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Cannabinoids, inflammation, and fibrosis

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Abstract

Cannabinoids apparently act on inflammation through mechanisms different from those of agents such as nonsteroidal anti-inflammatory drugs (NSAIDs). As a class, the cannabinoids are generally free from the adverse effects associated with NSAIDs. Their clinical development thus provides a new approach to treatment of diseases characterized by acute and chronic inflammation and fibrosis. A concise survey of the anti-inflammatory actions of the phytocannabinoids Δ^9-tetrahydrocannabinol (THC), cannabidiol, cannabichromene, and cannabinol is presented. Mention is also made of the noncannabinoid plant components and pyrolysis products, followed by a discussion of 3 synthetic preparations—Cesamet (nabilone; Meda Pharmaceuticals, Somerset, NJ, USA), Marinol (dronabinol; THC; AbbVie, Inc., North Chicago, IL, USA), and Sativex (*Cannabis* extract; GW Pharmaceuticals, Cambridge United Kingdom)—that have anti-inflammatory effects. A fourth synthetic cannabinoid, ajulemic acid (AJA; CT-3; Resunab; Corbus Pharmaceuticals, Norwood, MA, USA), is discussed in greater detail because it represents the most recent advance in this area and is currently undergoing 3 phase 2 clinical trials by Corbus Pharmaceuticals. The endogenous cannabinoids, including the closely related lipoamino acids, are then discussed. The review concludes with a presentation of a possible mechanism for the anti-inflammatory and antifibrotic actions of these substances. Thus, several cannabinoids may be considered candidates for development as anti-inflammatory and antifibrotic agents. Of special interest is their possible use for treatment of chronic inflammation, a major unmet medical need.—Zurier, R. B., Burstein, S. H. Cannabinoids, inflammation, and fibrosis.

endocannabinoids specialized proresolving mediators anti-inflammatory antifibrotic

Preparations derived from *Cannabis* have been the source of medical therapies since the earliest records on pharmacobotany (1). Many beneficial effects of *Cannabis* on the human body, including those on “rheumatism” were noted 4000 yr ago in a work reported by Hui-Lin Li called *Pen-tsao* (2). The term cannabinoid usually refers to compounds that activate the G-protein-coupled cannabinoid receptors 1 and 2 (CB1 and -2). CB1 receptors, located mainly on neurons in the hippocampus and basal ganglia, mediate the psychoactive actions of cannabinoids (3). CB2 receptors are present mainly on tissue and circulating cells of the immune system (4). However, many *Cannabis* components that do not activate either receptor are sometimes called cannabinoids. Given that the *Cannabis* plant contains more than 60 cannabinoids and 200–250 noncannabinoid constituents, it follows that the therapeutic benefits of marijuana are related to some combination of these compounds. We review the current knowledge of the mechanisms whereby phytocannabinoids, noncannabinoid plant components, and their pyrolysis products aid in the control of inflammation and fibrosis. We also address the development of synthetic cannabinoids as treatment for patients with diseases characterized by chronic inflammation and subsequent fibrosis. The ability of some cannabinoids to facilitate the resolution of inflammation by stimulating the action of several specialized proresolving mediators (SPMs), an important emerging concept, is also discussed. The roles of endogenous cannabinoids (endocannabinoids) and the closely related lipoamino acids in control of inflammation are also discussed.

CANNABIS CONSTITUENTS

Experiments with Δ^9 -tetrahydrocannabinol (THC; Fig.1), the main psychoactive cannabinoid in the plant, have been helpful in understanding the anti-inflammatory actions of the nonpsychoactive cannabinoids (5, 6). Although there is rich documentation of the anti-inflammatory actions of several of the nonpsychoactive constituents, that literature has been crowded out by discussions about psychoactivity and legalization of marijuana. For example, the noncannabinoid, prenylated flavone cannflavin is 30 times more potent as an inhibitor of cyclooxygenase (COX) than the time-honored anti-inflammatory drug aspirin. In addition, Sofia *et al.* (7, 8) demonstrated the anti-inflammatory actions of a crude extract of THC and of the nonpsychoactive *Cannabis* constituents cannabidiol (CBD) and cannabinol in a carrageenan-induced paw edema model of acute inflammation in rats. They showed in the same model that THC is 80 times more potent than aspirin and twice as potent as hydrocortisone and that the nonpsychoactive constituent cannabichromene also suppresses the induced inflammation (9⇓-11). Moreover, CBD reduced acute inflammation in a murine model of collagen-induced arthritis (12). The precise mechanisms whereby CBD reduces inflammation are not clear. CBD does reduce production of the proinflammatory cytokine TNF-α and induces reduction of fatty acid aminohydrolase (FAAH) activity, thereby increasing production of anandamide, an anti-inflammatory endocannabinoid. Volatile oil components of *Cannabis sativa* suppress COX1 activity (13, 14), and pyrolysis products of CBD exhibit activity in COX-1-suppression assays (15). Several of the most abundant cannabinoid and noncannabinoid constituents of the plant are not psychoactive (16). Thus, it is clear that cannabinoid and noncannabinoid constituents of *Cannabis* are potential nonpsychoactive anti-inflammatory agents.

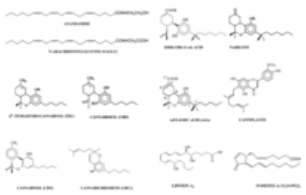

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Figure 1.

Structures of compounds discussed in this review.

As the most abundant nonpsychoactive cannabinoid in *Cannabis*, CBD has been studied extensively for its anti-inflammatory properties. As noted, it is active in a murine model of collagen-induced arthritis. In addition, CBD reduces carrageenan-induced paw edema in rats (17) and intestinal inflammation in mice (18). CBD also counters psychoactivity, sedation, and tachycardia induced by THC (19).

SYNTHETIC CANNABINOIDS

Synthetic cannabinoids are being developed in an effort to separate psychoactivity from their analgesic and anti-inflammatory actions. The dimethylheptyl-11-oic-acid analog of CBD (DMH-CBD-11-oic acid; Fig. 1) reduces joint inflammation and tissue injury (cartilage degradation and bone erosion) in collagen-induced arthritis in mice (20). Hydrogenation of DMH-CBD-11-oic acid yields 4 distinct epimers (21). Hydrogenation at different double bonds leads to compounds with different bioactivities, none of which depend on CB1 activation. Thus, several potential therapeutic agents devoid of psychotropic activity may eventually be derived from this one phytocannabinoid. Three cannabinoids—Cesamet (nabilone; Meda Pharmaceuticals, Somerset, NJ, USA), Marinol (dronabinol; THC; AbbVie, Inc., North Chicago, IL, USA), and Sativex (*Cannabis* extract; GW Pharmaceuticals, Cambridge, United Kingdom)—which activate both the CB1 and -2 receptors have been approved by the U.S. Food and Drug Administration (FDA) for clinical use.

Nabilone (Fig.1), a dimethylheptyl analog of THC, is approved in many countries, including the United States, for treatment of the severe nausea and vomiting associated with chemotherapy. It is also used for the management of neuropathic pain and pain associated with cancer and fibromyalgia (22). It is used most commonly as an adjunctive therapy and as such results in small but significant reductions in pain.

Dronabinol, THC, was approved by the FDA in 1985 for treatment of nausea and vomiting in patients receiving cancer chemotherapy who failed to respond to conventional antiemetics. It is administered in capsule form. Dronabinol has also been used as an appetite stimulant for patients with wasting diseases such as cancer and HIV/AIDS (23).

THC with CBD (Sativex) is approved in 24 countries for the treatment of muscle spasticity associated with multiple sclerosis. Sativex was granted fast track designation by the FDA in 2014. Administered as a mint-flavored oral spray, it is now in phase 3 clinical trials in the United States for treatment of cancer-related pain. Similar to nabilone and dronabinol, Sativex treatment has the same potential adverse effects as marijuana (24). In a double-blind placebo-controlled 5 wk study of 58 patients with rheumatoid arthritis (RA) who received Sativex by oral spray (25), pain at rest, pain on movement, sleep quality, and clinical responses (disease activity score 28) were improved significantly by Sativex.

Ajulemic acid (AJA; CT-3; Resunab; Corbus Pharmaceuticals, Norwood, MA, USA) is a synthetic cannabinoid derived from a modification of THC-11-oic acid, the major metabolite of THC. Extension of the pentyl side chain from 5 to 7 carbons, addition of 2 methyl groups to increase receptor affinity, and a carboxylic acid at the 9 position to reduce blood-brain barrier penetration, results in the formation of AJA (1′,1′-dimethylheptyl-THC-11-oic acid; Fig. 1 (26). AJA, administered by mouth, is 50–100 times more potent than THC as an analgesic (27). The recently developed preparation of AJA has 12 times greater affinity for CB2 than for CB1, which renders it nonpsychoactive at therapeutic doses (28). The anti-inflammatory and antifibrotic actions of AJA have been demonstrated in several *in vitro* systems and in animal models. Anti-inflammatory effects were first demonstrated in arachidonic acid-induced rodent paw edema (26). In an adjuvant-induced arthritis model, rats treated with 0.1 mg/kg AJA 3×/wk for 5 wk did not display evidence of active synovitis or cartilage or bone damage, whereas control animals had cartilage degradation and bone erosion that resembled RA (29). In other experiments, rats treated with AJA at up to 30 mg/kg/d for 5 d, did not show signs of physical dependence on the drug (30).

In studies designed to explore mechanisms of AJA action, it was found that addition of AJA to human peripheral blood and synovial fluid monocytes *in vitro* reduces production of the proinflammatory, bone-degrading cytokine IL-1β (31). It is of interest that AJA did not reduce production of TNFα in these studies, given the finding that clinical trials of TNFα inhibitors in patients with systemic lupus erythematosus (SLE) have been limited by toxicity and increases in disease activity (32, 33). We have observed (unpublished data) that oral administration of single doses of 3–10 mg AJA to healthy volunteers reduced pro-IL-1β gene expression in and secretion of IL-1β from LPS-stimulated peripheral blood monocytes (PBMs) (Table 1; Zurier RB, Rossetti RG, Burstein SH, *et al.*, unpublished data). In contrast, AJA had no appreciable effect on TNFα mRNA levels or TNFα secretion. Maximum serum concentration of AJA reached 0.15 μM at 5 h after a dose of 10 mg AJA (Corbus Pharmaceuticals, unpublished data).

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TABLE 1.

IL-1β secretion from stimulated PBMs from healthy volunteers administered AJA orally in capsules

No marijuana-like CNS effects were noted in the volunteers, as assessed by the Addiction Research Center Inventory-Marijuana (ARCI-M; developed in conjunction with the Addiction Research Center of the National Institute on Drug Abuse (National Institutes of Health, Bethesda, MD, USA) scale (34) (Table 2; Corbus Pharmaceuticals, unpublished data). Overall, the ARCI-M scores for treated subjects were not different from baseline scores or from placebo-treated subjects. The largest mean number of items positively responded to by subjects given AJA

was 0.5 and occurred when the inventory was given at the second hour after administration. The largest mean number of positive responses among placebo-treated subjects was 0.375 and occurred before administration. The mean response rate of placebo-treated subjects at h 2 was 0:25. These numbers are relatively small compared to those from experienced marijuana smokers. Subjects smoking marijuana report mean scores of 5.2 and, under placebo or presmoking conditions, 0.7–1.0. The relatively few positive responses obtained in this study were not dose related. These results suggest that AJA is not psychoactive at the doses tested.

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TABLE 2.

ARCI-M scores for AJA given orally in capsules

Addition of AJA (3–30 μM) to human monocyte-derived macrophages reduces steady-state levels of IL-6 mRNA and the subsequent secretion of IL-6 from LPS-stimulated cells (35). IL-6 is a multifunctional cytokine that contributes to inflammation and tissue injury in several diseases. It has been identified in kidney biopsy tissue from patients with SLE with active glomerulonephritis (36). Skin biopsies from patients with SLE have exhibited increased expression of IL-6 in active sites (37), and plasma levels of IL-6 have correlated with lupus arthritis (38). In addition, higher levels of IL-6 in synovial fluid increase the risk of joint destruction in patients with RA (39). Because activation of osteoclasts is central to the pathogenesis of bone erosion in patients with RA, the influence of AJA on osteoclast differentiation and survival was investigated (40). Addition of AJA to cell cultures suppressed development of multinucleated osteoclasts (osteoclastogenesis), and prevented further osteoclast formation in cultures in which osteoclastogenesis had already begun. Addition of AJA to fibroblastlike synovial cells also reduces production of matrix metalloproteinases, enzymes that facilitate cartilage and bone destruction (41).

In addition to its capacity to bind to CB2, AJA binds to and activates peroxisome proliferator-activated receptor (PPAR)-γ (42). PPARγ receptors are members of a family of nuclear receptors that modify the transcription of target genes in response to a variety of signaling proteins. They are expressed on immune cells, such as monocytes and macrophages and regulate inflammatory responses through inhibitory effects on expression of proinflammatory cytokines and eicosanoids (43). AJA binds directly to a second site in the PPARγ receptor that is separate from that utilized by other partial agonists, such as the thiazolidinediones (44). Thus, the problems of weight gain, fluid retention, and heart failure caused by the thiazolidinediones, have not been seen in animals or humans given AJA. Activation of PPARγ by AJA suppresses IL-8 promoter activity. IL-8 is a chemoattractant cytokine with specificity for the neutrophil, the major cell involved in acute inflammation. Thus, suppression of neutrophil migration and reduction of enzyme release from neutrophil granules limits acute inflammation and tissue injury. The loss of PPARγ in fibrotic tissues results in enhanced signaling by TGFβ, a major fibrogenic cytokine, and compounds that activate PPARγ reduce fibrosis in a murine model of scleroderma (45). AJA exhibits antifibrotic effects in murine models of systemic sclerosis (46) and reduces collagen synthesis in dermal fibroblasts of patients with scleroderma (47).

The discovery of SPMs (48) has broadened our understanding of how inflammation is controlled: not simply by passive cessation of proinflammatory mediators, but also by an increase in programmed cell death (apoptosis) of immune-inflammatory cells and by activation of stop signals that lead to resolution of inflammation. It is the lack of resolution of inflammation that is in large part responsible for the signs and symptoms of diseases characterized by chronic inflammation, tissue injury, and fibrosis. Novel actions of AJA include its capacity to induce apoptosis in human T lymphocytes (49) and to increase production of 2 proresolving eicosanoids—prostaglandin (PG)J_2 and LXA_4 (Fig. 1)—that facilitate the resolution of inflammation (50, 51).

In a phase 2 proof-of-principal trial, 21 patients with neuropathic pain received twice daily doses of 20 mg AJA in a double-blind, placebo-controlled manner for 7 d (52). No clinically significant adverse events were noted. A significant reduction in neuropathic pain was noted in 30% of patients.

ENDOGENOUS CANNABINOIDS

Endocannabinoids are groups of naturally occurring members of the eicosanoid superfamily that can activate cannabinoid receptors and are derivatives of long-chain fatty acids, primarily arachidonic acid. They are produced rapidly from lipid precursors, are released from neurons by neurotransmitters or from immune cells by inflammatory agents, and can subsequently activate cannabinoid receptors on the same or on adjacent cells. Some are metabolized rapidly by the serine hydrolase FAAH to release the free fatty acid.

Anandamide (Fig. 1), the amide conjugate of arachidonic acid and ethanolamine, is one of the most important of the endocannabinoids and is well named. *Ananda*, from the Sanskrit word for bliss, alludes to the capacity of anandamide to increase motivation and pleasure (53). Other endocannabinoids include 2-arachidonylglycerol (2-AG), and virodhamine. Enzymes known to hydrolyze endocannabinoids include FAAH, monoglyceride lipase, and *N*-acetylethanolamine. Endocannabinoids act to regulate inflammation and immune responses (54). Anandamide reduces mitogen-induced T- and B-lymphocyte proliferation, probably because of increased apoptosis (55). Anandamide concentrations are increased in cerebrospinal fluid and in circulating lymphocytes of patients with multiple sclerosis (56), perhaps as an attempt at regulation of the neuroinflammation characteristic of the disease. In a murine model of colitis, CB1-knockout ($CB1^{-/-}$) mice exhibited far more inflammation than animals with intact CB1 receptors (57). CB1 and -2 are up-regulated on gingival fibroblasts of patients with periodontitis. Anandamide reduces production of *Porphyromonas gingivalis* LPS-induced IL-6, IL-8, and monocyte chemoattractant protein-1 by these cells. Anandamide also blocks LPS-triggered activation of NFκB, a protein complex that controls transcription of DNA, cytokine production, and cell survival (58). Anandamide also suppresses TNFα-induced NFκB activation by direct inhibition of I-κB kinase, the enzyme responsible for NFκB activation (59). Of interest is the observation that the inhibitory activity was independent of CB1 and -2 activation. Another endocannabinoid, 2-AG, appears to inhibit COX-2 *via* the CB1 receptor and cause down-regulation of the MAPK/NFκB signaling systems (60). Thus, further investigation and a better understanding of the regulation of endocannabinoid production and metabolism may lead to new therapy for diseases characterized by chronic inflammation and fibrosis.

LIPOAMINO ACIDS

An endogenous subfamily of eicosanoids, the lipoamino acids, are structurally and metabolically related to the endocannabinoids and also exhibit analgesic, anti-inflammatory, and proinflammatory resolving properties (61). The best-studied member of this family is *N*-arachidonoyl glycine (NAgly), which is similar in structure to anandamide (Fig. 1). Indeed, oxidation of the hydroxyl group of anandamide leads to NAgly, and NAgly inhibits the FAAH-mediated metabolism of anandamide with moderate potency. There is evidence to suggest that rather than acting through the CB1 or -2 receptors, NAgly binds and activates an orphan G-protein-coupled receptor GPR18 (62). In addition, GPR18, expressed on human leukocytes, binds directly to resolvin D2 (RvD2), an immunoresolvent synthesized during the resolution phase of inflammation. In studies with mice, GPR18, bound to RvD2, stimulated macrophage phagocytosis of bacteria (*Escherichia coli* and *Staphylococcus*) and apoptosis of PMNs, thereby enhancing clearance of bacteria, limiting PMN infiltration, accelerating resolution, and reducing tissue injury. These protective actions were substantially reduced in GPR18-deficient mice (63).

It has long been thought that acute inflammation, a primitive, protective response, simply resolves—or not—on its own, spontaneously. It is now clear that just as mediators of inflammation initiate and sustain the inflammatory response, so also do lipid mediators, including LXs, resolvins, protectins, and maresins, together called SPMs, facilitate an active process of resolution of inflammation, a series of events that prevent chronic inflammation, tissue injury, and fibrosis, and promote a return of tissue to physiologic homeostasis (64). As exemplified by the animal study cited above, a deficiency of SPM impairs resolution of inflammation, just as an abundance of inflammation mediators increases the intensity of inflammation. As noted, select cannabinoids, such as AJA and NAgly, stimulate particular SPMs. In an effort to identify the precise proresolving actions of SPMs, a set of quantitative resolution indices designed to determine the active components (inflammatory and resolving) of a particular resolution process were introduced

(65). In addition, the impact of a known therapeutic agent on the resolution process can be determined. For example, down-regulation of the intracellular protein myeloid cell leukemia 1 (Mcl-1) induces apoptosis of human PMNs but does not impair their phagocytosis by macrophages, a series of actions crucial to resolution. In a murine model of bacteria-induced (*E. coli*) lung inflammation, down-regulation of inflammatory cell Mcl-1 accelerated resolution time, maintained appropriate lung function, and enhanced bacterial clearance (66). These results may in future be applied directly to treatment of patients with cystic fibrosis who experience ongoing pulmonary inflammation, even though their lung bacterial infections are cleared by antibiotics.

Just as different prostaglandins derive from different fatty acids (proinflammatory PGE_2 from arachidonic acid, anti-inflammatory PGE_1 from linoleic acid) so, too, do lipoamino acids derive from different fatty acids. *N*-linoleoyl glycine (LINgly), for example, at doses as low as 0.3 mg/kg, reduced leukocyte migration into an area of inflammation in a murine model of peritonitis (67). In addition, LINgly treatment increases production by cells in the peritoneum of the proresolving eicosanoid 15-deoxy-$\Delta^{13,14}$-PGJ_2 (Fig. 1). A small group of *N*-linoleoyl analogs have been studied for their ability to stimulate PGJ_2 production in mouse macrophage RAW cells. The D-alanine derivative was the most active, whereas the D-phenylalanine showed almost no response. A high degree of stereo specificity was observed when comparing the D- and L-alanine isomers, the latter being the less active, a finding that suggests the response is receptor mediated.

McHugh *et al.* (68⇓-70) found that recruitment of BV-2 microglia by NAgly results in anti-inflammatory actions in the brain. They reported that NAgly potently acts on GPR18 to produce directed migration, cell proliferation, and perhaps other MAPK-dependent actions. These results advance our understanding of the lipid-based signaling mechanisms used in the CNS to actively recruit microglia to sites of injury. The NAgly-GPR18 pathway offers a novel approach to development of therapeutic agents to elicit a population of regenerative microglia, or alternatively, to prevent the accumulation of misdirected, proinflammatory microglia that contribute to and intensify neurodegenerative disease. These effects on microglia may also apply to inflammation in the periphery. The concept of an inflammatory reflex (71), a reflex circuit that maintains immunologic homeostasis mediated by the vagus nerve, is pertinent to a discussion of CNS regulation of inflammation. The CNS receives input from the peripheral immune system *via* inflammatory cytokines and chemokines that inform resident microglia and neurons, which in turn act to reduce further production of the cytokines. The result is that, for example, patients with RA who receive anti-TNFα treatment develop changes in brain activity before resolution of inflammation (redness, swelling, heat, and pain) in the affected joints and before reduction in C-reactive protein, a circulating marker of inflammation. It appears that the nervous system is hardwired to monitor the presence of cytokines and molecular products of invaders. It may well be that the lipoamino acids promote resolution of inflammation through the inflammatory reflex. Thus, the lipoamino acids, including the cannabinoids and endocannabinoids, contain a multitude of compounds to investigate as potential new, effective, and safe treatments for diseases characterized by chronic inflammation, tissue injury, and fibrosis.

CONCLUSIONS

From the reports presented in this review, it may be concluded that several cannabinoids can be considered candidates for development as anti-inflammatory agents (Table 3). These compounds are generally free from the adverse effects associated with drugs now in clinical use. In addition, cannabinoids apparently act on inflammation through mechanisms that are different from those of other agents such as NSAIDs. A putative mechanism of action (MOA) of cannabinoids on inflammation is shown in Fig. 2, in which 2 well-studied examples, AJA and NAgly, are illustrated. The initial event is the binding to and activation of CB2 (for AJA) and GPR18 (for NAgly) at low doses in cells that are part of the immune system. In both cases an increase in release of free arachidonic acid leads to the increased production and release of proresolving eicosanoids such as PGJ_2 and LXA_4. Ultimately, this process results in an increase in the rate of resolution of chronic inflammation. These released eicosanoids may also act locally on fibroblast-like cells to reduce TGFβ production and signaling, resulting in turn, in a decrease in collagen synthesis and subsequent fibrosis. At high doses, AJA can activate PPARγ, which may also result in a reduction of fibrosis. As is true of all MOAs, this one will probably be modified as more data are reported. Regardless of the MOA, it

appears likely that some of the cannabinoids will be developed into safe and effective anti-inflammatory drugs.

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TABLE 3.

Summary of the targets and anti-inflammatory actions of substances discussed in this review

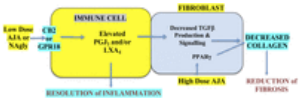

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Figure 2.

A proposed mechanism for the anti-inflammatory and antifibrotic actions of selected cannabinoids is presented. Two examples are shown; the synthetic cannabinoid AJA and the endocannabinoid NAgly. The former activates the CB2 receptor, and the latter activates the orphan receptor GPR-18. In cells of the immune system, this results in increased levels of the proresolving eicosanoids PGJ_2 and LXA_4. Ultimately, this process produces an increase in the rate of resolution of chronic inflammation. A second outcome is the action on fibroblast cells, resulting in decreased collagen production and reduced fibrosis.

AUTHOR CONTRIBUTIONS

R. B. Zurier and S. H. Burstein conceived of the content of the article and wrote the manuscript.

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2-AG
: 2-arachidonoylglycerol

AJA
: ajulemic acid

ARCI-M
: Addiction Research Center Inventory-Marijuana

CB1/2
: cannabinoid receptor 1/2

CBD
: cannabidiol

COX
: cyclooxygenase

DMH
: dimethylheptyl

FAAH
: fatty acid aminohydrolase

FDA
: U.S. Food and Drug Administration

LINGly
: *N*-linoleoyl glycine

LX
: liposin

Mcl-1
: myeloid cell leukemia 1

MOA
: mechanism of action

NAGly
: *N*-arachidonoyl glycine

NLINgly
: NSAID, nonsteroidal anti-inflammatory drug

PBM
: peripheral blood monocyte

PG
: prostaglandin

PPAR-γ
: peroxisome proliferator-activated receptor-γ

RA

RA rheumatoid arthritis
SLE systemic lupus erythematosus
SPM specializing proresolving mediators
THC Δ^9–tetrahydrocannabinol

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