My Journey with Cannabis: Past, Present and Future......

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National Center for Natural Products Research
School of Pharmacy
The University of Mississippi
University, MS 38677
Ole Miss and Marijuana Research Since 1968
Botany, Production, Processing, Analysis, and New Drug Leads

Started working on Cannabis - 1976

[Images of cannabis plants and fields]
Discovery of Cannabinoids

(1899) Isolation of first phytocannabinoid (Cannabinol)
(1932-1940) Cannabinol structure elucidation
(1940) Isolation of Cannabidiol
(1941) Synthesis and evaluation of $\Delta^{6a,10a}$ THC
(1942-1950) Early pharmacological investigations
(1963) Cannabidiol structure elucidation
(1964) $\Delta^9$-THC isolation and structure elucidation
(1964- till date) Isolation and identification of additional cannabinoids
Isolation Work
Chemical Structures of Major Cannabinoids Present in *Cannabis sativa*

- Δ⁹-THC
- THCV
- CBD
- CBC
- CBG
- CBN
<table>
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<tbody>
<tr>
<td>CBG type</td>
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<td>7</td>
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<tr>
<td>CBC type</td>
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<td>$\Delta^9$-THC type</td>
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<td>$\Delta^8$-THC type</td>
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<td>CBL type</td>
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<td>CBE type</td>
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<td>CBN type</td>
<td>6</td>
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<td>CBND type</td>
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<td>CBT type</td>
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<td>Misc type</td>
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<td>12</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>61</strong></td>
<td><strong>66</strong></td>
<td><strong>70</strong></td>
<td><strong>120</strong></td>
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</table>

Out of 50 new cannabinoids in last ten years 43 are isolated by our group at NCNPR
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<td>Cannabinoids</td>
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<td>66</td>
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<td>Amino acids</td>
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<td>Proteins, enzymes and glycoproteins</td>
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<td>Sugars and related compounds</td>
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<td>Simple aldehydes</td>
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<td>Simple ketones</td>
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<td>Simple acids</td>
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<td>Fatty acids</td>
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<tr>
<td>Simple esters and lactones</td>
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<td>Steroids</td>
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<td>Terpenes</td>
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<td>120</td>
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<td>120</td>
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<td>Non-cannabinoid phenols</td>
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<td>Flavonoids</td>
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<tr>
<td>Vitamins</td>
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<td>Elements</td>
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<tr>
<td>Phenanthrenes</td>
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<tr>
<td>Spiroindans</td>
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<tr>
<td>Xanthones</td>
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<td></td>
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<tr>
<td>Biphenyls</td>
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<tr>
<td><strong>Total</strong></td>
<td>423</td>
<td>483</td>
<td>489</td>
<td>565</td>
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</tbody>
</table>
Cannabinoids Isolated by Our Group at The University of Mississippi

THC-Type

1 (Δ⁹-THC)

10 (cannabisol)

R¹ =

6

7

8

9

11

12

R¹ = α-OH
R¹ = β-OH

(-)-Δ⁹-trans-tetrahydrocannabinol (Δ⁹-THC)-type cannabinoids
Cannabinoids Isolated by Our Group at The University of Mississippi

CBG-Type

Cannabigerol (CBG) type cannabinoids
Cannabinoids Isolated by Our Group at The University of Mississippi

**CBC-Type**

Cannabichromene (CBC) type cannabinoids
Cannabinoids Isolated by Our Group at The University of Mississippi

CBN-Type

Cannabinol (CBN) type cannabinoids

\[ \text{26} \]

\[ R^1 = \text{COOH} \quad 27 \]
\[ R^1 = \text{H} \quad 28 \]

\[ \text{29} \]
Cannabinoids Isolated by Our Group at The University of Mississippi

CBN-Type

Miscellaneous-type cannabinoids
Cannabinoids Isolated by Our Group at The University of Mississippi

Miscellaneous-Type

Miscellaneous-type cannabinoids
Spermideine Alkaloids

Cannabisativine

Anhydrocannabisativine
Spiroindans

Phenanthrene and Dihydrophenanthrene
**Proposed Outline for the Biosynthetic Formation of the Spiroindans and Dihydrostilbenes of Cannabis**

- **Cannabispirenone**
- **3-[2-(4-hydroxyphenyl)ethyl]-5-methoxyphenol**
- **Cannabispiradienone**
- **Cannabispirenone** (Dehydrocannabispiran)
- **Cannabispiran** (Cannabispirone)
- **β-Cannabispiranol** (cannabispirol)
Eight new Dihydrostilbene Derivatives (I-VIII) to be published in: Journal of Natural Products

<table>
<thead>
<tr>
<th>#</th>
<th>( \text{R} )</th>
<th>( \text{R}_1 )</th>
<th>( \text{R}_2 )</th>
<th>( \text{R}_3 )</th>
<th>( \text{R}_4 )</th>
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<td>H</td>
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<td>H</td>
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<td>H</td>
<td>OCH(_3)</td>
<td>H</td>
<td>OH</td>
<td>H</td>
</tr>
<tr>
<td>III</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>H</td>
<td>OH</td>
<td>H</td>
</tr>
<tr>
<td>IV</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>OH</td>
</tr>
<tr>
<td>V</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>H</td>
<td>OH</td>
<td>OCH(_3)</td>
</tr>
<tr>
<td>VI</td>
<td>H</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>H</td>
<td>OH</td>
</tr>
<tr>
<td>VII</td>
<td>H</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>OH</td>
</tr>
<tr>
<td>VIII</td>
<td>H</td>
<td>OCH(_3)</td>
<td>OCH(_3)</td>
<td>OH</td>
<td>OCH(_3)</td>
</tr>
</tbody>
</table>
Prenylated Flavonoids

R = G, \quad R_1 = H, \quad R_2 = \text{OCH}_3
R = H, \quad R_1 = G, \quad R_2 = \text{OCH}_3
R = R_1 = H, \quad R_2 = \text{OCH}_3
R = P \quad R_1 = H, \quad R_2 = H

THE UNIVERSITY OF MISSISSIPPI
National Center for Natural Products Research
Analytical Work
Cannabis Fingerprinting Project (1987)


Rudolf Brenneisen PhD
Professor of Phytochemistry and Pharmacognosy
Department of Clinical Research
University of Bern, Switzerland

http://www.cannabis-med.org/board-directors.htm
Cannabis Fingerprinting Project (1987)

GC Profile of cannabis from Jamaica

GC Profile of cannabis from USA
GC Profile of Cannabis from Thailand

GC Profile of Cannabis from Mexico
GC-FID Analysis of *Cannabis sativa*

Column: 15m DB-1
Mass Spectrometer (0.25mm ID, 0.25 µm film)
Temperature Program
170 (1 min) - 250 @ 10°C/min, Hold 3 min, runtime 12 min

Mehmedic et al. (2010)
*Journal of Forensic Science, 55*: 1209-1217

ElSohly et al. (2016)
*Biological Psychiatry, 79* (7): 613-619
Fiber-Type Cannabis (CBD > THC)

Intermediate-Type Cannabis (THC=CBD)

Drug-Type Cannabis (THC-type)

Mixture of 8 standard cannabinoids, THCV; CBL; CBD; CBC; Δ⁸-THC; Δ⁹-THC; CBG; CBN and Internal Standard
HPLC analysis of *Cannabis sativa* L.

**Column:** Phenomenex, Luna C18(2) (150 mm x 4.6 mm x 5 µ)

**Flow rate:** 1.00 mL/min.

**Detection:** 220 nm

**Eluent:** ACN/H$_2$O (0.1% FA) 77/23
HPLC chromatogram the standard cannabinoids at 220 nm
Representative chromatogram of the extract of a high Δ⁹-THC/low CBD variety of cannabis.
Representative chromatogram of the extract of approximately equal $\Delta^9$-THC/CBD variety of cannabis THC- and CBD-rich variety.
Representative chromatogram of the extract of a fiber type variety of cannabis
Fingerprinting Analysis of *Cannabis sativa* L. and Quantitative Determination of Cannabinoids by UHPLC-UV-MS

**LC system:** Waters Acquity UPLC system with a Single Quadrupole Detector (SQD)  
**Column:** Waters Cortec UPLC C18 1.6 µm, 2.1 × 100 mm I.D.  
**Mobile phases:** water w/ 0.05% formic acid (A) and acetonitrile w/ 0.05% formic acid (B)  
**Column temperature:** 35 °C  
**SQD parameters:** Capillary voltage: 3.0 kV  
Cone voltage: 30 V  
Source temperature: 150 °C  
Desolvation temperature: 350 °C  
MS scan range: 100-900 amu
Calibration curve, Linearity range, LOD and LOQ by UHPLC-UV

UV Chromatogram of a Mixture of 11 Cannabinoid Standards at UV 220 nm

[Order of peaks: 1, CBDA; 2, CBGA; 3, CBG; 4, CBD; 5, THCV; 6, CBN; 7, Δ⁹-THC; 8, Δ⁸-THC; 9, CBL; 10, CBC; 11, THCAA]
# SFC analysis of *Cannabis sativa L.*

<table>
<thead>
<tr>
<th>Column</th>
<th>Waters ACQUITY UPC² BEH 2-EP (2-ethylpyridine) column with dimensions of 150 x 3.0 mm and 1.7 µm particle size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile Phase</td>
<td>consisted of CO₂ as solvent A, and isopropanol: acetonitrile (80:20) with 1% water as solvent B.</td>
</tr>
<tr>
<td></td>
<td>0-4.5 Min - 4%-9%B</td>
</tr>
<tr>
<td></td>
<td>4.5-7.00 Min - 9%-30%B</td>
</tr>
<tr>
<td></td>
<td>7-10 Min -30%B</td>
</tr>
<tr>
<td>Detection and Quantitation (UV)</td>
<td>PDA was set to scan from 190 - 400 nm, and 220 nm was used for the quantification.</td>
</tr>
<tr>
<td>Detection and Quantitation (ESMS)</td>
<td>Waters ACQUITY single quadrupole mass spectrometer. The MS electrospray ionization (ESI) source was operated in scan mode for both positive and negative in a mass range from 100-800 amu.</td>
</tr>
<tr>
<td>Run Time</td>
<td>10 Mins.</td>
</tr>
</tbody>
</table>
The quantification results from SFC-UV/MS were compared with a standard UHPLC method. The RSD of these two methods was within $+13.0\%$ for $\Delta^9$-THC.
Decarboxylation Study of THCA

![Chemical structures and graphs showing the decarboxylation process of THCA to THC at different temperatures.](attachment:image.png)
Decarboxylation Study of CBDA

[Diagram showing the chemical structures of CBDA and CBD with a graph depicting the decarboxylation process at different temperatures.]
# Kinetic Studies

Rate constants, $k \times 10^3$ (sec$^{-1}$), and activation energetics, $E_A$, for the decarboxylation of the acidic cannabinoids were calculated

$$ln k = ln k_0 - \frac{E_A}{RT}$$

<table>
<thead>
<tr>
<th>Reactant</th>
<th>Rate Constants ($k \times 10^3$ (sec$^{-1}$))</th>
<th>Activation Energy $E_A$ (kJ/mol)</th>
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<tbody>
<tr>
<td></td>
<td>80 ℃</td>
<td>95 ℃</td>
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<tr>
<td><strong>Extracts</strong></td>
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<tr>
<td>THCA-A</td>
<td>0.18</td>
<td>0.66</td>
</tr>
<tr>
<td>CBDA</td>
<td>0.05</td>
<td>0.27</td>
</tr>
<tr>
<td>CBGA</td>
<td>0.06</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Pure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBDA</td>
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### Major Terpenes of the Three Varieties of Cannabis

<table>
<thead>
<tr>
<th>Detected and/or Identified compounds</th>
<th>High CBD</th>
<th>High THC</th>
<th>THC/CBD</th>
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<tbody>
<tr>
<td>Monoterpenes</td>
<td>71</td>
<td>52</td>
<td>58</td>
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<tr>
<td>% Major constituents</td>
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<tr>
<td>Monoterpene</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Absence of:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α-pinene</td>
<td>(Absent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-pinene</td>
<td>(27.9 %)</td>
<td></td>
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<tr>
<td>Limonene</td>
<td>(12.5 %)</td>
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<tr>
<td>p-Mentha-1,4(8)-diene</td>
<td>(10.2 %)</td>
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<td></td>
</tr>
<tr>
<td>β-caryophyllene</td>
<td>(9.70 %)</td>
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<tr>
<td>α-humulene</td>
<td>(2.9 %)</td>
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<tr>
<td>Eudesma-3,7(11-diene)</td>
<td>(16 %)</td>
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<tr>
<td>Elmene</td>
<td>(2.3 %)</td>
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<tr>
<td>Bisabolol</td>
<td>(1.45 %)</td>
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<td>Sesquiterpene</td>
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<tr>
<td><strong>Absence of:</strong></td>
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</tr>
<tr>
<td>β-pinene</td>
<td>(1.8 %)</td>
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<tr>
<td>Limonene</td>
<td>(1.8 %)</td>
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<tr>
<td>p-Mentha-1,4(8)-diene</td>
<td>(6.5 %)</td>
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<tr>
<td>β-caryophyllene</td>
<td>(25.3 %)</td>
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<td></td>
</tr>
<tr>
<td>α-humulene</td>
<td>(6.9 %)</td>
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</tr>
<tr>
<td>Eudesma-3,7(11-diene)</td>
<td>(6.5 %)</td>
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</tr>
<tr>
<td>Elmene</td>
<td>(7.9 %)</td>
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<tr>
<td>Bisabolol</td>
<td>(1.0 %)</td>
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<tr>
<td>Absence of: α-pinene</td>
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</table>
GC/FID Chromatogram of the oil from High THC Variety (Drug type)

52 compounds
The Potency Monitoring Program, provides analytical potency data on confiscated cannabis and cannabis preparations in The United States.
Analysis of Cannabinoids in Illicit Drugs (40 years)
Samples of All Types of Cannabis have been Received

Sensimilla Buds

Kilobricks

Thai Sticks
Confiscated Cannabis Products
THC potency distribution of cannabis samples from DEA seizures and average THC by year seized, 1995 - 2014
CBD concentration distribution in Cannabis samples seized by DEA and average CBD by year seized, 1995 - 2014
Ratio of the average concentration of THC to CBD average concentration in DEA seized cannabis samples by year seized, 1995 - 2014
Product Development
Extraction of High THC Cannabis Variety
High THC Cannabis Extract
Extraction of High CBD Cannabis Variety

1- Dried at 40 °C and powdered 4.03 % CBD

4- Decarboxylation
   Heating at 130 °C for 30 min.

5- Distillation
   Thin film Distillation 78 % CBD

2- Extraction with hexanes

3- Concentration under reduced pressure at 60 °C till dryness 52.2 % CBD
Thin Film Distillation

- Temperature
- RPM
- Vacuum
- Flow rate

Cleaner Distillate
High CBD contents > 75%
Overview of SFE 2X5000 System Shown with Optional Co-Solvent
Flow Diagram of Typical Botanical Extraction

Flow Diagram:
- CO2 Tank
- CO2 Recycler
- Cooling Heat Exchanger
- CO2 Pump 150-175
- Heat Exchanger 45-60C
- Extraction Vessel 1 40-50C
- Extraction Vessel 2 40-50C
- 5000 psi 344 Bar ABPR
- 175 Bar – 210Bar 2500-3500
- 100-150 bar 1200-1800
- 55 bar ~800
- Collection Vessel 1 45-60C
- Collection Vessel 2 45-60C
- Collection Vessel 3 45-60C

Symbols:
- Manual Switch Valve (A-B)
- Manual Back Pressure Regulator

Institution: The University of Mississippi
National Center for Natural Products Research
Long-chain, high MW waxes, bio active compounds

Short-chain, low MW waxes, majority of bio active compounds

Volatile terpenes, some bio-active compounds, residual water
Jan. 18, 1934

*Cannabis Indica*, Wesson Pharmacy, Mississippi

Keleher Pharmacy, Mississippi

*Cannabis Indica*, Wesson Pharmacy, Mississippi
US Trends in Use of “Cannabis/CBD Oil” in Refractory Childhood Epilepsy

“Hemp” oil products

Concentrated CBD oil

CBD oil products

Not Regulated by FDA
Medicines from Cannabis

**Marinol**
- Synthetic THC, approved by FDA in the 1980s

**Sativex**
- Extracted THC (50%) and cannabidiol (50%);
- Mouth spray to treat MS, in FDA clinical trials for advanced cancer pain

**Epidiolex**
- Extracted cannabidiol (CBD, 98%) oil to treat rare forms of epilepsy. In FDA clinical trials; available to children who can’t enroll in clinical trials via FDA expanded access programs

**Cesamet**
- Synthetic THC, Approved by FDA in the 1980s
Cannabis Products

Cannabis Useable Biomass in Barrels

A: THC Derivative Crystals and B: THC from Cannabis

Cannabis Cigarettes

Cannabis Extract
Cannabis Products

A: CBD Crystals
B: CBD Powder
C: CBD Powder
D: THC
# Drug Pipeline

<table>
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<th>Drug Name</th>
<th>Target</th>
<th>Research</th>
<th>Pre-Clinical</th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
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<td>NB2221</td>
<td>MS Spasticity</td>
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Marijuana Program in the News

Structures of THC-hemiglutarate (THC-HG) and THC-valine-hemisuccinate (THC-Val-HS)
THC-VHS IN WECOBE ELI-PER-129 (7.9 mg/animal)
THC-VHS IN WECOBE ELI-PER-131 (3.67 mg/animal)
Transmucosal Matrix Patch Designs

**Multi-directional**

**Water-impermeable backing**

**Water-impermeable spray coating**

**Bioadhesive + Drug + Excipients**

Prototype Transmucosal Matrix Patch (TMP) applied in-vivo (placebo)
Plasma THC concentrations as a function of time from THC-HG and THC-Val-HS loaded HME patches. Data represents the mean value from 4 pigs. The animals for maintained under anesthesia for the first 4 hours and were then allowed to come out of anesthesia and given access to food and water.
Plasma THC concentrations as a function of time and dose from THC-Val-HS loaded HME patches. Data represents the mean value. The animals for maintained under anesthesia for the first 4 hours and were then allowed to come out of anesthesia and given access to food and water.

- In view of the superior stability and equivalent *in vivo* performance with respect to THC-HG, THC-Val-HS was selected as the most promising prodrug for transbuccal administration.
- A dose dependent plasma concentration time profile was then evaluated.
- The results obtained have been depicted in Figure below.
Challenges in Ocular Drug Delivery

Figure was adapted and modified from National Eye Institutes (NEI), National Institutes of Health (NIH)
Glaucoma Animal Model Development

1. Inject alpha-chymotrypsin into vitreous humor of rabbits
2. Allow intraocular pressure (IOP) to stabilize (approximately 2 weeks)
3. Evaluate effect of drug/prodrug/formulation on IOP
IOP-Time Profile in rabbit glaucoma model (Mean ± SEM). THC-0.8: THC in Tocrisolve (0.8 %w/v, 400µg), WIN-0.8: WIN in Tocrisolve (0.8 %w/v, 400µg), THC-Val-HS (THC-0.6): THC-Val-HS in Tocrisolve (THC eq 0.6 %w/v, 300µg), THC-Val-HS (THC-0.55)MS: THC-Val-HS in micellar solution (THC eq 0.6 %w/v, 275µg)
IOP-Time Profile in rabbit glaucoma model (Mean ± SEM). THC-Val-HS (THC-0.6): THC-Val-HS in Tocrisolve (THC eq 0.6 %w/v, 300µg), Timolol-0.25: Timolol maleate eye drops (0.25 %w/v, 125µg), Pilocarpine-2.0: Pilocarpine HCl eye drops (2% w/v, 1000µg)
Where are We Today with Cannabis as a Medicine?
History of Marijuana as Medicine

(1961) – “UN Single Convention on Narcotic Drugs” Provides Basis for Future Federal Prohibition of Marijuana

(1964) - THC, Main Psychoactive Component of Cannabis, First Identified and Synthesized by Dr. Raphael Mechoulam (Professor of Medicinal Chemistry at the Hebrew University of Jerusalem)

(1968) - In USA, “The University of Mississippi” Becomes Official Grower of Marijuana for Federal Government

(Apr. 8, 1968) - President Johnson Creates Bureau of Narcotics and Dangerous Drugs (BNDD)
History of Marijuana as Medicine

(1970) - ‘Controlled Substances Act’ Classifies Marijuana as Schedule I - a Drug with "No Accepted Medical Use“, in USA

(June 17, 1971) - President Nixon Declares War on Drugs

(1973) - Drug Enforcement Agency (DEA) Established

The Bureau of Narcotics and Dangerous Drugs (BNND) and the Office of Drug Abuse Law Enforcement (ODALE) are merged to form the US Drug Enforcement Agency (DEA)

(1974) - NIDA Established

Placed in Charge of Contracts to Grow Marijuana for Research Purposes

(1978) - Federal Government IND Compassionate Use Program Supplies Patients with Marijuana

(June 1991) - Federal Government Suspends IND Compassionate Use Medical Marijuana Program
## Legalize Medical Marijuana in USA
### (24 States and DC)

<table>
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<td>1998</td>
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Legislation for CBD-Oil: 17 States

Alabama  North Carolina
Florida   Oklahoma
Georgia   South Carolina
Iowa      Tennessee
Kentucky  Texas
Louisiana  Utah
Mississippi Virginia
Missouri  Wisconsin
          Wyoming
DEA Announces Actions Related to Marijuana and Industrial Hemp


AUG 11 (WASHINGTON) - The Drug Enforcement Administration (DEA) announced several marijuana-related actions, including actions regarding scientific research and scheduling of marijuana, as well as principles on the cultivation of industrial hemp under the Agricultural Act of 2014. The highlights are as follows:

• Based on the legal standards in the Controlled Substances Act (CSA), marijuana remains a schedule I controlled substance.
• DEA’s new policy will allow additional entities to apply to become registered with DEA so that they may grow and distribute marijuana for FDA-authorized research purposes.
• The 2014 Act did not remove industrial hemp from the list of controlled substances and, with certain limited exceptions, the requirements of the Federal Food, Drug, and Cosmetic Act and the CSA continue to apply to industrial hemp-related activities.
Medical Board Expectations for Physicians Recommending Marijuana

1. Patient-Physician Relationship
2. Patient Evaluation
3. Informed and Shared Decision Making
4. Treatment Agreement.
5. Qualifying Conditions
6. Ongoing Monitoring
7. Consultation and Referral
8. Medical Records
9. Physician Conflicts of Interest
10. Physician Use of Marijuana
Recommended Review of Attempted Measures Without Marijuana Use to Ease the Symptoms Caused by a Debilitating Medical Condition

1. Advice about other options for managing the condition.
2. Determination that the patient may benefit from the recommendation of marijuana.
3. Advice about the potential risks of the medical use of marijuana to include:
   - The variability of quality and concentration of marijuana.
   - The risk of cannabis use disorder.
   - Adverse events, exacerbation of psychotic disorder, adverse cognitive effects for children and young adults, and other risks, including falls or fractures.
   - Use of marijuana during pregnancy or breastfeeding.
   - The need to safeguard all marijuana and marijuana-infused products from children and pets or domestic animals.
   - The need to notify the patient that the marijuana is for the patient’s use only and the marijuana should not be donated or otherwise supplied to another individual.
4. Additional diagnostic evaluations or other planned treatments.
5. A specific duration for the marijuana authorization for a period no longer than 12 months.
6. A specific ongoing treatment plan as medically appropriate.
Conclusion

The primary mission of state medical boards in the United States is to protect the public and ensure that only individuals who are qualified and fit to practice medicine do so.

Although it is up to every state medical board to incorporate all, some, or none of the language in these marijuana recommendations, unanimous adoption of the recommendations by state board representatives at the FSMB’s annual meeting suggests they may influence local deliberations relating to the determination of professional conduct.

Even if these recommendations are not adopted as a state statute, rule, or policy, they represent a reasonable effort to offer best practices for clinicians to follow when considering marijuana in patient care.
Plant Biotechnology
A & B Callus on leaf segment on MS modified + 3.0 μM NAA + 1.0 μM TDZ; C & D: Multiple shoots regenerated on MS + 0.25 μM TDZ and Rooting on MS + 2.5 μM IBA; E: Full fledged regenerated plantlet

A: Shoot multiplication on MS medium supplemented with 0.5 µM TDZ; B: Rooting on 1/2MS medium supplemented with 500 mg l\(^{-1}\) activated charcoal and 2.5 µM IBA; C: Well rooted plantlet prior to the transfer of soil; D: \textit{Ex vitro} vegetatively propagated (VP) and \textit{In vitro} vegetatively propagated (IVP). Bars represent 1.22 cm (\textit{a}), 1.31 cm (\textit{b}), 2.3 cm (\textit{c}) and 32 cm (\textit{d}).

Micropropagation of *Cannabis sativa* using *meta*-topolin. (A) Mother plant, (B) shoot formation and (C, D and E) rooting in MS+2 μM *meta*-topolin, (F) and (G) well established plants in soil and (H) field plantation of *C. sativa* plants.

Short Term Conservation

Synthetic seeds (A), re-growth (B and C) after 24 weeks of storage, grow-room acclimatization (D) of Cannabis sativa plants


Selected Publications on Cannabis Biotechnology


ElSohly MA et al. (2013) Chapter 1, Chapter 2, Chapter 3, and Chapter 4, *American Herbal Pharmacopeia Monograph*, pp 1-32

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