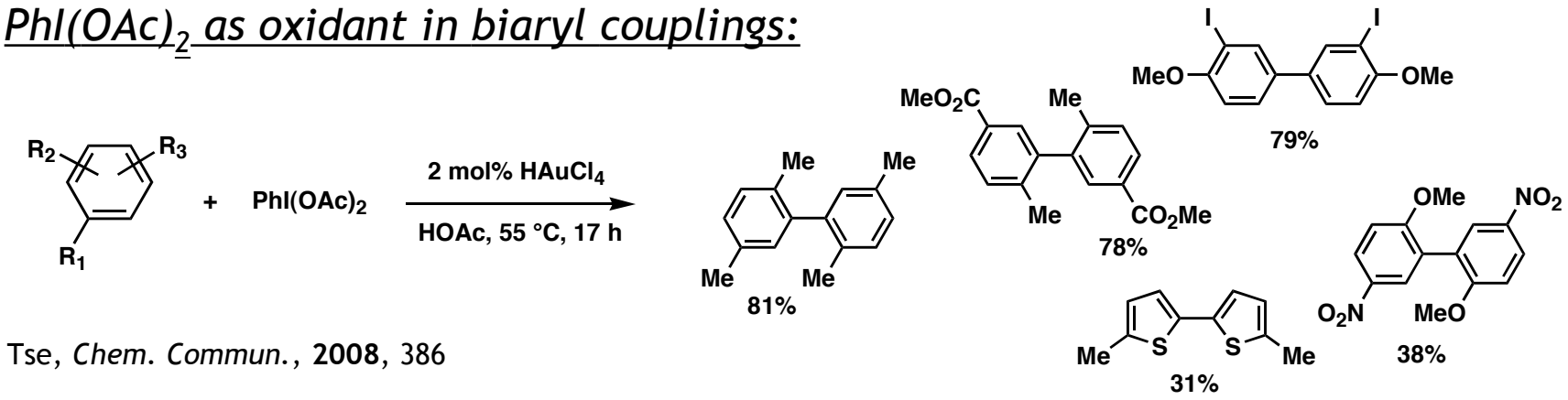
	cross-coupling	homo-coupling
Au(I)-Salen*	100 (80% yield)	0
$AuCl_3$	0	100

Palladium-Catalyzed Carboauration and Palladium/Gold Cross-Coupling:



Blum, *Organometallics*, **2009**, *28*, 1275

$PhI(OAc)_2$ as oxidant in biaryl couplings:

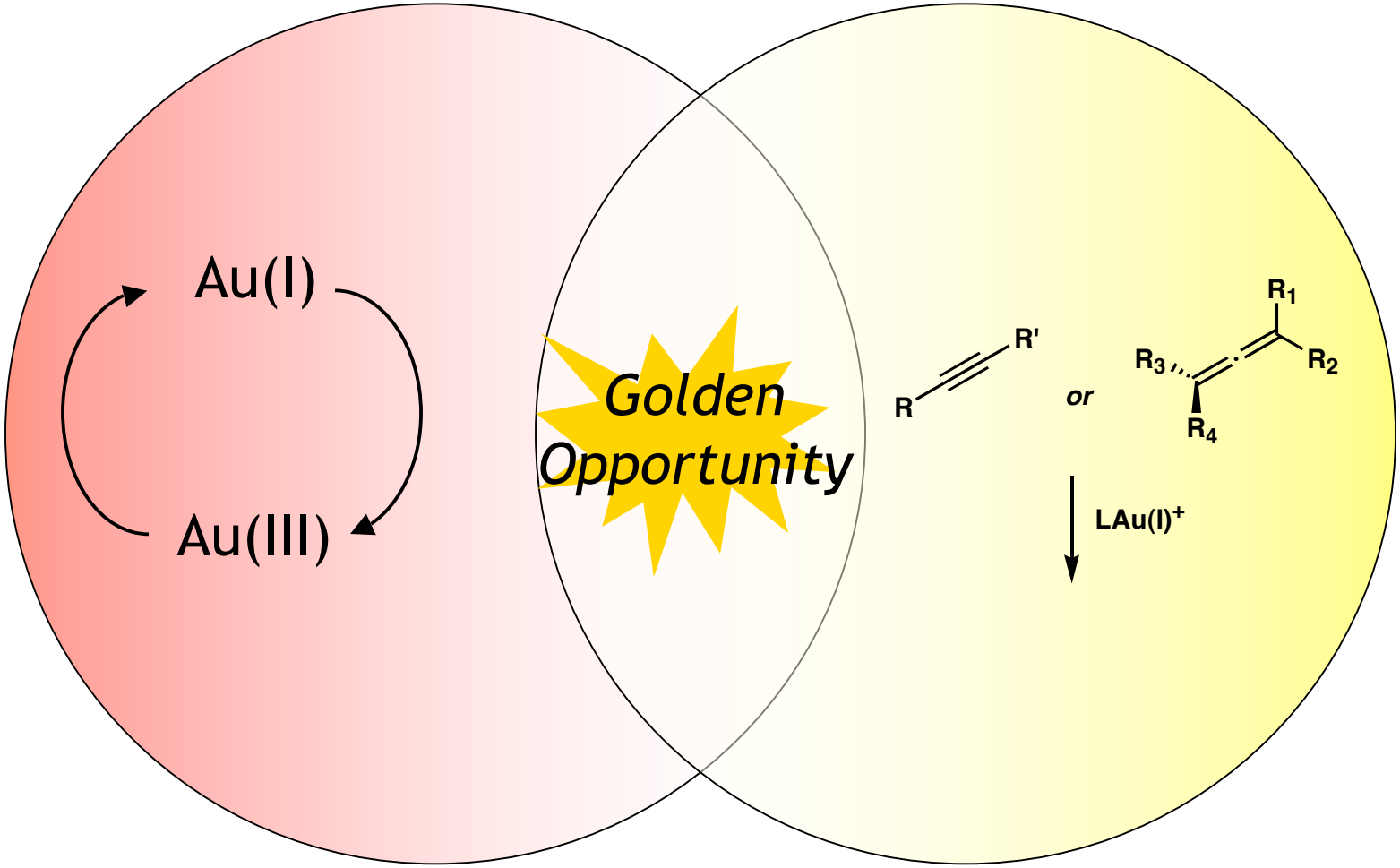


Tse, *Chem. Commun.*, **2008**, 386

Goal of title paper

Combine Au(I)/Au(III) catalytic cycle in a cross-coupling process

With contemporary gold chemistry using alkyne/allene substrates

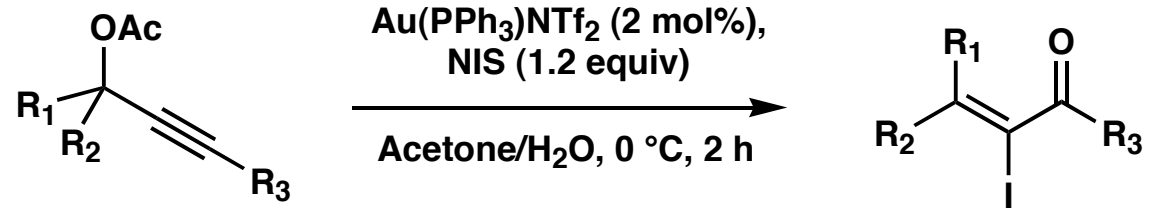


Challenges: Previously substrate as oxidant- oxidative insertion Au(I)-> Au(III) or harsh oxidants ($PhI(OAc)_2$, *t*-BuOOH, etc.) used.

-Need to find proper (mild, *selective*) oxidant for the catalytic cycle!

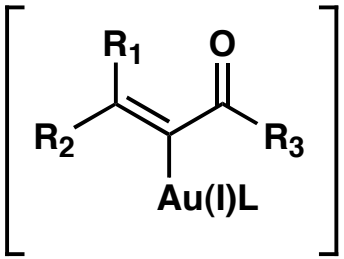
Selectfluor observation- Serendipity!

α-Iodo enones from propargylic acetates:

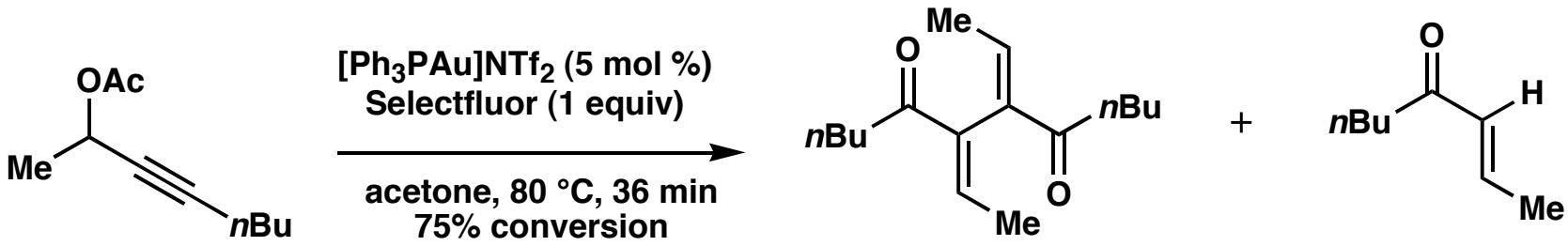


R_1, R_2 = alkyl, aryl, H
R_3 = alkyl, aryl

75-99%

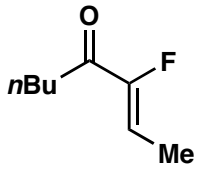


Zhang, *OL*, **2007**, *9*, 2147



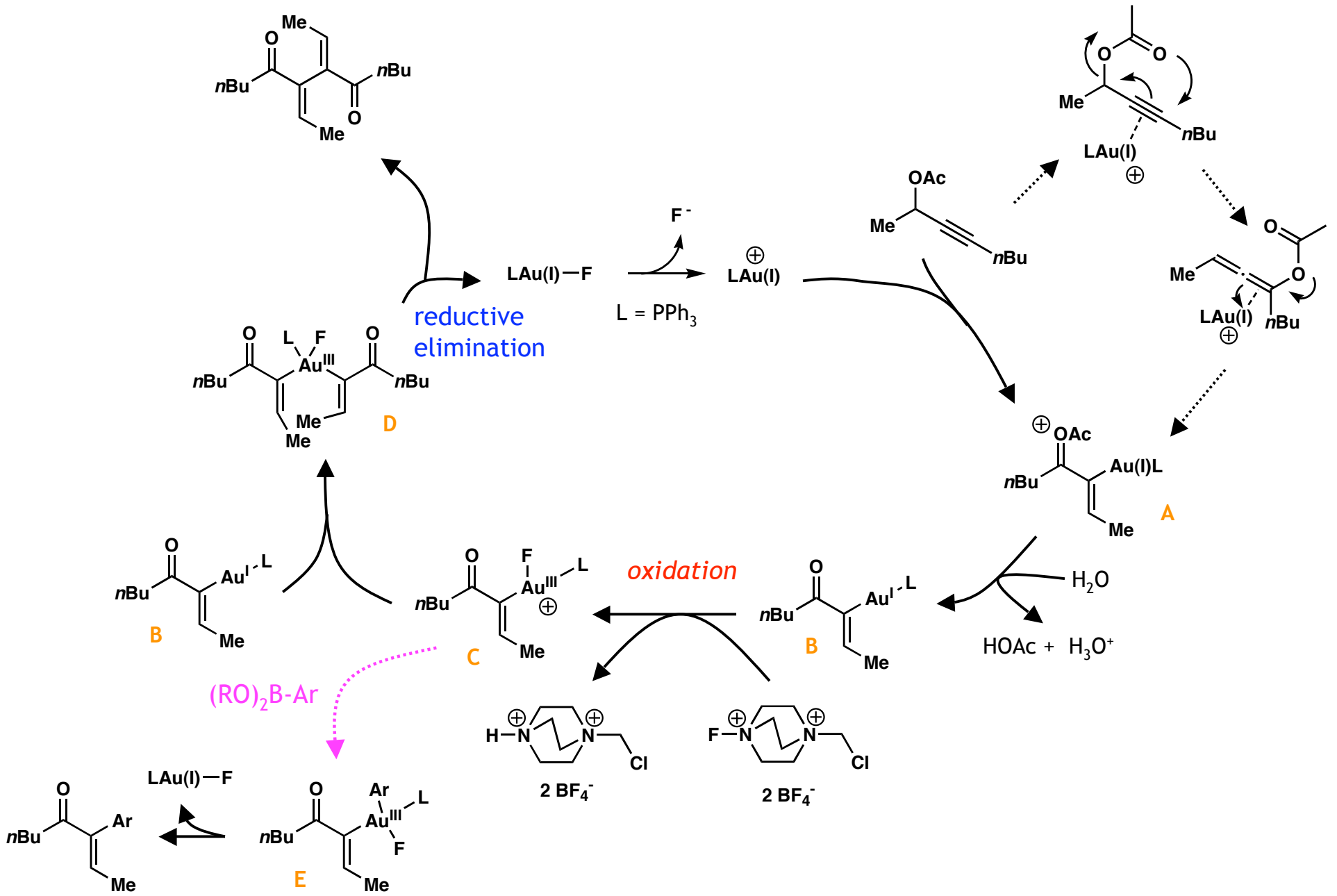
19% yield

11% yield

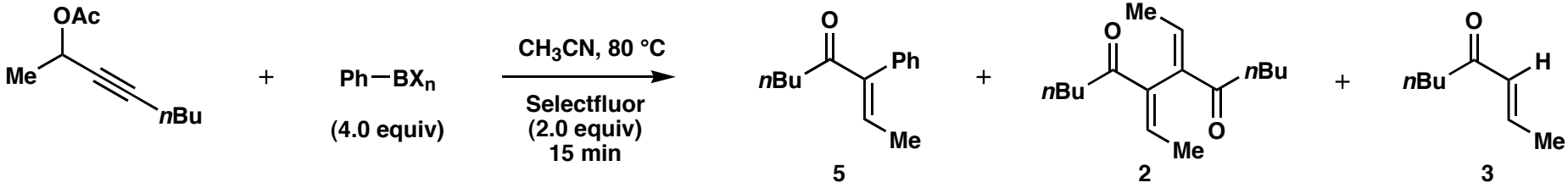


not observed

Proposed mechanism



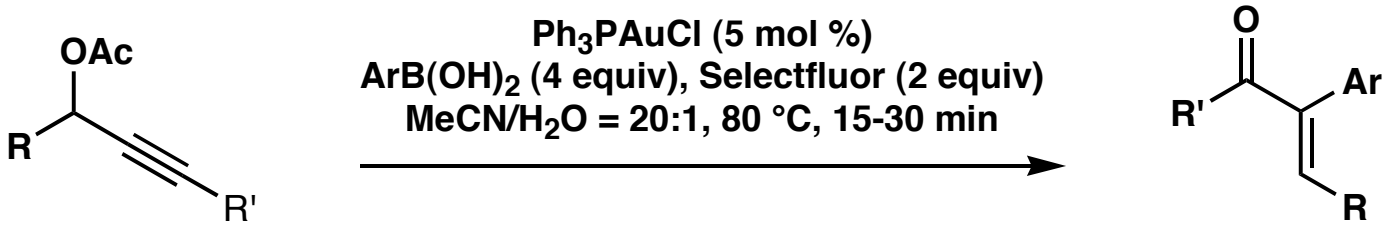
Suzuki reaction optimization



Entry	Catalyst (5 mol%)	$PhBX_n$	Reaction conditions	Yield [%][c] 5	2	3
1[b]	$[Ph_3PAu]NTf_2$	$PhBF_3K$	MeCN[d]	0	0	0
2[b]	$[Ph_3PAu]NTf_2$	$PhB(OCH_2)_2$	MeCN	30	60	0
3[b]	$[Ph_3PAu]NTf_2$	PhB(pin)	MeCN	21	66	<5
4[b]	$[Ph_3PAu]NTf_2$	$PhB[O(CH_2)_3O]$	MeCN	30	44	<5
5	$[Ph_3PAu]NTf_2$	$PhB[O(CH_2)_3O]$	MeCN/H_2O 100:1	50	17	9
6	$[Ph_3PAu]NTf_2$	$PhB(OH)_2$	MeCN/H_2O 100:1	25	14	13
7	$[Ph_3PAu]NTf_2$	$PhB(OH)_2$	MeCN/H_2O 20:1	53	9	23
8	$[Ph_3PAu]NTf_2$	$PhB(OH)_2$	MeCN/H_2O 5:1	39	10	24
9	**6**[e]	$PhB(OH)_2$	MeCN:H_2O 20:1	54	10	<5
10	$[(CF_3Ph)_3PAu]NTf_2$	$PhB(OH)_2$	MeCN/H_2O 20:1	50	8	21
11	$[(Ph_3PAu)_3O]H_2F_3$	$PhB(OH)_2$	MeCN/H_2O 20:1	64	8	11
12	$Ph_3PAuOBz$	$PhB(OH)_2$	MeCN/H_2O 20:1	59	8	5
13	Ph_3PAuCl	$PhB(OH)_2$	MeCN/H_2O 20:1	72	9	6
14[f]	Ph_3PAuCl	$PhB(OH)_2$	MeCN/H_2O 20:1	50	9	15
15	$AuCl_3$	$PhB(OH)_2$	MeCN/H_2O 20:1	25	16	14

[a] Reaction run in a flask using MeCN distilled over CaH_2. The reaction concentration was 0.05 M. [b] Reaction run in a 7 mL vial with HPLC-grade MeCN. [c] Estimated by ^1H NMR analysis using diethyl phthalate as internal reference. [d] Reaction time: 40 min. [e] $[(2\text{-Biphenyl})Cy_2PAu]NTf_2$. [f] Used 1.5 equiva of Selectfluor and 3 equiv of $PhB(OH)_2$.

Suzuki reaction substrate scope



Entry	R	R′	$ArB(OH)_2$	**8** (Yield [%])
1	Ph	*n*-butyl	$PhB(OH)_2$	**8a** (62)
2	*i*Pr	*n*-butyl	$PhB(OH)_2$	**8b** (65)
3	Me	Ph	$PhB(OH)_2$	**8c** (59)
4	Me	$MeOCH_2CH_2$	$PhB(OH)_2$	**8d** (60)
5	Me	cyclohexyl	$PhB(OH)_2$	**8e** (68)
6	cyclohexyl	cyclohexyl	$PhB(OH)_2$	**8f** (70)
7	$PhCH_2CH_2$	*n*-butyl	$PhB(OH)_2$	**8g** (70)
8	*p*-BrC_6H_4	*n*-butyl	$PhB(OH)_2$	**8h** (59)
9	$AcOCH_2CH_2$	*n*-butyl	$PhB(OH)_2$	**8i** (61)
10	H	cyclohexyl	$PhB(OH)_2$	**8j** (61)
11	cyclohexyl	*n*-butyl	*p*-$MePhB(OH)_2$	**8k** (72)
12	cyclohexyl	*n*-butyl	*p*-$MeO_2CPhB(OH)_2$	**8l** (57)[b]
13	cyclohexyl	*n*-butyl	*p*-$ClPhB(OH)_2$	**8m** (58)
14	cyclohexyl	*n*-butyl	*m*-$MeO_2CPhB(OH)_2$	**8n** (45)[c]

[a] Reactions run in flasks using MeCN distilled over CaH_2. The reaction concentration was 0.05 M. [b] $CH_3CN/H_2O = 100:1$. [c] $MeCN/H_2O = 200:1$.

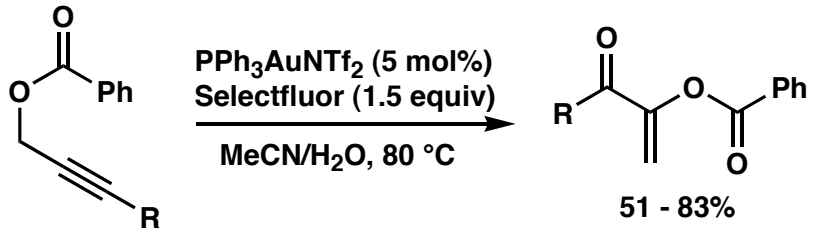
Oxidative C-O bond formation (3-20-09)

Communication

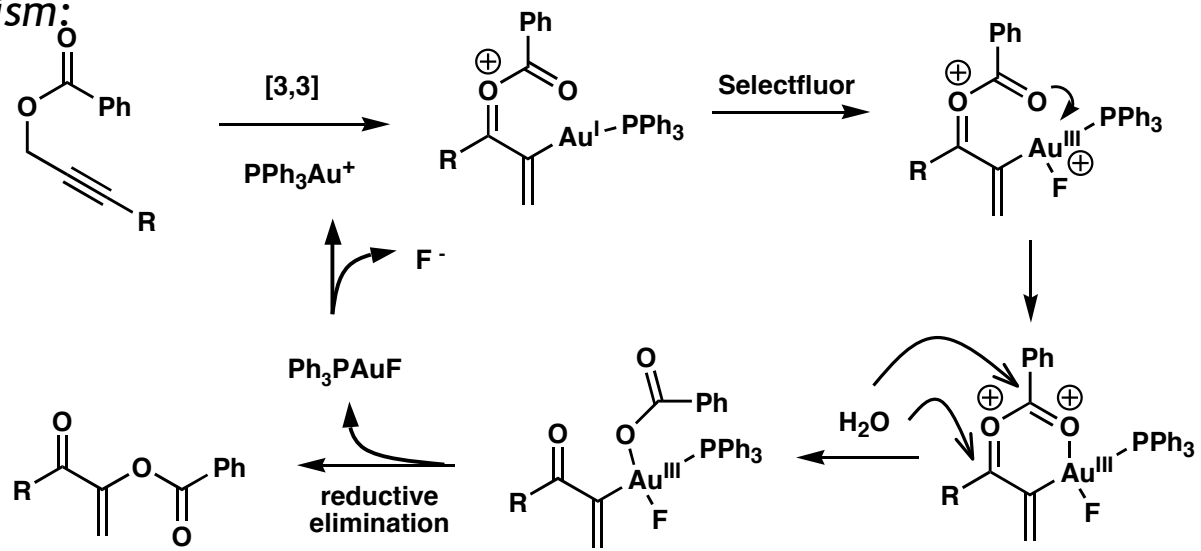
Gold-Catalyzed Homogeneous Oxidative C#O Bond Formation: Efficient Synthesis of 1-Benzoxyvinyl Ketones

Yu Peng, Li Cui, Guozhu Zhang, and Liming Zhang

J. Am. Chem. Soc., **2009**, 131 (14), 5062-5063• DOI: 10.1021/ja901048w • Publication Date (Web): 20 March 2009

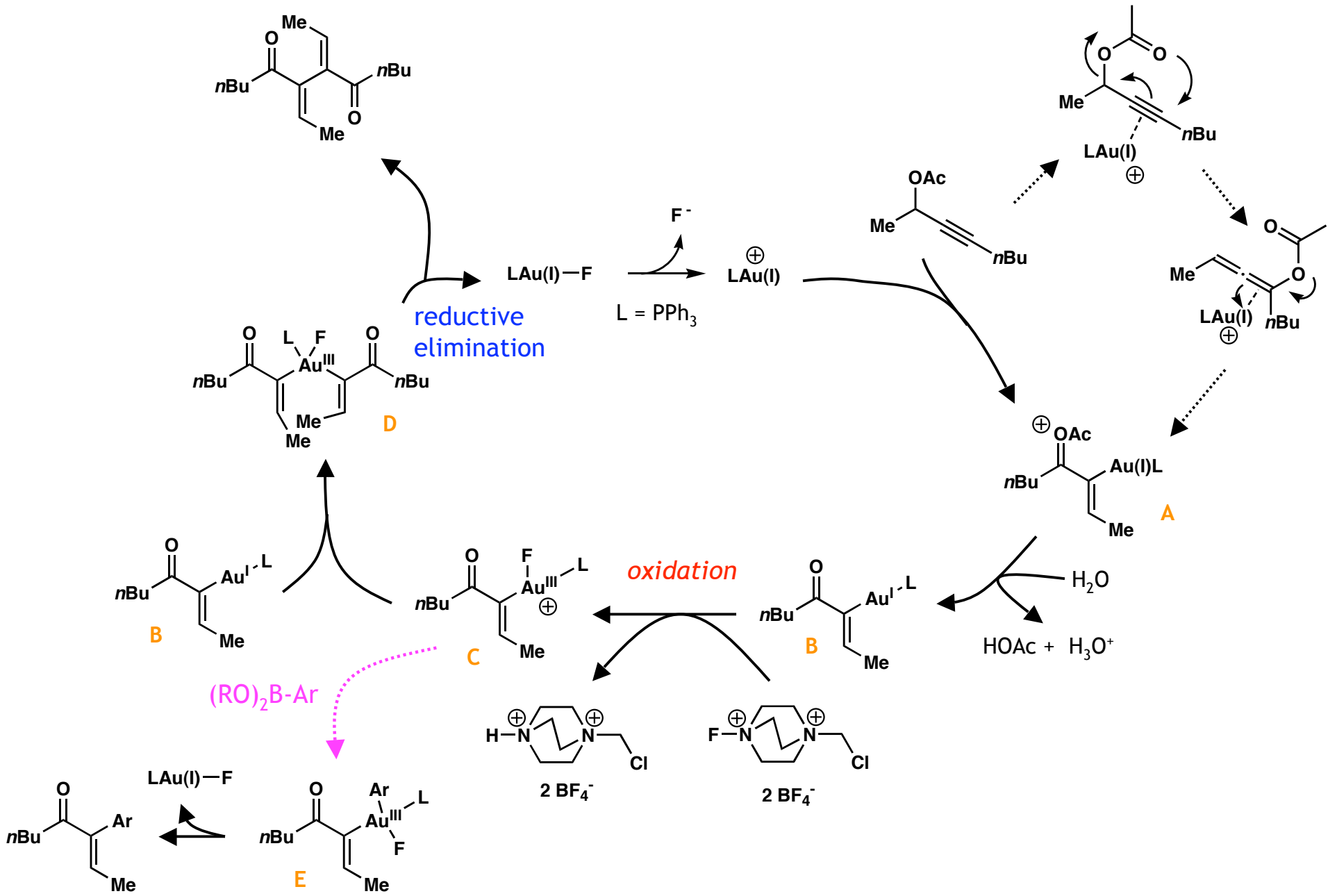


Proposed Mechanism:

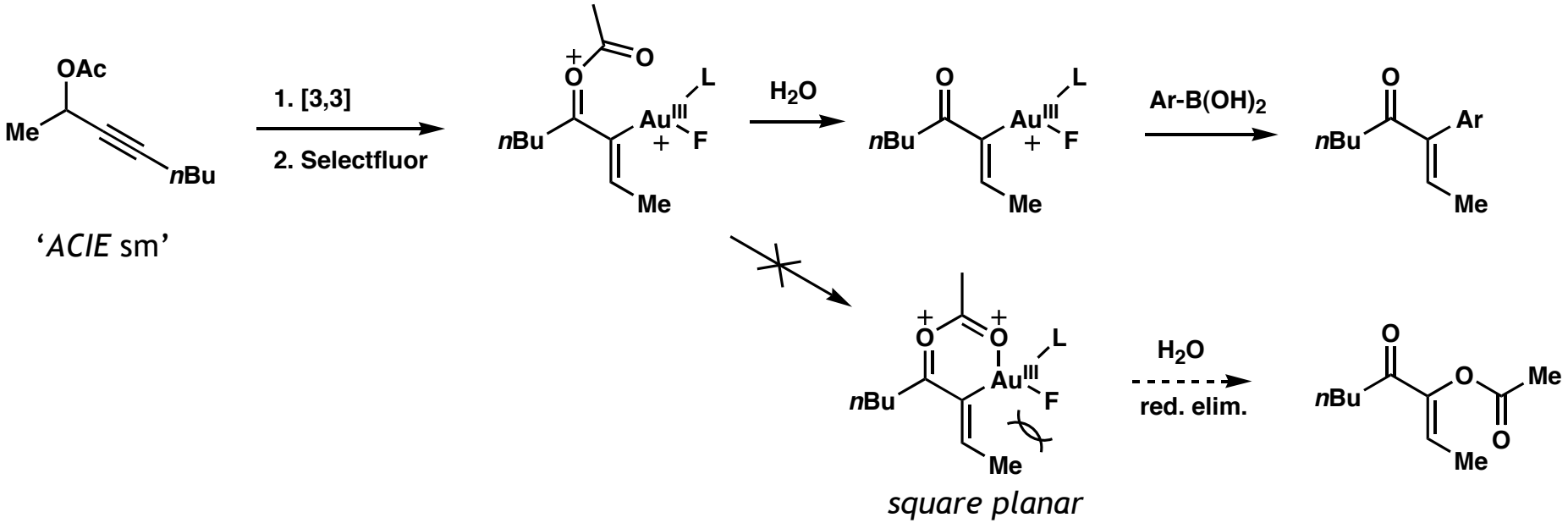


If '*JACS* mechanism' is correct, why not C-O bond formation in *ACIE* publication???

Proposed mechanism

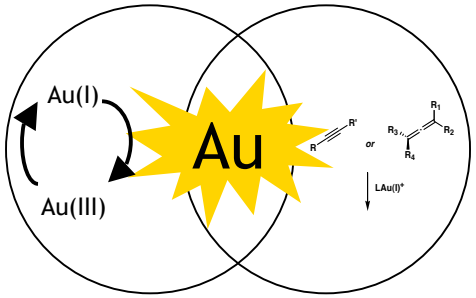


Compare two mechanistic proposals…



'*JACS* mechanism' appears to be more consistent with experimental results

Outlook/future directions



Merges contemporary Au catalysis with transition metal-catalyzed cross-coupling reactions

-Strongly suggests the feasibility of Au(I)/Au(III) catalytic cycle

-New opportunities for Au-catalyzed processes.

Drawbacks:

-Limitation of Selectfluor compatibility
-Mechanistic hypothesis needs investigation