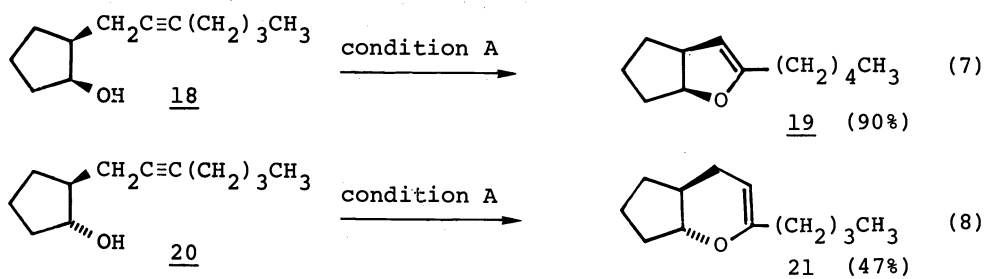
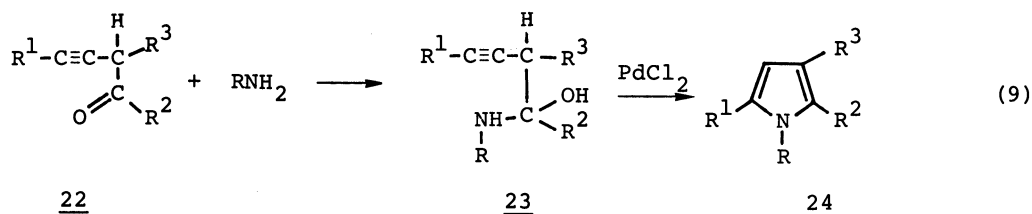


The above described reaction is applied to cyclic systems. Orientation of the addition depends upon the stereochemistry of the starting material. Two examples of intramolecular addition of alcohol to acetylene are illustrative (eq. 7,8). Riediker and Schwartz have reported similar results (Ref. 3).

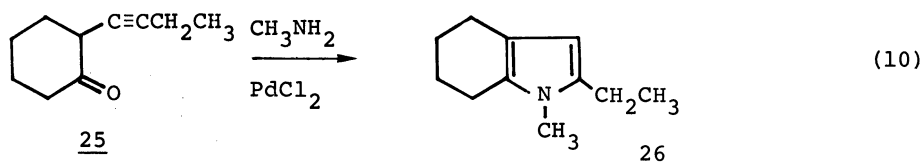


SYNTHESIS OF PYRROLES AND FURANS

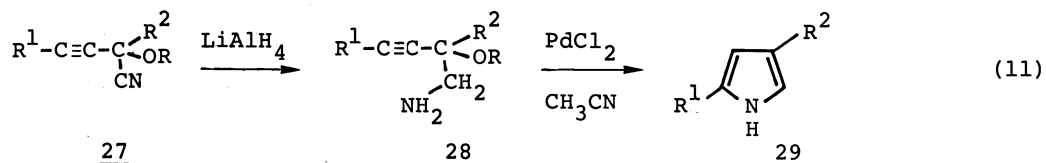
Pyrrroles. Pyrrole ring can be constructed by the application of the above described intramolecular addition of amino group to acetylene bond. One general scheme is presented as follows:



Reaction of 4-undecyn-2-one (22, R¹ = CH₃(CH₂)₅, R² = CH₃, R³ = H) and methylamine under the catalytic action of PdCl₂ gives pyrrole 24 (R¹ = CH₃(CH₂)₅, R² = CH₃, R³ = H, R = CH₃) in 50% yield. 2-(1-Butynyl)cyclohexan-1-one affords 26 in 30% yield (eq. 10).



Equation 11 presents another synthetic reaction of pyrroles.



Starting material 27 (R = CH₃) can be prepared from the corresponding acetal (27, R = CH₃, R² = OCH₃) by the treatment with cyanotrimethylsilane (Ref. 5). Compound 27 (R = SiMe₃) is obtained from acetylenic ketone by the reaction with cyanotrimethylsilane.

Conversion of 28 to 29 is effectively catalyzed by PdCl₂. Palladium acetate, in place of PdCl₂, gives a similar result but Pd(Ph₃P)₄ is less effective. Pyrroles prepared by eq. 11 are shown in Table 1.

TABLE 1. Pyrrole 29 prepared from 28^a

Entry	Starting material <u>28</u>			Catalyst (equiv.)	Yield of <u>29</u> (%) ^b
	R ¹	R ²	R		
1	CH ₃ (CH ₂) ₅	CH ₃ CH ₂	H	PdCl ₂ (0.01)	84
2	"	"	"	PdCl ₂ (0.001)	83
3	"	"	"	Pd(OAc) ₂ (0.01)	73 ^c
4	"	"	"	Pd(PPh ₃) ₄ (0.01)	17 ^d
5	"	(CH ₃) ₃ C	"	PdCl ₂ (0.01)	85
6	"	"	CH ₃	PdCl ₂ (0.01)	88
7	Ph	CH ₃ CH ₂	H	PdCl ₂ (0.01)	>99
8	(CH ₃) ₃ Si	CH ₃ CH ₂	H	PdCl ₂ (0.01)	28 ^e

- a) Reaction was carried out in refluxing acetonitrile for 3 h.
 b) Glc yields are quantitative except entries 3, 4 and 8.
 c) The yield diminished to 70% when benzene was employed as solvent.
 d) Air was introduced to an acetonitrile solution of catalyst, yield increased to 70%.
 e) The obtained product was 29 (R¹ = H, R² = CH₃CH₂).

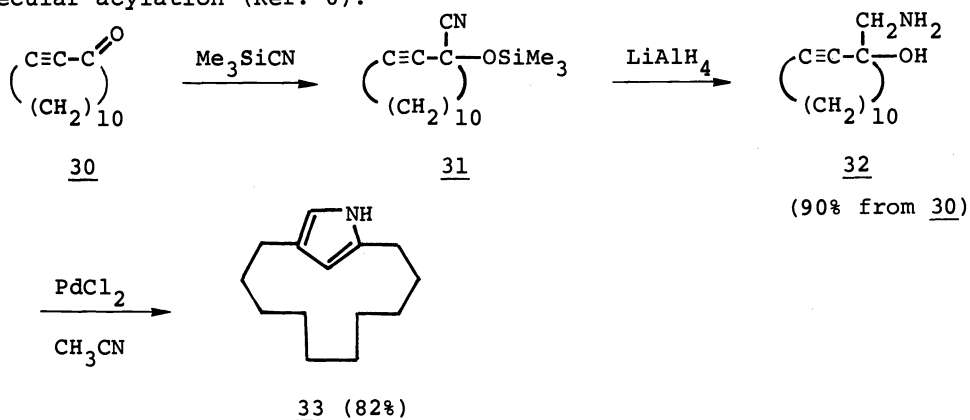
Cyclization using various different metal salts as catalysts was examined. Results are given in Table 2.

TABLE 2. Synthesis of 4-ethyl-2-hexylpyrrole^a

Catalyst	Yield (%)	Catalyst	Yield (%)
PdCl ₂	84	RhCl ₃ ·3H ₂ O	57
H ₂ PtCl ₆ ·6H ₂ O	70	NiCl ₂	28
AgOCOCH ₃	67	SnCl ₄	23
CuCl	62	AlCl ₃	11

- a) Used 0.01 equiv. of metal salt as catalyst and heated to reflux for 3-5 h in acetonitrile.

The above new method is applied to the synthesis of pyrrolophanes. An example is shown in eq. 12. 2-Cyclotridecyn-1-one is easily prepared by intramolecular acylation (Ref. 6).



Furans. Analogous to the above described pyrrole synthesis, furans are prepared from β,γ -acetylenic ketones (eq. 13) or 2-methoxy-3-alkyn-1-ols (eq. 14). Combinations of the starting material, reaction conditions, and the yield of furan 35 are summarized in Table 3.

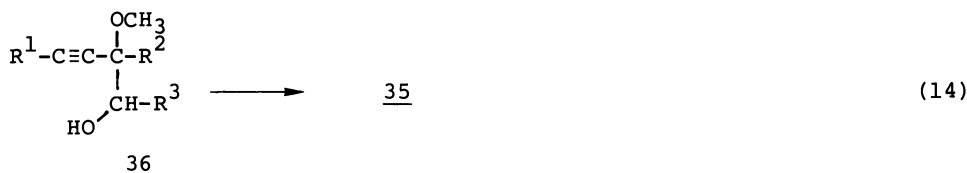
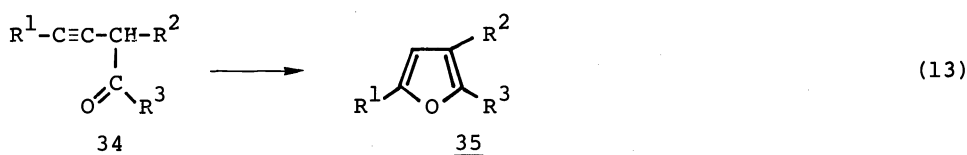


TABLE 3. Synthesis of furan 35

Entry	Starting material	R ¹	R ²	R ³	Condition ^a	<u>35</u> Yield (%)
1	<u>34</u>	CH ₃ CH ₂	-(CH ₂) ₄ -		D	60
2	<u>34</u>	CH ₃ (CH ₂) ₅	H	CH ₃	D	75
3	<u>36</u>	"	CH ₃	H	E	80
4	<u>36</u>	"	"	"	F	24
5	<u>36</u>	"	"	CH ₃	E	94
6	<u>36</u>	"	"	"	F	27
7	<u>36</u>	"	"	"	G	94
8	<u>36</u>	"	H	H	E ^b	90
9	<u>36</u>	"	"	"	E	0

a) Condition D: PdCl₂ (0.05 equiv.) in aq. CH₃CN, reflux 3 h.

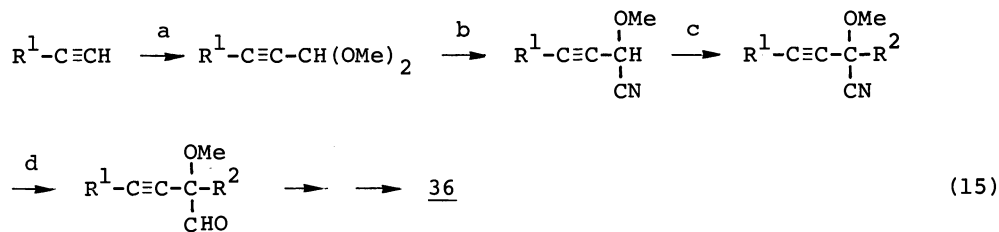
E: PdCl₂(PhCN)₂ (0.05) in aq. THF, r.t., 5 h.

F: PdCl₂ (0.05) in anhydrous CH₃CN, reflux 10 h.

G: PdCl₂ (0.05) in aq. CH₃CN, r.t., 5 h.

b) Reaction in THF-dil. HCl, r.t., 24 h.

Starting material 36 can be prepared in excellent overall yield from simple building blocks such as 1-alkynes, orthoformate, and cyanotrimethylsilane (eq. 15).



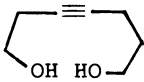
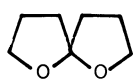
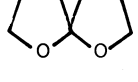
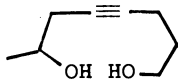
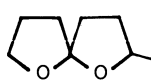
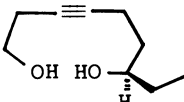
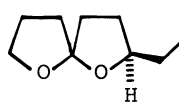
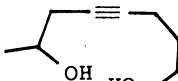
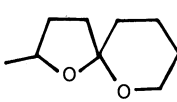
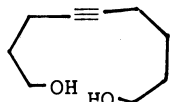
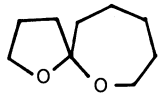
a: EtMgBr, HC(OMe)₃

c: LDA, R²I

b: Me₃SiCN-BF₃·OEt₂

d: ⁱBu₂AlH

TABLE 4. Synthesis of spiroacetals from alkyne diols

Entry	Alkyne diol	Condition ^a	Spiroacetal (Yield %)
1		A	 (90)
		G	 (95)
2		A	 (85)
3		G	 (95)
4		G	 (85)
5		G	 (60)

a) Condition A: PdCl₂(PhCN)₂ (0.01 equiv.) in ether, r.t., 5 h.

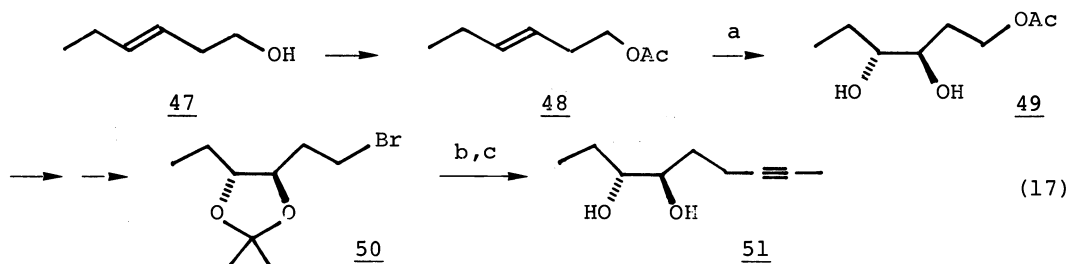
G: PdCl₂ (0.01 equiv.) in aq. CH₃CN, reflux, 1 h.

b) Mixture of two diastereomers (1:1).

c) Pheromone isolated from *Dolichovespula saxonica*, *Paravespula germanica*, and *Paravespula vulgaris*.

d) 2,7-Dioxaspiro[5.5]undecane could not be detected.

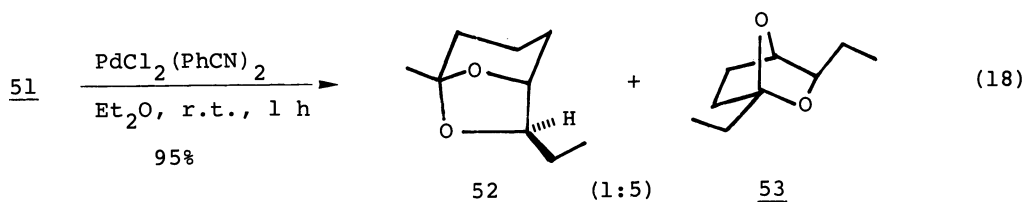
Pheromones with bicyclic acetal linkage are the next target molecules. *exo*-Brevicomins, the principal aggregation pheromone of the western pine beetle (*Dendroctonus brevicomis*), and frontalin, aggregation pheromone of southern pine beetle (*Dendroctonus frontalis*), are synthesized. Starting from (*E*)-3-hexen-1-ol, threo-7-nonyne-3,4-diol is prepared and treated with palladium catalyst in ether affording a mixture of two acetals (eq. 17, 18).



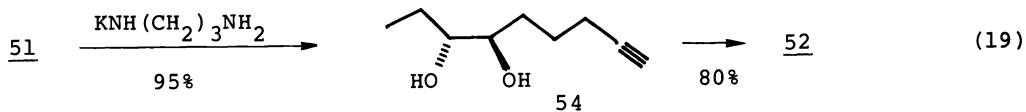
a: KMnO₄

b: CH₃C≡CLi/THF-HMPT

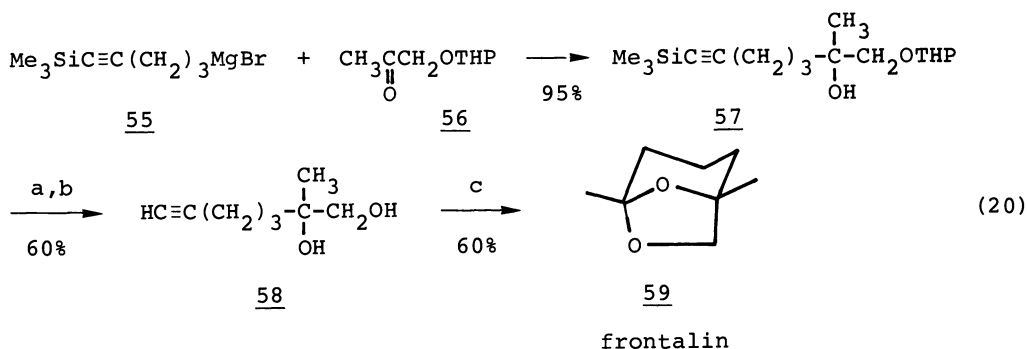
c: MeOH, p-CH₃C₆H₄SO₃H



Migration of internal triple bond in 51 to the terminal position affords 54 in 95% yield. Palladium catalyzed cyclization of 54 gives exo-brevicomin exclusively (eq. 19).



Analogous to the synthesis of exo-brevicomin shown in eq. 19, frontalin can be prepared (eq. 20).



a: KF in DMSO b: MeOH, p-CH₃C₆H₄SO₃H
 c: PdCl₂(PhCN)₂ (0.01 equiv.) in THF, r.t., 24 h

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