

# Органическая химия – успехи и достижения

Ненайденко В.Г.



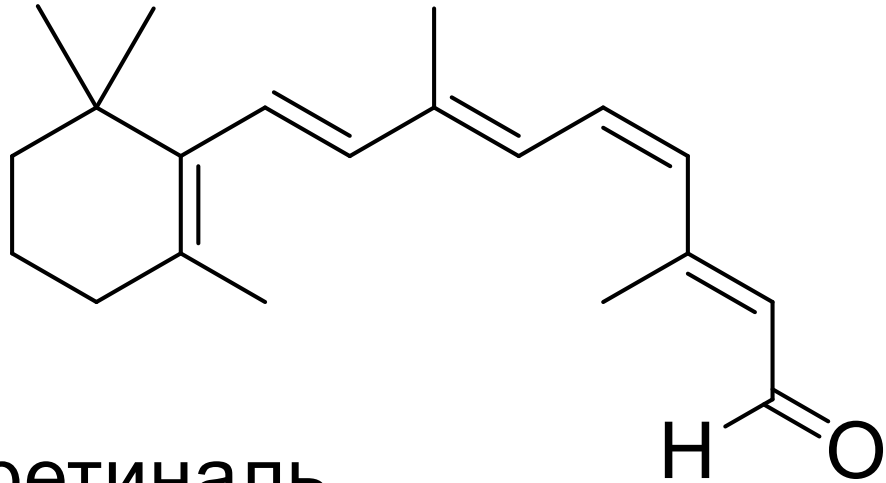
# Фридрих Велер (1800-1882)

## синтез мочевины 1828



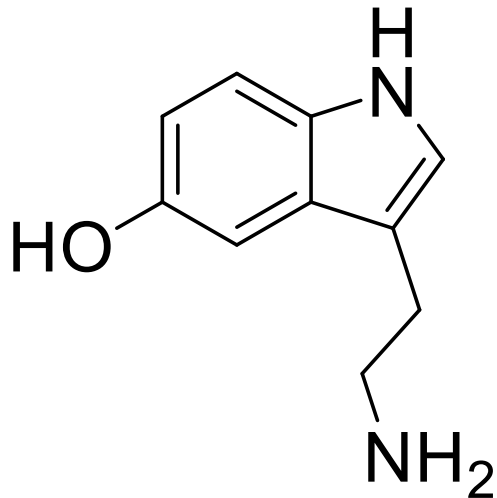
# Бутлеров Александр Михайлович (1828-1886)





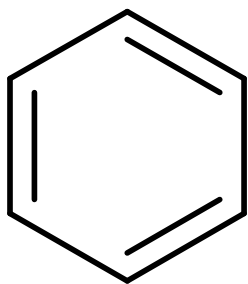
11-*цис* ретиналь

поглощает свет когда мы видим

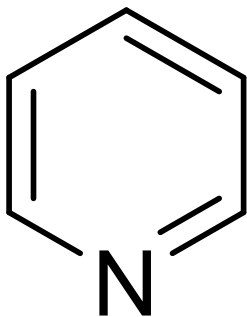


серотонин

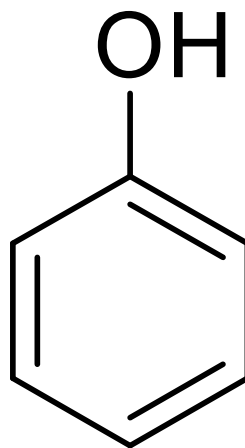
человеческий нейромедиатор



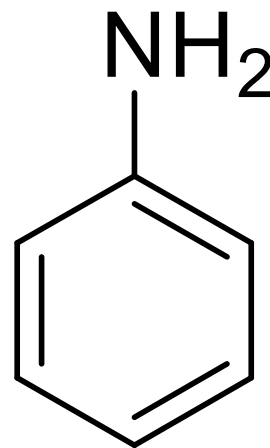
бензол



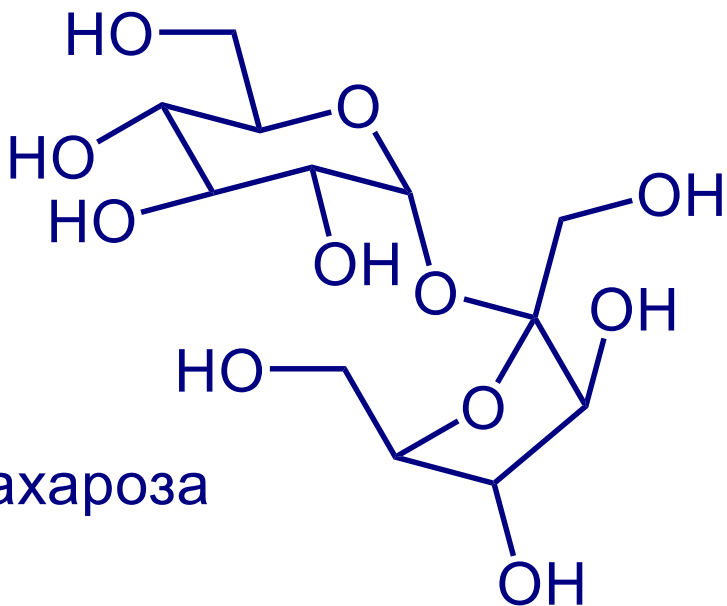
пиридин



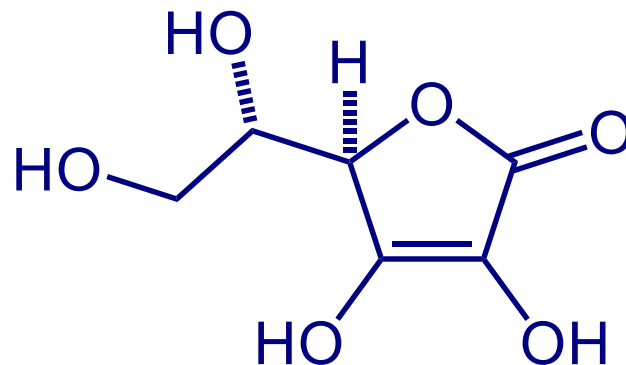
фенол



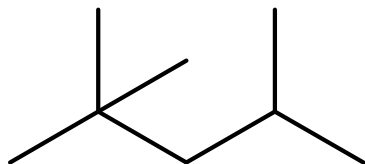
анилин



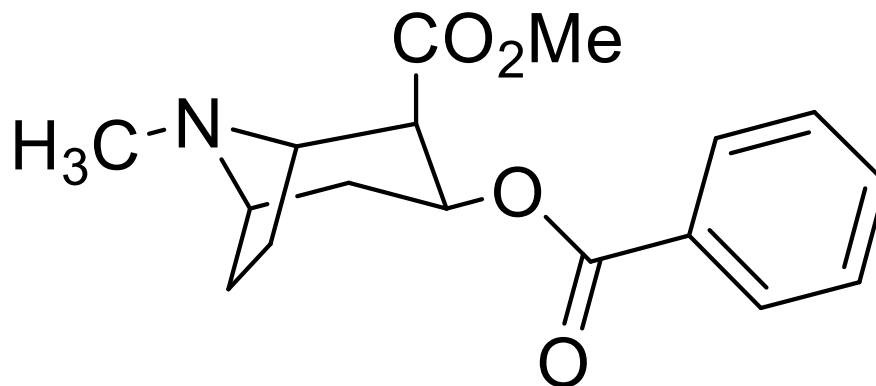
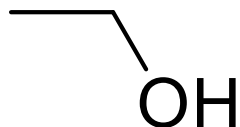
сахароза



витамин С  
(аскорбиновая кислота)

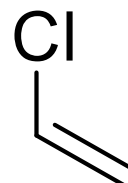
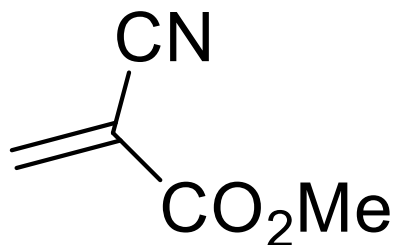
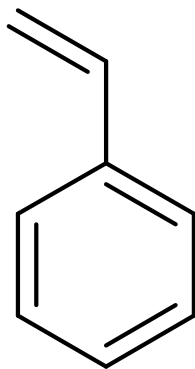


ИЗООКТАН

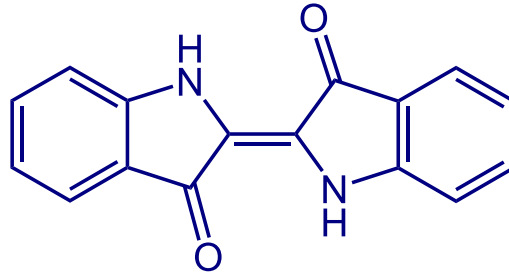


КОКАИН

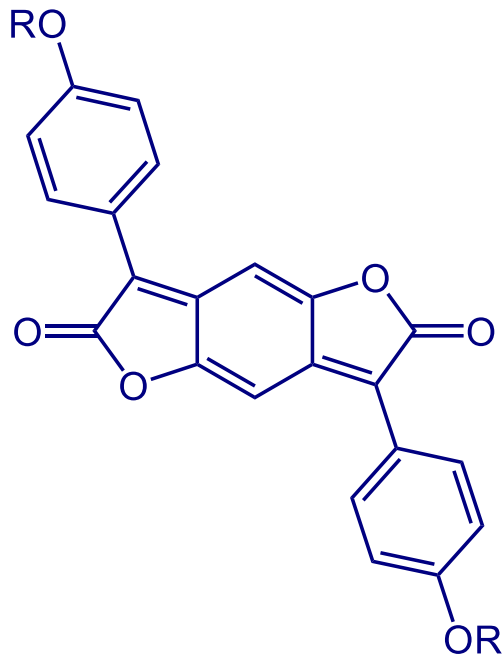
Мономеры для производства материалов



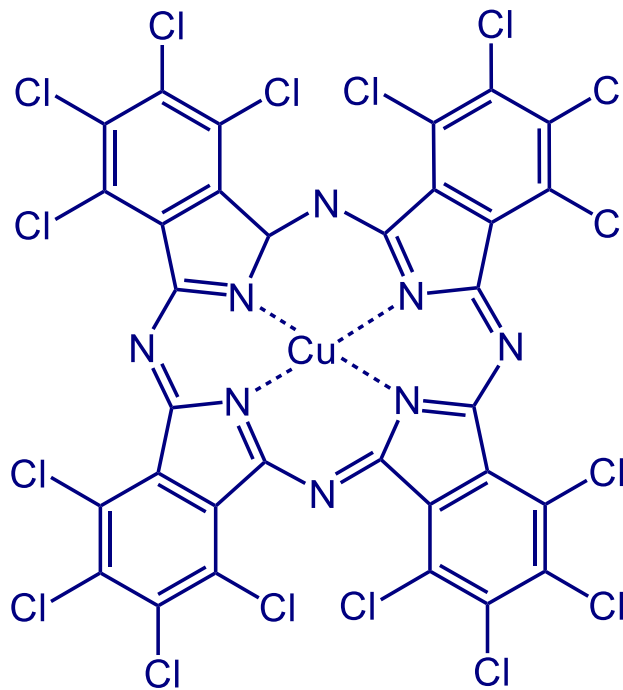
# Красители



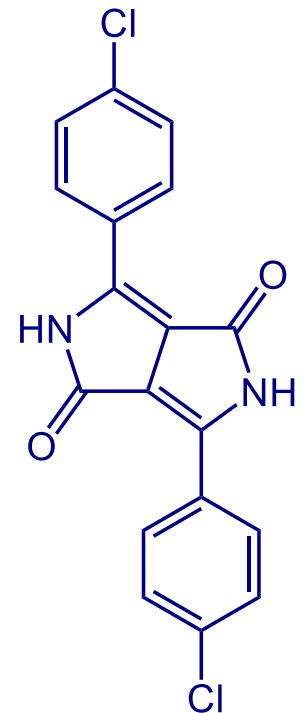
индиго



красный

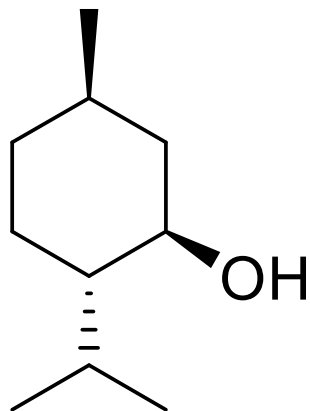


зелёный

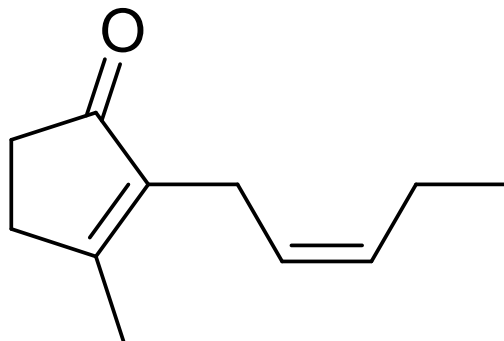


красный

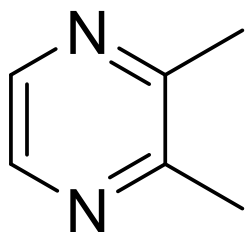
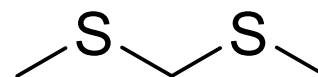
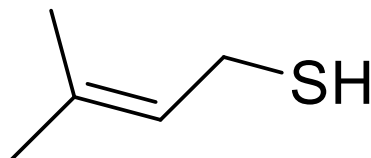
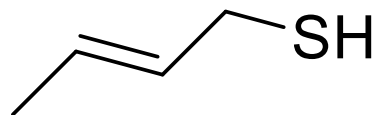
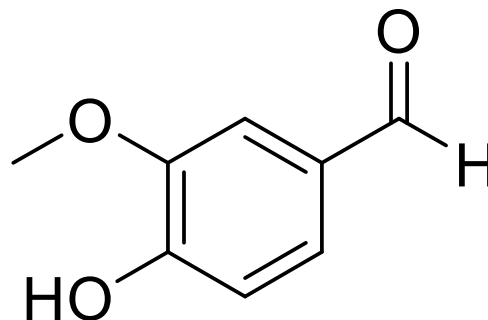
# Запахи: приятные и не очень



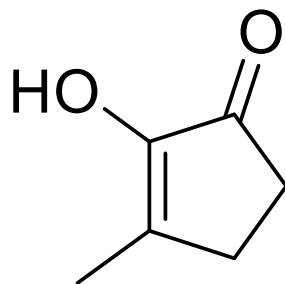
МЕНТОЛ



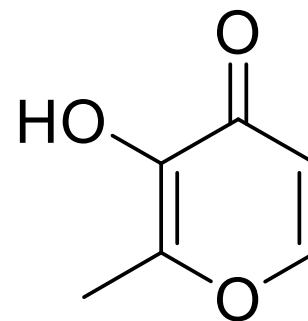
ЦИС-ЖАСМОН



запах  
жареного мяса



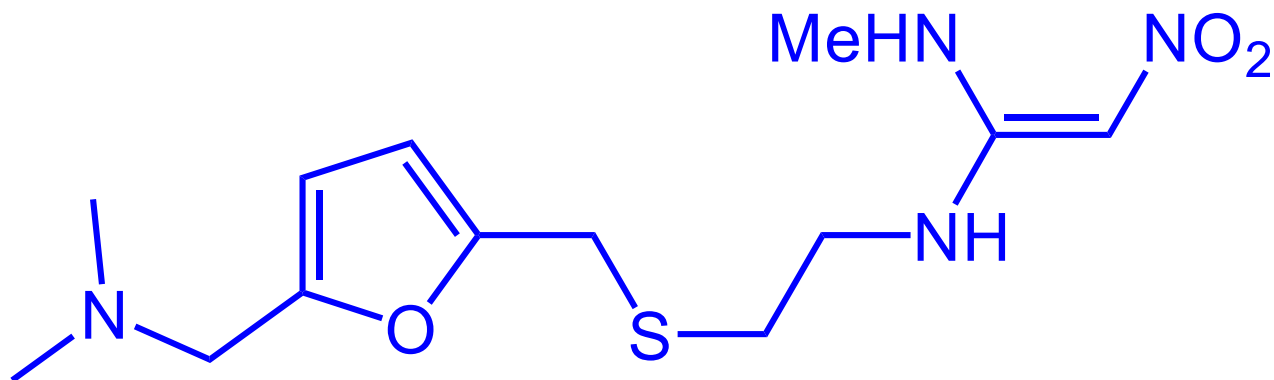
corylon  
запах карамели



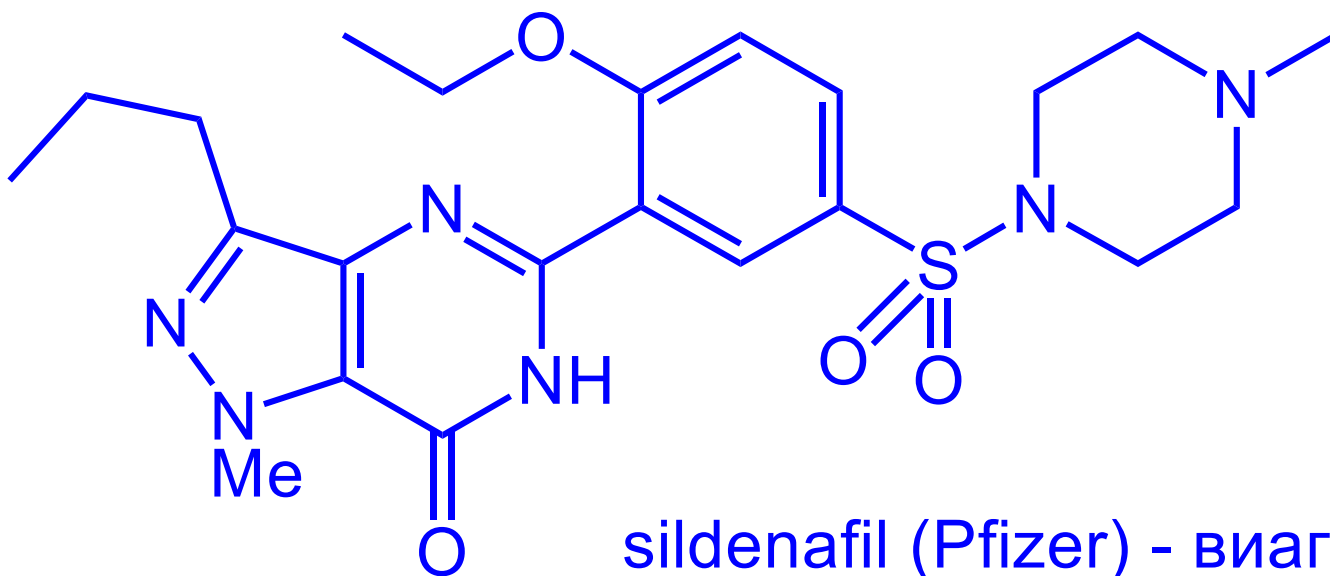
maltol  
добавка в бисквит



# Лекарства

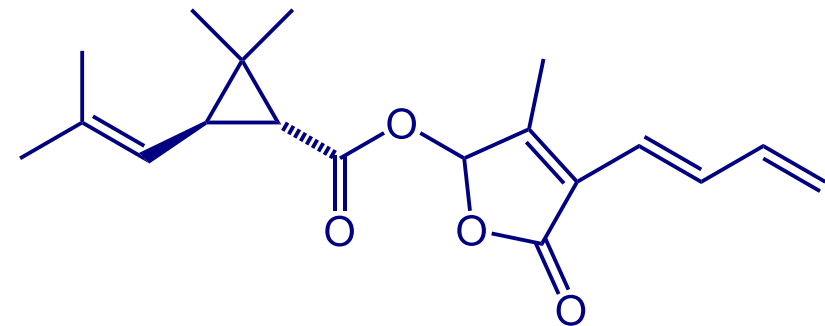


rantidine Zantag (GSK)  $>10^9$  \$

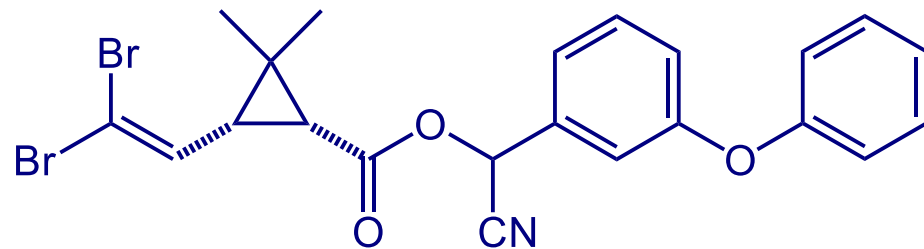


sildenafil (Pfizer) - виагра

# Средства защиты растений: пиретроиды и фунгициды

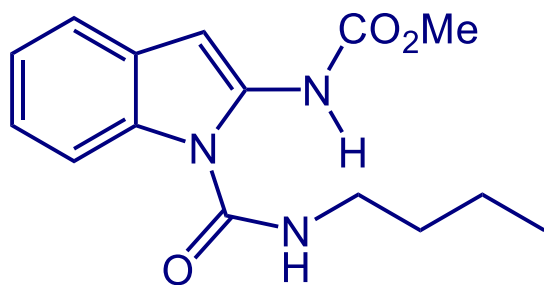


a natural pyrethrin



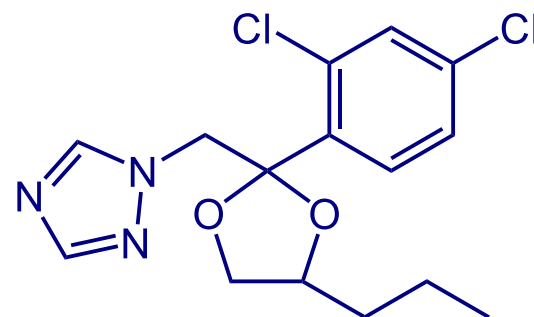
decamethrin

синтетический, более активен и стабилен



bemomyl

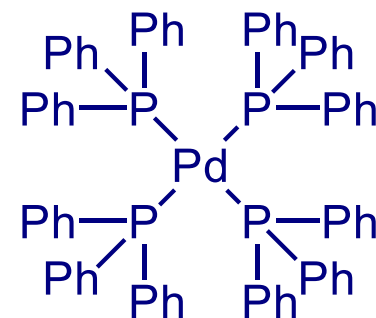
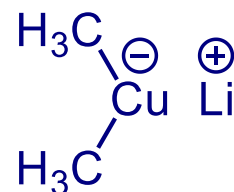
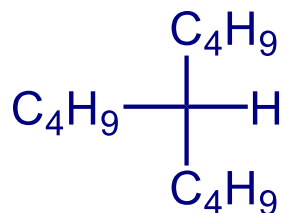
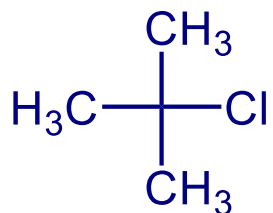
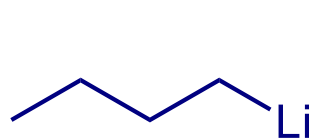
фунгицид, для борьбы с заболеваниями растений



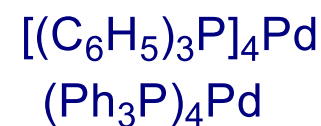
propiconazole

# the organic chemist's periodic table

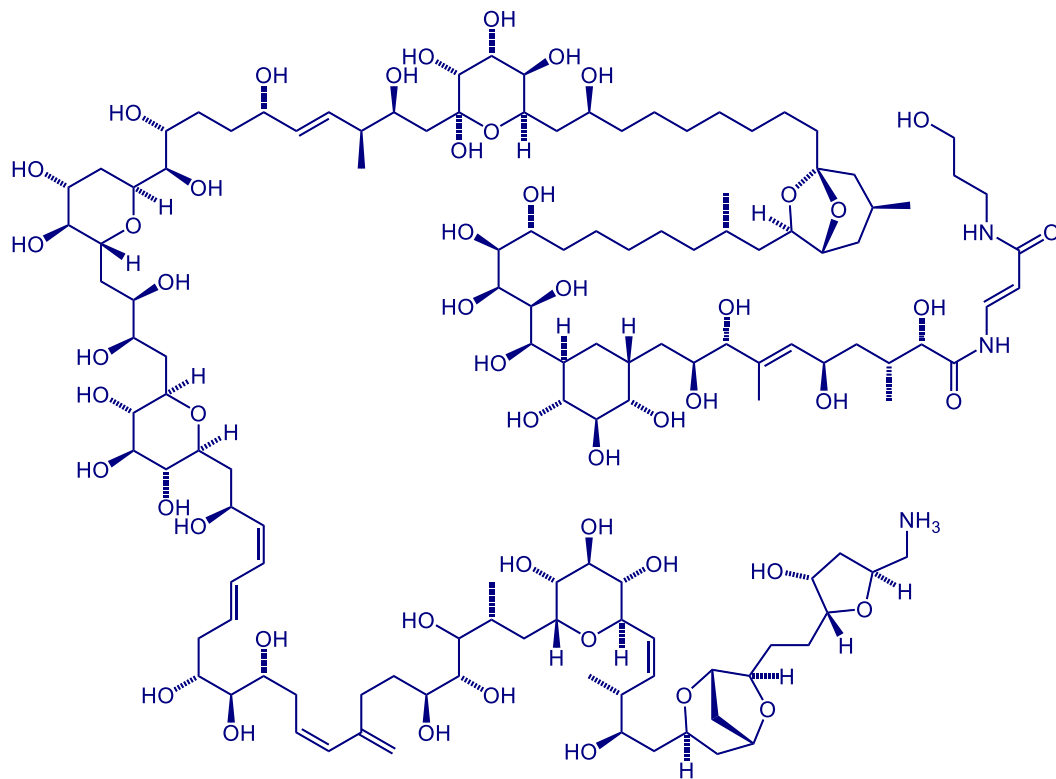
1	the organic chemist's periodic table												13	14	15	16	17
<b>H</b>													<b>B</b>	<b>C</b>	<b>N</b>	<b>O</b>	<b>F</b>
<b>Li</b>													<b>Al</b>	<b>Si</b>	<b>P</b>	<b>S</b>	<b>Cl</b>
<b>Na</b>	<b>Mg</b>	3	4	5	6	7	8	9	10	11	12						
<b>K</b>			<b>Tl</b>		<b>Cr</b>					<b>Cu</b>	<b>Zn</b>					<b>Se</b>	<b>Br</b>
									<b>Pd</b>				<b>Sn</b>				<b>I</b>
							<b>Os</b>				<b>Hg</b>						



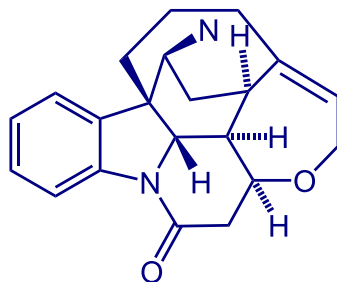
тетракис  
трифенилфосфин  
палладий



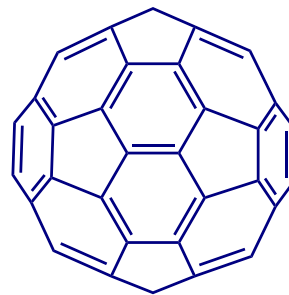
# Органические соединения бывают очень сложны и ядовиты



palytoxin  $10^{-7}$  г

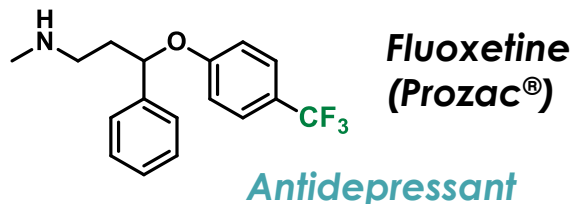


стрихнин

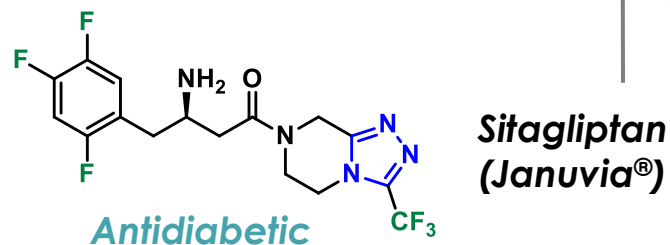
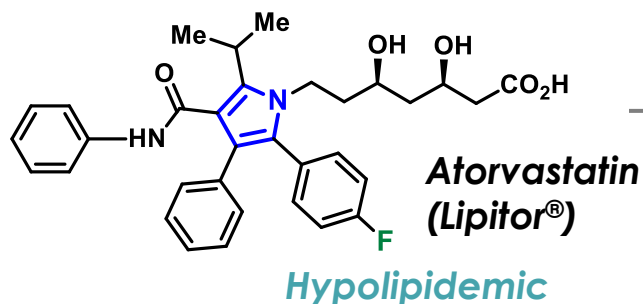


фуллерен

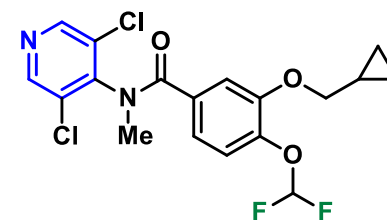
# Applications of organofluorine chemistry: Healthcare



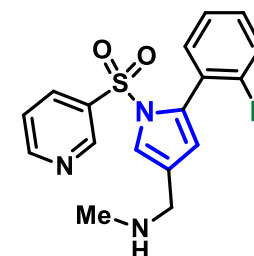
≈ 20%



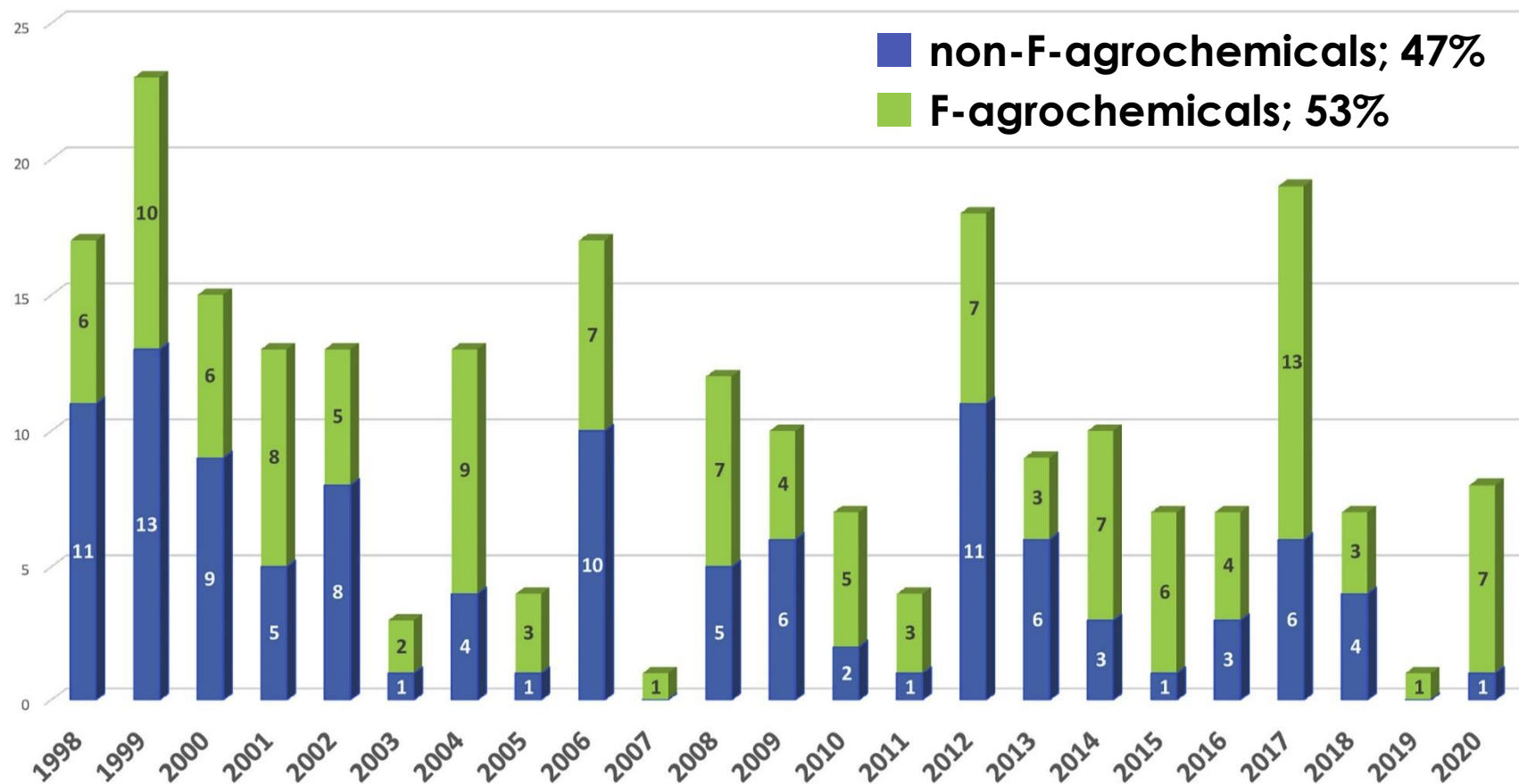
**Roflumilast (Daxas®)**



**Vonoprazan (Takecab®)**

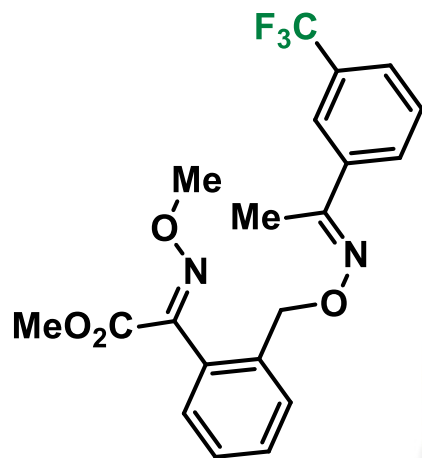


# Applications of organofluorine chemistry: Food security

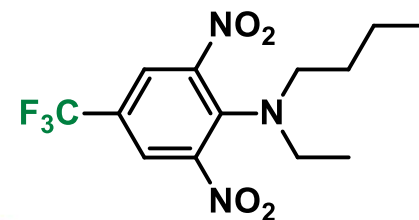
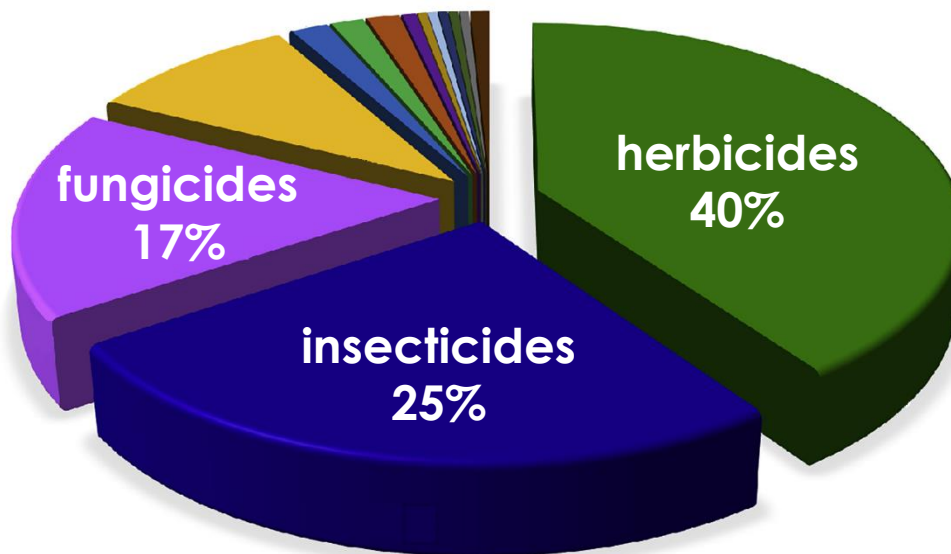


**Prevalence of *fluoro*/*non-fluoro*-agrochemicals assigned new ISO common names (1998–2020)**

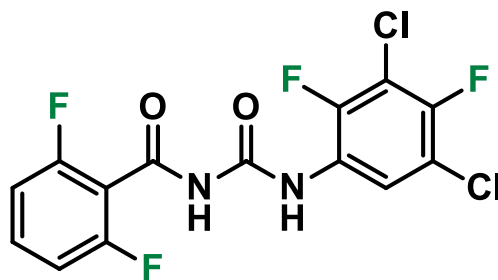
# Some marketed fluoro-agrochemicals



*Trifloxystrobin*  
(*Flint*®)



*Benfluralin*  
(*Balan*®)



*Teflubenzuron*  
(*Nomax*®)

# Applications of organofluorine chemistry: Materials

- highly fluorinated **polymers**



coated cookware  
**Teflon®**



lubricants  
**Fomblin®**



protective clothing  
**Goretex®**

- perfluorinated sulfonic acid **membranes** for fuel cells

**Flemion®**



- refrigerants**

Chlorofluorocarbons

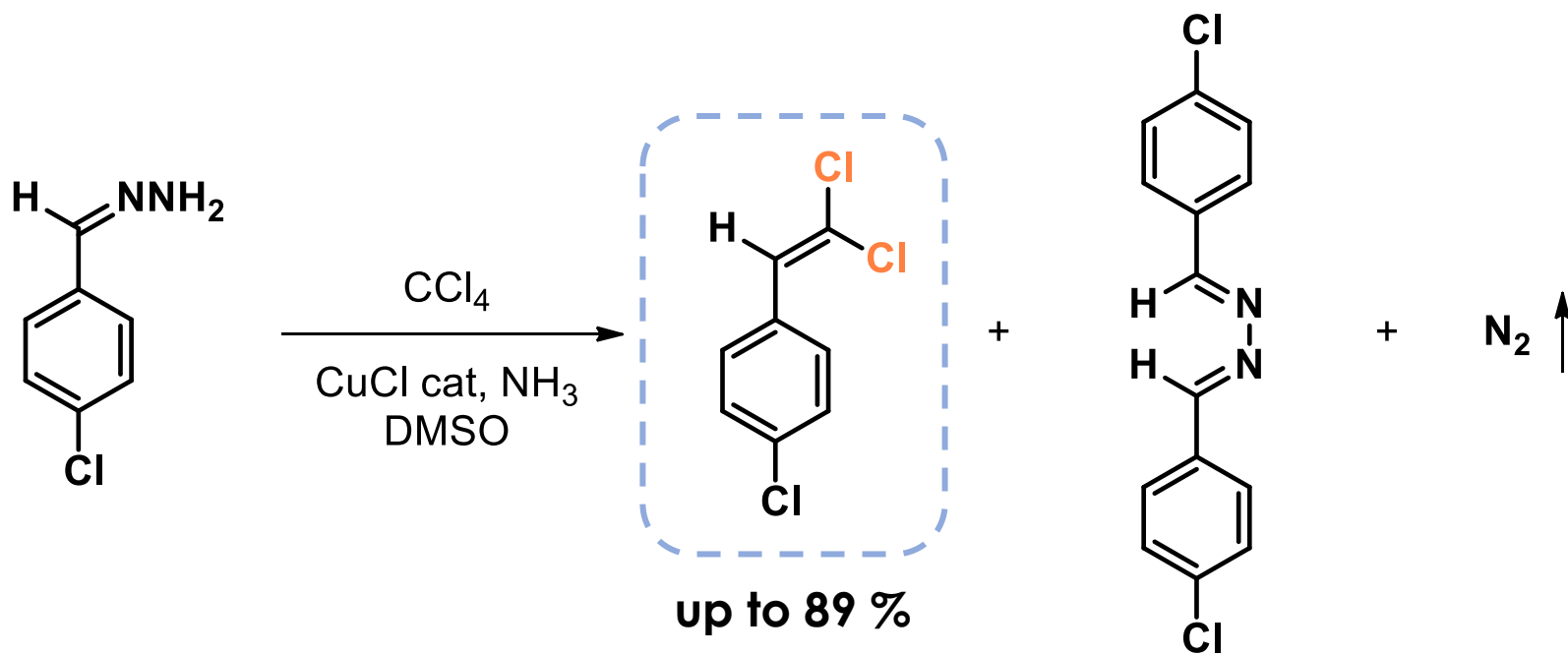
Hydrofluorocarbons

**HFC-134a**  
( $\text{CF}_3\text{-CFH}_2$ )





# Catalytic Olefination Reaction - COR





Springer, 2014, 2 volumes, ~1450 pages

Valentine Nenajdenko *Editor*

# Fluorine in Heterocyclic Chemistry Volume 1

5-Membered Heterocycles and  
Macrocycles

 Springer

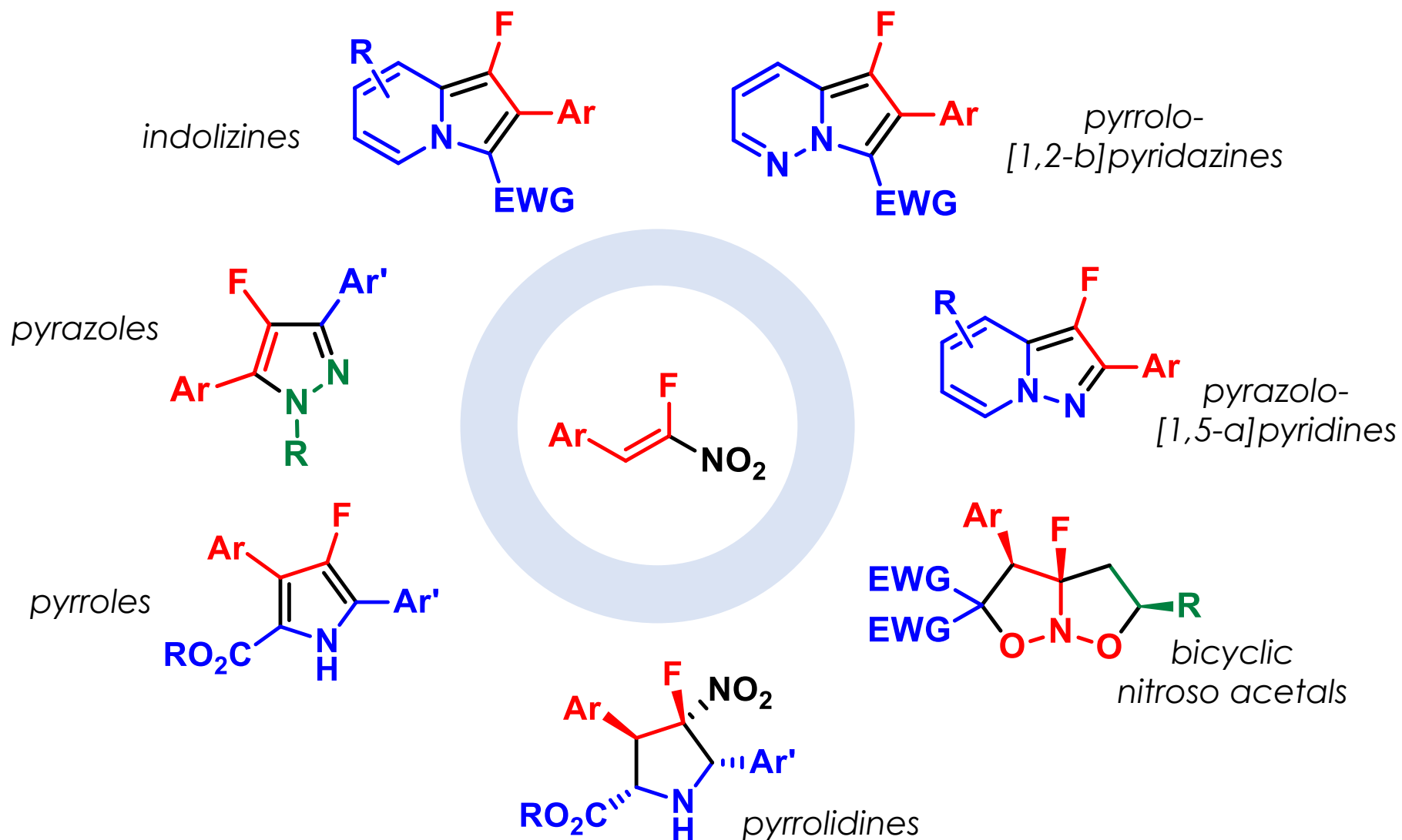
Valentine Nenajdenko *Editor*

# Fluorine in Heterocyclic Chemistry Volume 2

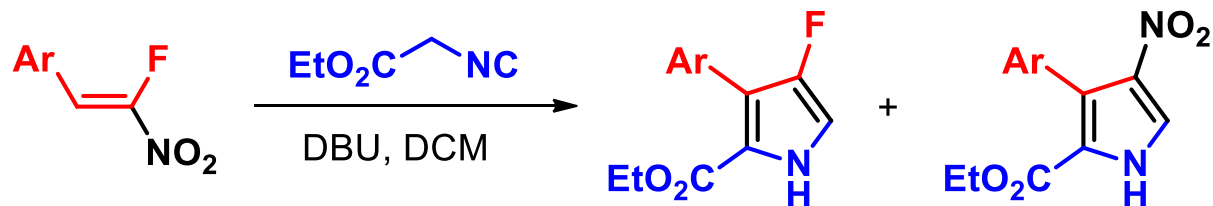
6-Membered Heterocycles

 Springer

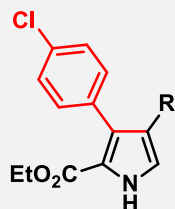
# Variety of heterocycles based on $\beta$ -fluoro- $\beta$ -nitroalkenes



# Barton-Zard synthesis of F-pyrroles



19 examples  
up to 77 % yield

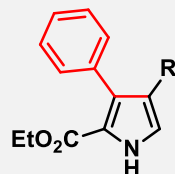


R = F  
R = NO<sub>2</sub>

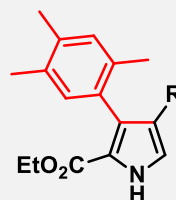
73 %  
14 %



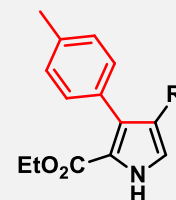
68 %  
16 %



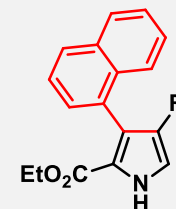
77 %  
12 %



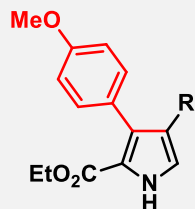
72 %  
6 %



73 %  
11 %

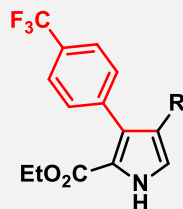


76 %  
10 %

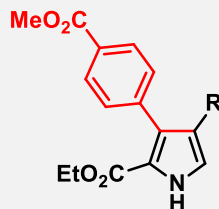


R = F  
R = NO<sub>2</sub>

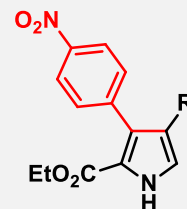
74 %  
16 %



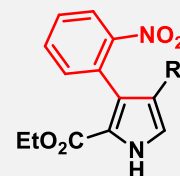
69 %  
14 %



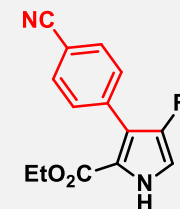
67 %  
16 %



58 %  
8 %

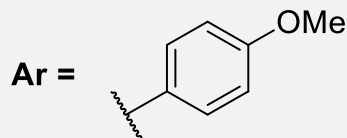
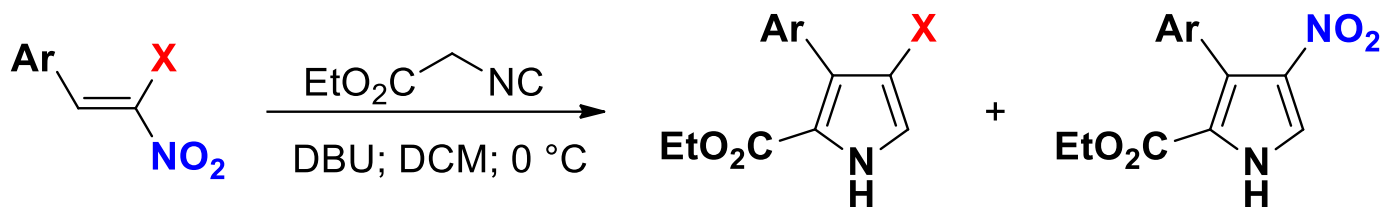


70 %  
10 %

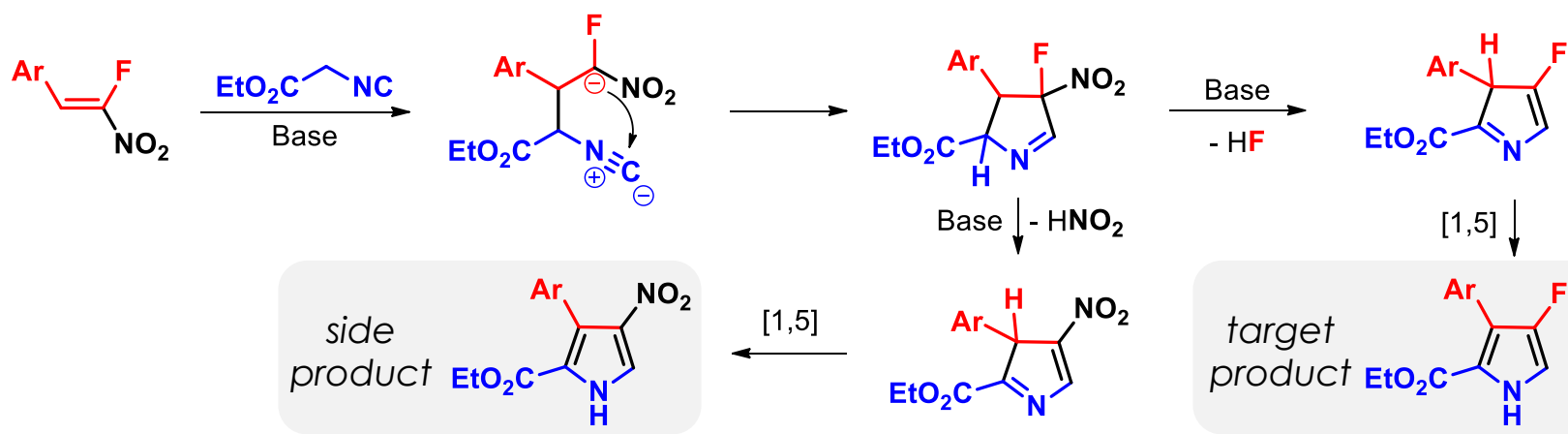


69 %  
14 %

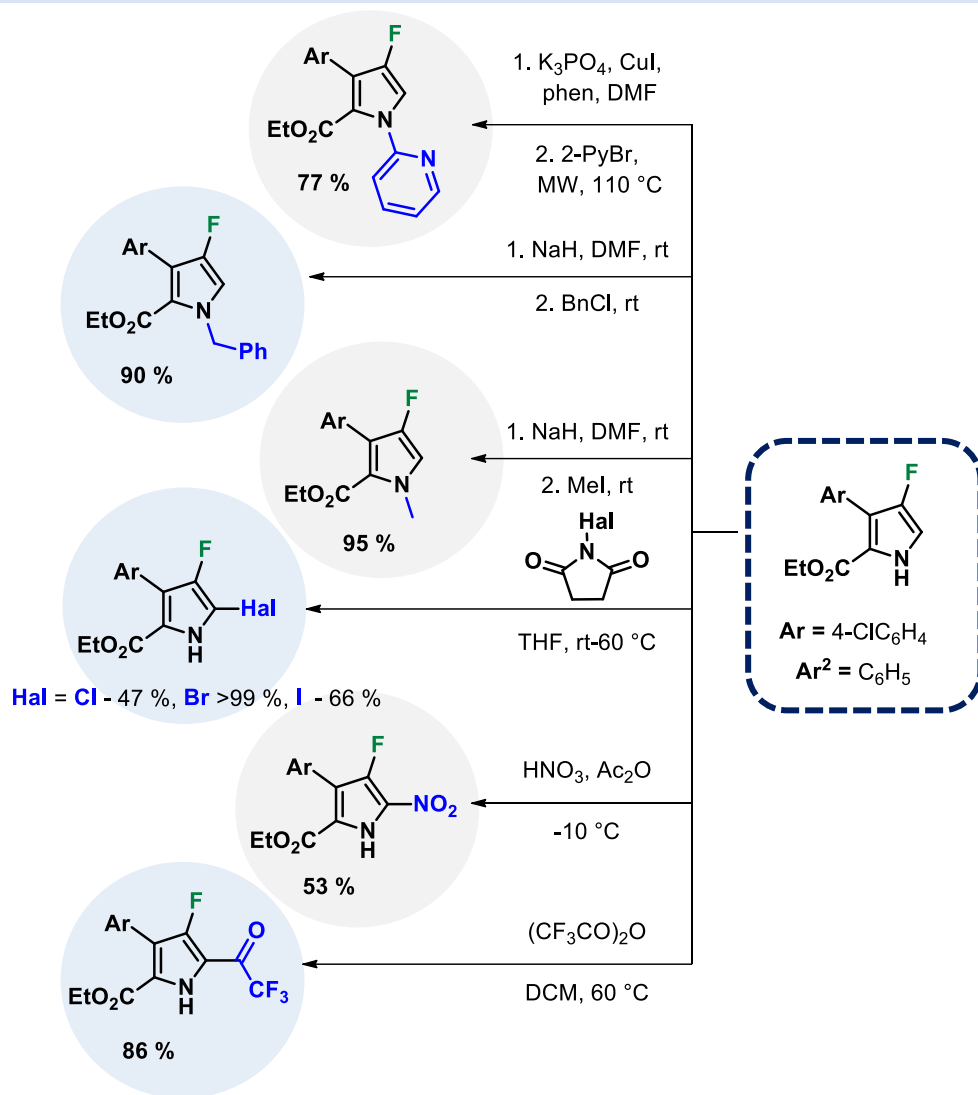
# A series of nitrostyrenes in the Barton-Zard reaction



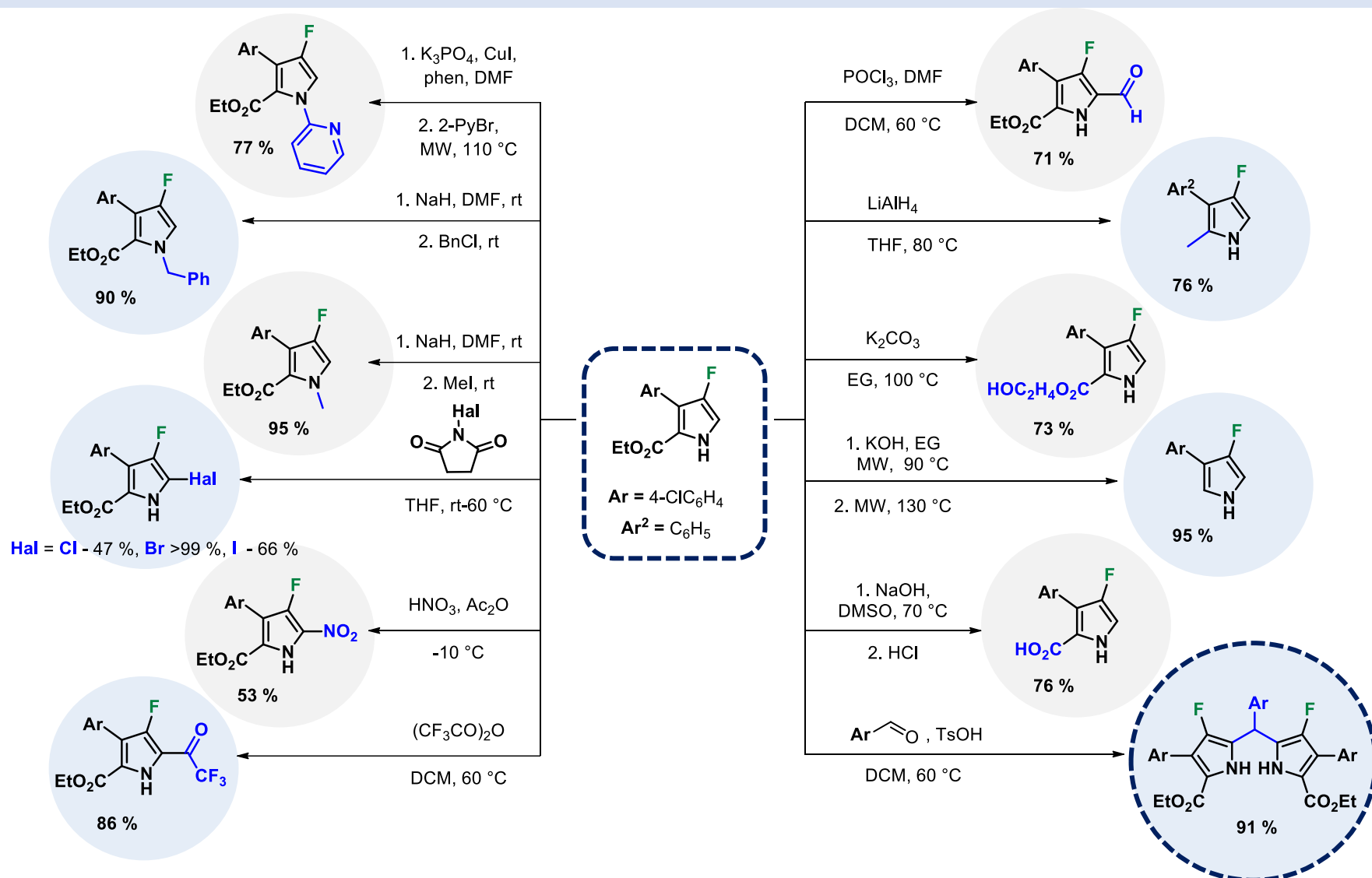
X = H	0 %	0 %
X = Br	0 %	0 %
X = Cl	0 %	62 %
X = F	74 %	16 %
X = Me	83 %	0 %



# Functionalization of 4-fluoropyrrole

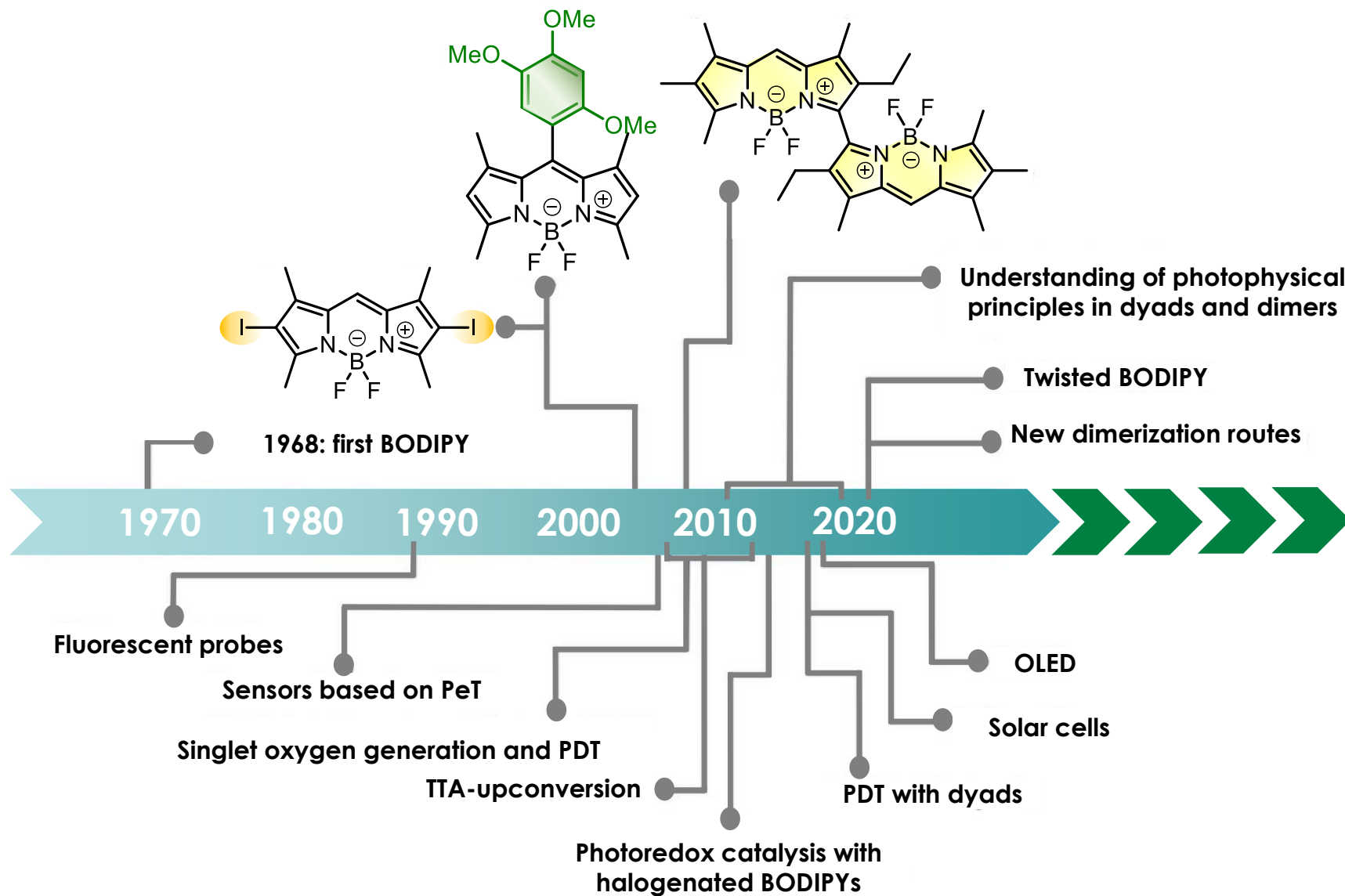


# Functionalization of 4-fluoropyrrole

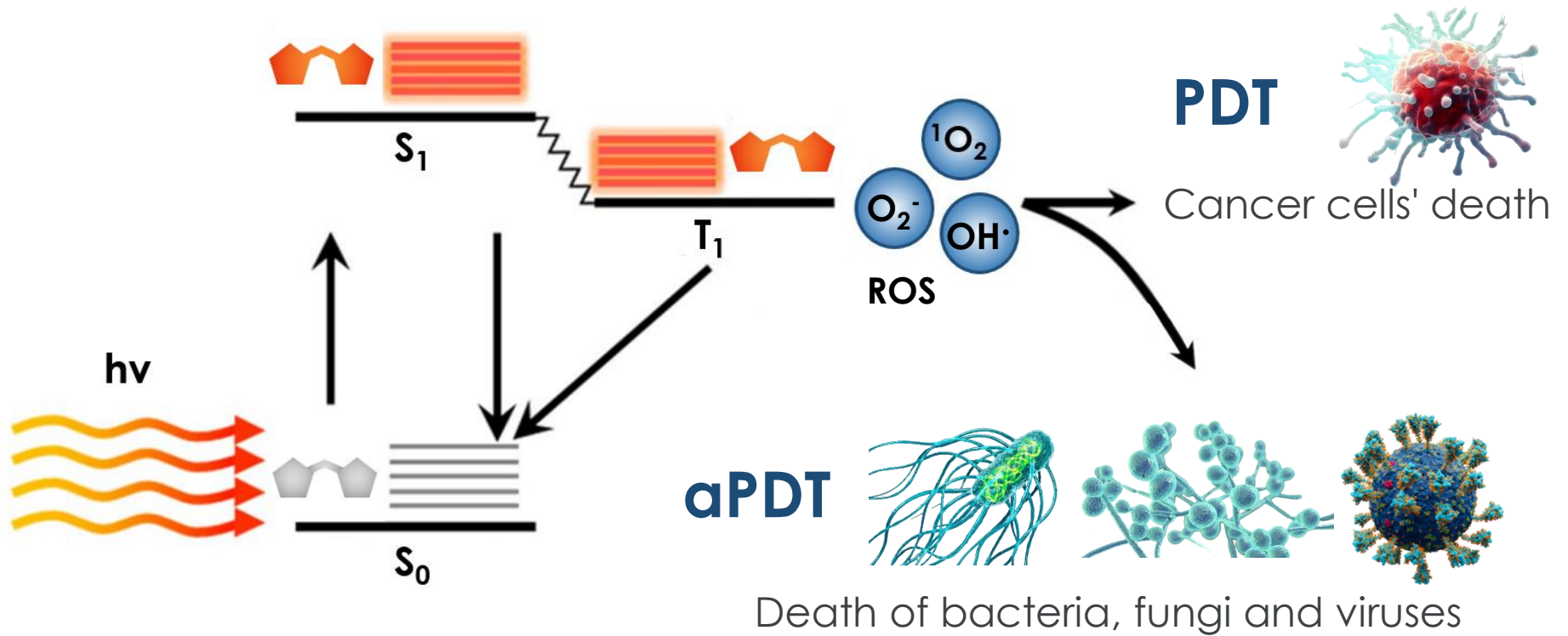




# Historical development of BODIPY dyes

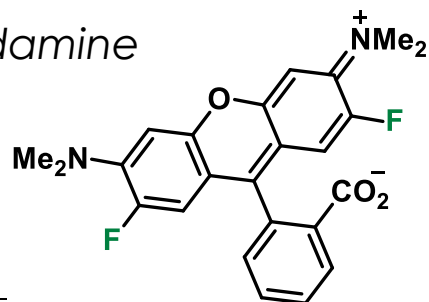


# PDT principle

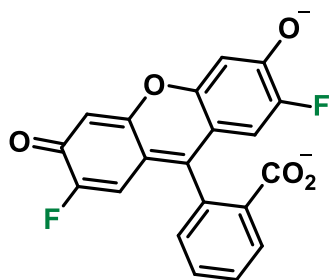
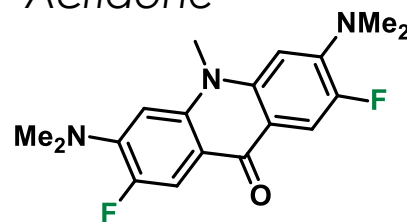


# Advantages of introducing fluorine into the structure of fluorophores

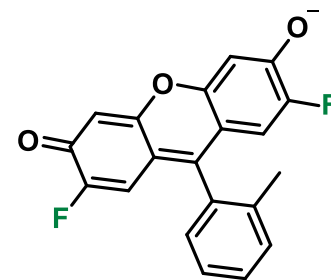
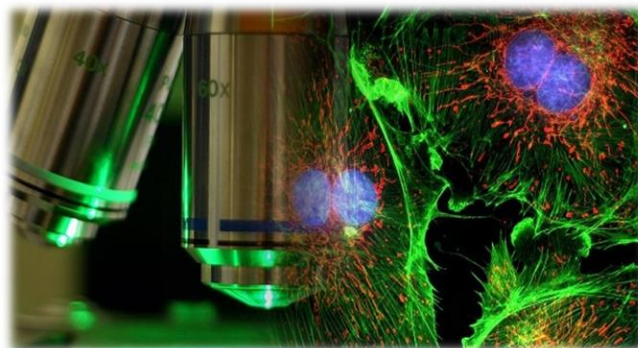
**F**-Rhodamine



**F**-Acridone



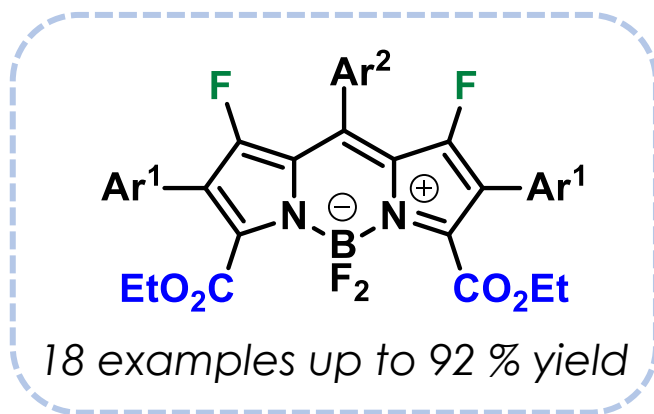
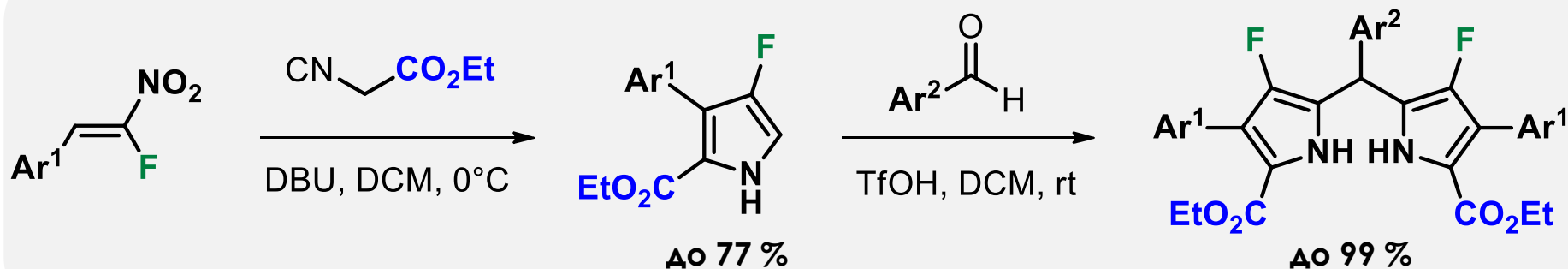
**F**-Fluorescein  
or **Oregon Green**



**Pennsylvania Green**

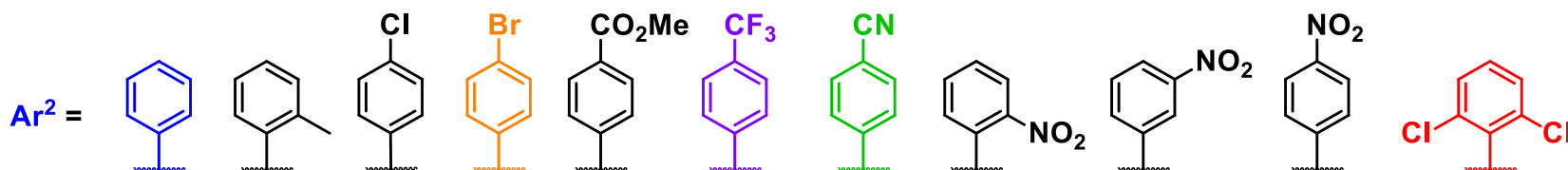
**Enhancing photostability**  
Improving fluorescence  
Decreasing pKa

# Novel core-fluorinated BODIPYs

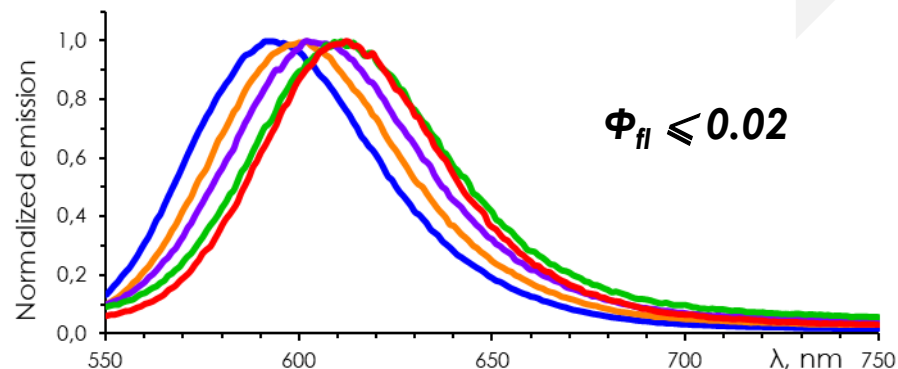
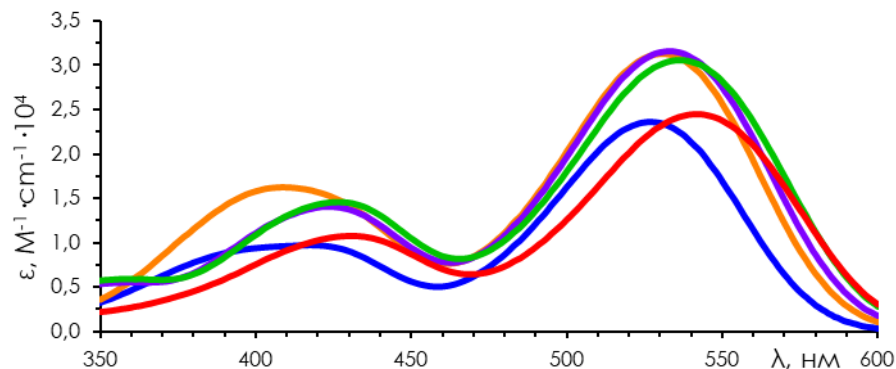


1. DDQ, DCM,  $\mu\text{W}$ ,  $80^\circ\text{C}$   
 2.  $\text{Et}_3\text{N}$ ,  $\text{BF}_3\cdot\text{Et}_2\text{O}$ ,  $\mu\text{W}$ ,  $80^\circ\text{C}$

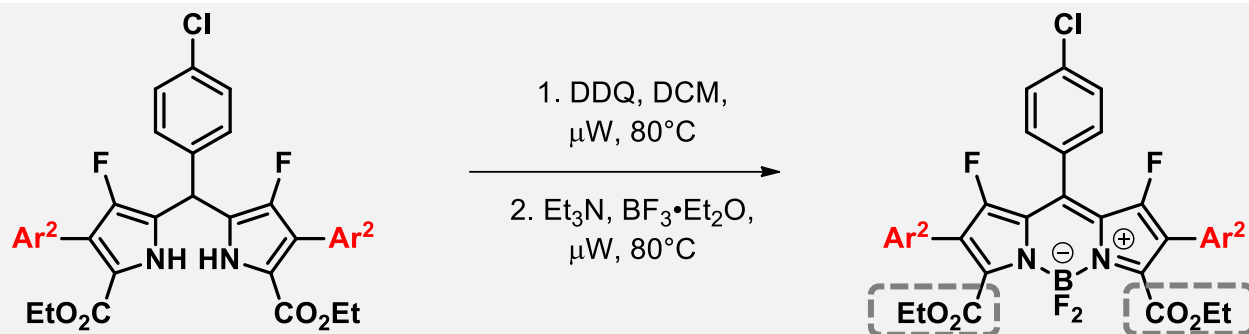
# Novel core-fluorinated BODIPYs



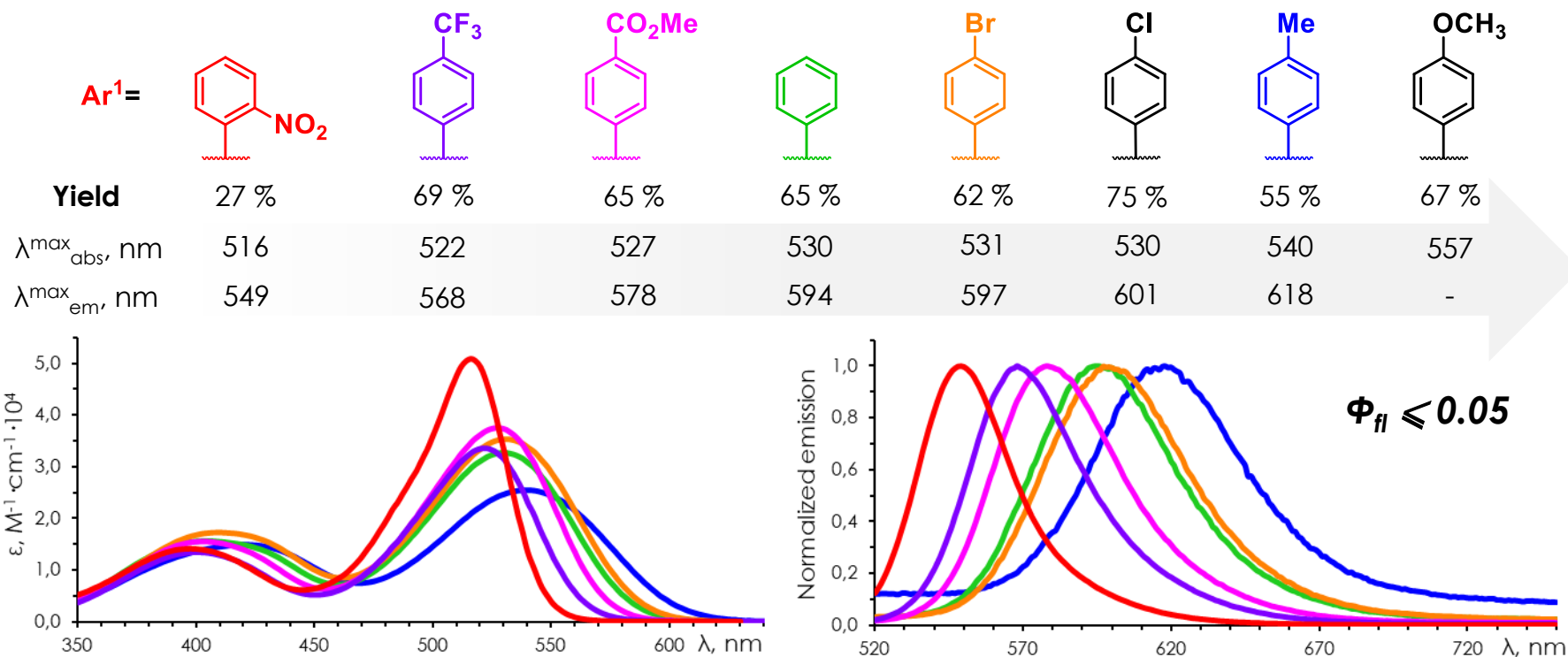
Yield	27 %	74 %	75 %	53 %	42 %	68 %	53 %	92 %	57 %	72 %	64 %
$\lambda_{\text{abs}}^{\text{max}}$ , nm	527	527	530	531	532	534	536	535	536	537	542
$\lambda_{\text{em}}^{\text{max}}$ , nm	593	593	601	602	605	602	611	609	612	615	612



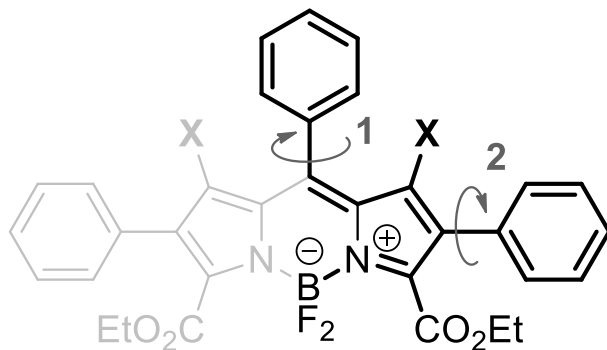
# Novel core-fluorinated BODIPYs



*electronic aspects  
free rotation*

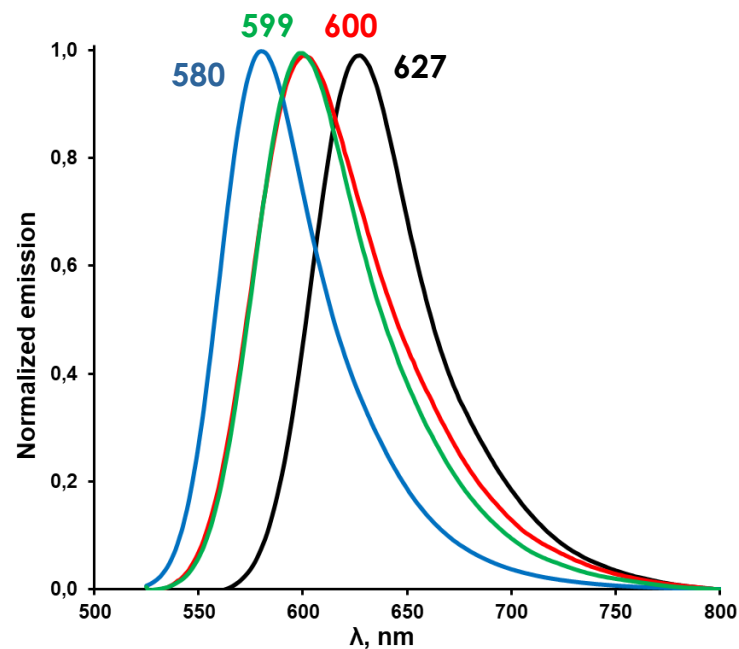
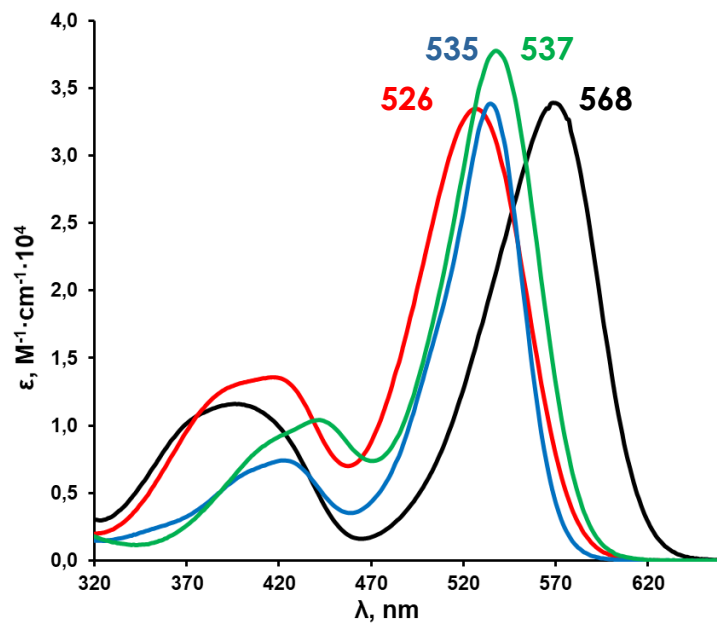


# Structural modifications at the 1,7-positions of BODIPY-3,5-dicarboxylates

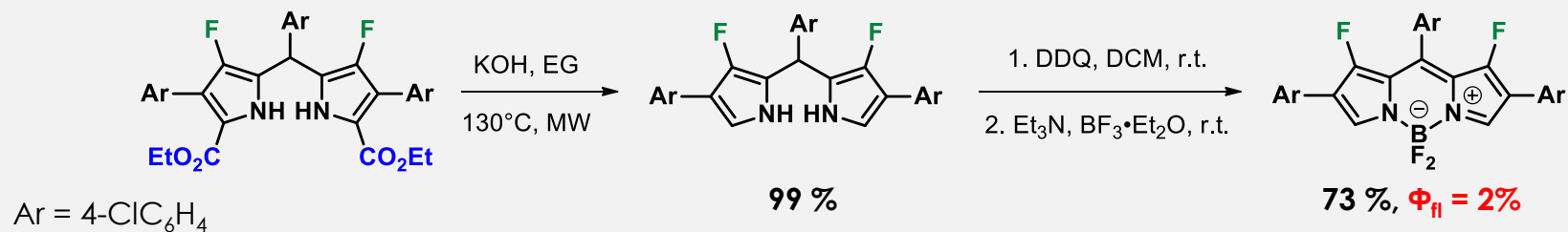


Rotational barrier,  
kcal/mol

X	1	2	$\Phi_{fl}$	$\Phi_{\Delta}$
H	11.6	2.7	0.02	0.02
F	10.4	2.6	0.01	0.02
Cl	16.0	6.0	0.02	0.52
Me	18.5	7.8	0.14	0.20

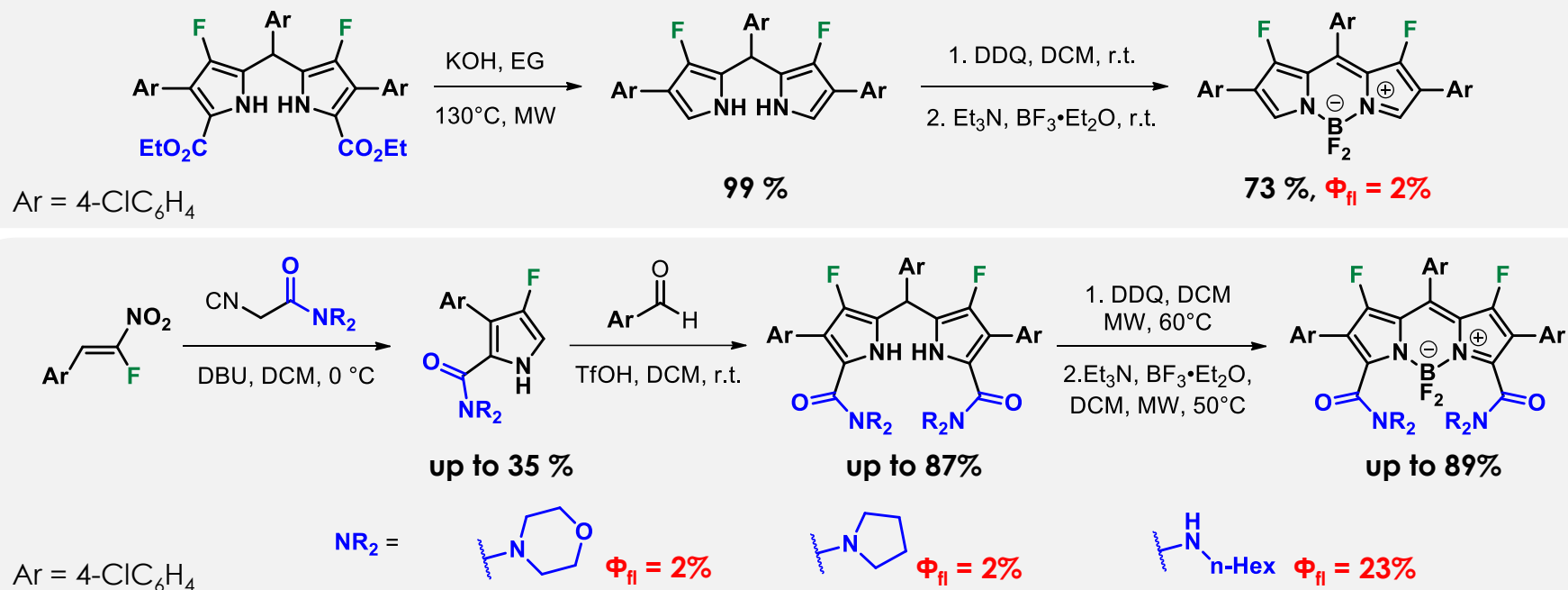


# Transition to efficient fluorinated fluorophores

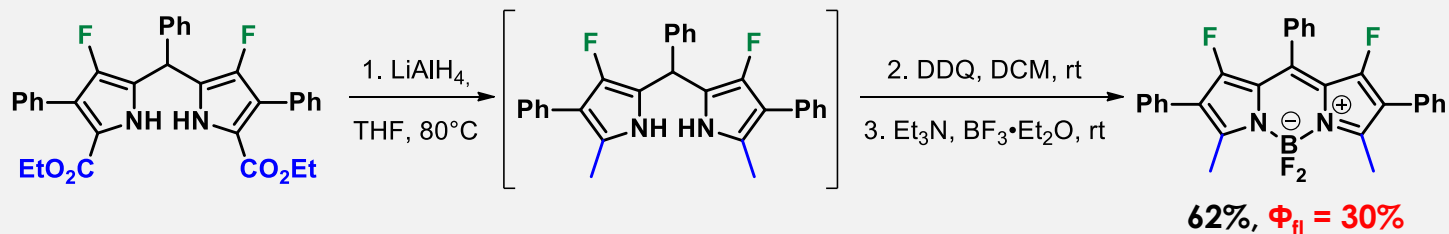
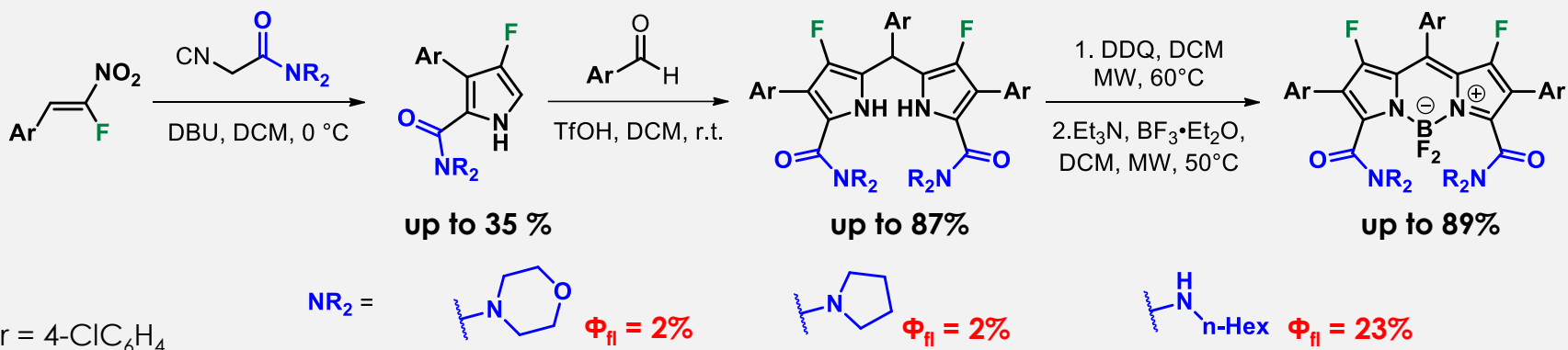
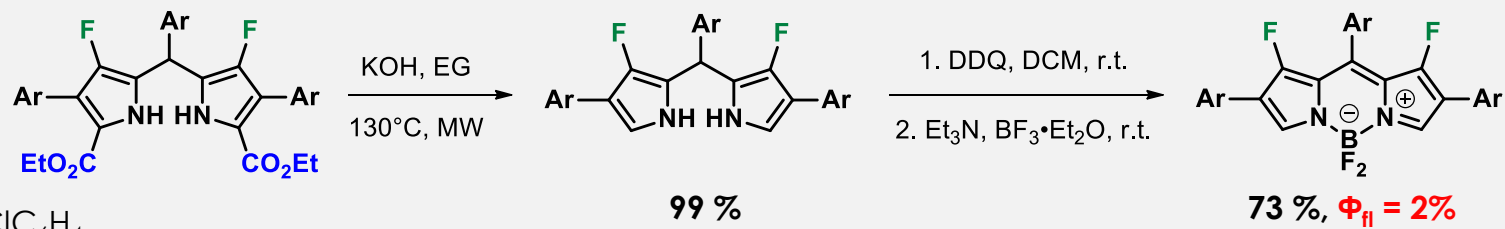




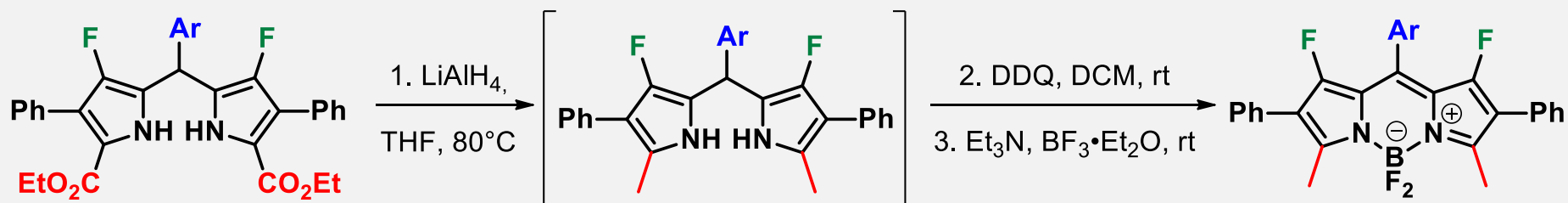
# Transition to efficient fluorinated fluorophores



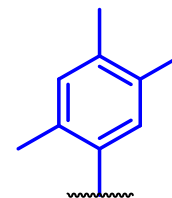
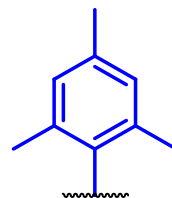
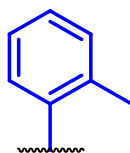
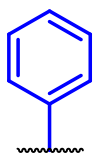
# Transition to efficient fluorinated fluorophores



# Novel core-fluorinated BODIPYs as efficient fluorophores

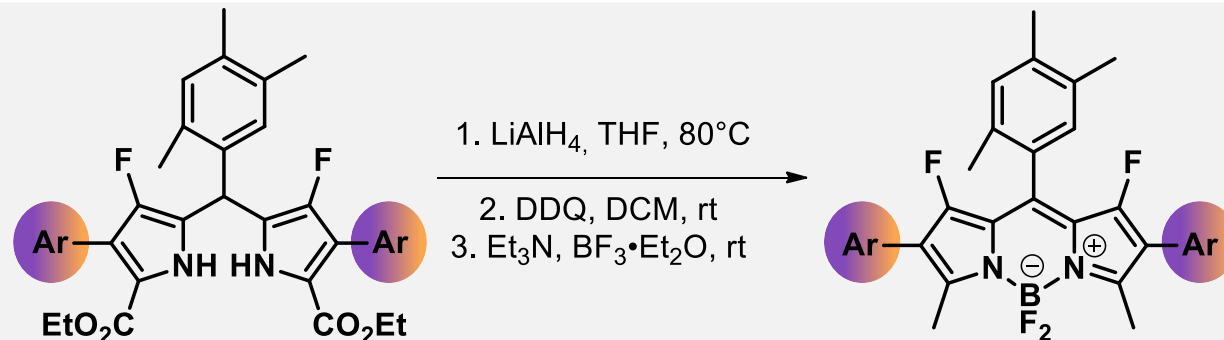


Ar =



Yield	62 %	64 %	62 %	66 %
$\lambda_{\text{abs}}^{\text{max}}$	519 nm	519 nm	519 nm	518 nm
$\lambda_{\text{em}}^{\text{max}}$	558 nm	555 nm	554 nm	554 nm
$\Phi_{\text{fl}}$	0.30	0.64	0.67	0.77

# Novel core-fluorinated BODIPYs as efficient fluorophores



Ar =

Ar	Yield	$\lambda_{\text{abs}}^{\text{max}}$	$\lambda_{\text{em}}^{\text{max}}$	$\Phi_{\text{fl}}$
	72 %	492 nm	508 nm	> 0.99
	42 %	512 nm	540 nm	> 0.99
	66 %	508 nm	546 nm	0.75
	66 %	518 nm	554 nm	0.77
	73 %	516 nm	554 nm	0.51
	61 %	508 nm	556 nm	0.48
	69 %	523 nm	564 nm	0.47
	62 %	524 nm	565 nm	0.45
	74 %	528 nm	586 nm	0.12

